VARIABILITY AND GENETIC DIVERSITY STUDIES IN FRENCH BEAN (*Phaseolus vulgaris* L.)

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C E R T I F I C A T E

This is to certify that the thesis entitled **"VARIABILITY AND GENETIC DIVERSITY STUDIES IN FRENCH BEAN (*Phaseolus vulgaris* L.)"** submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **VEGETABLE SCIENCE** to the University of Horticultural Sciences, Bagalkot, is a record of research work carried out by **JHANAVI D. R.** under my guidance and supervision and that no part of the thesis has been submitted for the award of any degree, diploma, associateship, fellowship or other similar titles.

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AUGUST, 2016

BAGALKOTE **(JHANAVI D. R.)**

Affectionately Dedicated to

My Beloved Parents

Jagadish and Chandramma and

my grandfather Bommanna and

my adorable Chairperson

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1. 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. According to Vavilov (1950) the primary centre origin of french bean is Southern Mexico and Central America, while Peruvian-Ecuadorian-Bolivian area is considered to be secondary centre. It is originated from wild species *Phaseolus aborigineus* L. and domesticated in Mexico, Peru and Colombia about 8000 years ago. It has extensive geographical distribution in the world.

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 (Abate, 2006). 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 (Prajapati, 2003).

The nutritive value of the crop per100 g of green pod is 1.7 g protein, 0.1 g fat, 4.5g carbohydrate, 1.8 g fiber and is also rich in minerals and vitamins. French bean possesses medicinal properties which is 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 (Duke, 1981). Beans are the “meat of the poor”, contribute essential protein to the undernourished people and it can be grown under different cropping patterns of hills and plains of India.

Being a short duration crop french bean can be grown under different cropping patterns of hills and plains of India. In India, it is mainly grown in Himachal Pradesh, Punjab, Haryana, Uttar Pradesh, Bihar, Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu. In India, french bean is grown over an area of 1.36 lakh ha with annual production of 13.7 lakh tons (Anon., 2013).

French bean is a cool season vegetable widely cultivated in temperate and sub tropical region and in many part of the tropics with a temperature around 21^0C. The optimum temperature for better growth is $16\text{-}24^0$C. It occupies the third position after soybean (*Glycine max* L.) and peanut (*Arachis hypogea* L.) among major food legumes in the world and stands second position in terms of bean vegetables (Singh, 1999).

Considering its use as a vegetable which fits well in different cropping systems, there is need for improvement and development of varieties to specific agro ecological conditions. Northern part of Karnataka has large area with arid climatic conditions. Though, french bean has been under cultivation in small area as a vegetable, its potentiality is yet to be exploited. Therefore, there is a need for identification or development of french bean genotypes suited for northern Karnataka. This invites attention for evaluation of germplasm to know the variability for identification of suitable genotypes and also to take up further crop improvement programmes.

The success of any crop improvement programme largely dependent on the nature and magnitude of genetic variability existing in the breeding material with which breeder is working. The phenotypic expression of plant character is mainly controlled by its genetic makeup of the plant and the environment, in which it is grown and their interaction between the genotype and environment. Further, variance in any quantitative traits depends on additive variance (heritable) and non- additive variance (non- heritable), which include dominance and epistatis (non allelic interaction). Therefore, it becomes necessary to partition the observed phenotypic variability into genotypic (partly heritable) and environmental (non heritable) components with suitable parameters, such as phenotypic and genotypic co- efficient of variation and heritability in broad sense. Further, genetic advance can be used to predict the efficiency of selection.

Yield is a complex character controlled by large number of contributing characters and their interactions. A study of correlation between different quantitative characters provides an idea of association that could be effectively exploited to formulate selection strategies for improving yield and quality of a crop. In order to have clear picture of yield components for effective selection programme, it would be desirable to consider the relative magnitude of association of various characters with yield. The path coefficient technique developed by Wright (1921) helps in estimating direct and indirect contribution of various components in building up the total correlation towards yield. On the basis of these studies, the quantum importance of individual character is marked to facilitate the selection programme for better gains.

Generally diverse plants of compatible texa are expected to give high hybrid vigour (Harrington, 1940) and hence, it to study the genetic divergence among the existing varieties and germplasm collection for identification of more diverse parents for hybridization programme. The information of genetic divergence of various traits particularly of those that contribute to yield and quality would be most useful in planning the breeding programme.

The D^2 statistics developed by Mahalanobis (1936) provides a measure of magnitude of divergence between two groups under comparison. It considers the variation produced by any character and their consequent effect that it bears on other characters. Grouping of genotypes based on D^2 analysis will be useful in choosing suitable parent lines for hybridization programme.

With this background, the present investigation to evaluate the genetic variability of different characters to understand the scope for selection and diversity of genotypes for identification of suitable parents for hybridization to improve the yield and yield attributing characters is undertaken with following objectives.

1. To study the nature and extent of genetic variability in french bean germplasm for productivity and quality traits.

2. To study the character association and path analysis for different traits in french bean germplasm.

3. To study the extent of genetic diversity in french bean germplasm.

2. REVIEW OF LITERATURE

Vegetable breeder is primarily concerned with the improvement of both quantitative and qualitative characters. Several studies have been carried out for improvement of various characters in french bean. The magnitude of such success studies lies with the selection of the base material and its creative manipulation. The research that has been done on genetic variability, heritability, genetic advance, characters association, path coefficient analysis and genetic divergence has been very useful in support of plant improvement activities in french bean. In this chapter, attempt has been made to review the available relevant literature on french bean and other legume vegetables.

2.1 Genetic variability, heritability and genetic advance

2.2 Correlation studies and Path coefficient analysis

2.3 Genetic divergence

2.1 Genetic variability, heritability and genetic advance

The success of breeding programme depends upon the magnitude of variability existing in the germplasm. Variability may be defined as the amount of variation present among the members of population or species for one or more characters at genotypic or phenotypic levels. A comprehensive summary method for estimating genetic variance was presented by Cockerham (1963) where phenotypic variability is observable and includes both genotypic and environmental variation and also called as total variation, while genotypic variation refers to genetic or inherent variability, which remains unaltered by environmental conditions. It is measured in terms of genotypic variance and consists of additive, dominance and epistatic components. Environmental variance is measured in terms of error mean variance. Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are derived from standard deviation divided by mean and are used to assess the extent of variation.

Heritability is the transmissibility of characters from parent to off-spring. Heritability in broad sense is the ratio of genotypic variance to total phenotypic variance generally expressed in percentage. Effectiveness of selection of genotypes depends on heritability. Genetic advance (GA) is the improvement over the base population that can be potentially achieved from selection. It is a function of the heritability of the trait the breeder uses. High heritability is accompanied with high genetic advance and indicates predominance of additive gene effects and selection may be effective. When low heritability is accompanied with low genetic advance, it indicates predominance environmental effects and selection would be ineffective. High heritability with low genetic advance indicates the importance of non-additive gene action, the high heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarding, while low heritability with high genetic advance, reveals that the character is governed by additive gene effects. The low heritability is being exhibited due to high environmental effects and selection may be effective in such cases.

Variability for growth, earliness, yield and its components in french bean has been reported by several workers. The review of literature on variance and its components, heritability, genetic advance and genetic advance over mean for various characters are presented in tabular form as under (Table 1).

2.2 Correlation and path analysis

The correlation coefficient analysis measures the mutual relationship between various characters and it determines the component traits on which selection can be relied upon to effect the improvement. The correlation characters may be due to genetic linkage or pleiotropy (Harland, 1939). There are three types of correlations *viz.*, phenotypic, genotypic and environmental correlations.

Phenotypic correlation is the observable correlation between two variables and includes both genotypic and environmental effects. Genotypic correlation on the other hand, is the inherent association between two variables may be either due to pleiotropic action of genes or linkage, more likely both are developmental induced relationships.

The path coefficient analysis was originally developed by Wright (1921), but the technique was first used in plant breeding by Dewey and Lu (1957). It is a technique

Table 1. Review of literature on mean, range, components of variance, heritability, genetic advance and genetic advance over mean in french bean

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
A.	**Growth parameters**											
1.	**Plant height (cm)**	27.08	-	22.80	18.02	17.63	15.67	79.04	777.4	-	French bean	Raffi and Nath (2004)
		141.12	75.26- 210.13	807.13	806.72	20.13	20.12	99.95	58.49	41.45	Dolicos bean	Gnanesh *et al.* (2006)
		34.33	-	36.75	27.40	17.66	15.25	74.58	09.31	27.12	French bean	Roy *et al.* (2006)
		66.76	45.67- 132.67	-	-	41.36	40.96	98.06	55.79	83.55	French bean	Kamaluddin and Ahmed (2011)
		91.32	31.51- 161.50	1596.8	1425.97	43.76	41.35	89.30	-	80.51	Pea	Tyagi *et al.* (2012)
		127.07	93.35- 193.38	812.26	533.06	22.43	18.17	65.60	38.53	30.32	Dolicos bean	Chaudhari *et al.* (2013)
		44.7	28.00- 78.00	-	-	29.02	20.60	00.50	-	30.15	Pea	Dar *et al.* (2013)
		-	-	241.01	214.47	16.33	15.40	88.99	28.45	29.93	Dolicos bean	Magalingam *et al*. (2013)
		59.97	38.00- 90.56	-	-	27.12	26.82	97.84	32.79	54.67	Pea	Sharma and Bora (2013)
		-	-	9.863	8.814	08.71	8.23	0.894	05.78	16.04	Mung bean	Ahmad *et al.* (2014)
		-	110.99- 201.32	599.51	556.41	16.34	15.74	92.81	46.81	31.24	French bean	Kumar *et al.*(2014)

Table 1. Continued.....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
A.	**Growth parameters**											
1.	**Plant height (cm)**	-	-	13014.18	12314.3	47.44	46.14	94.00	222.36	92.48	Dolicos bean	Chaitanya *et al.* (2014)
		50.16	34.62- 129.16	-	-	41.21	40.58	97.00	41.29	82.31	French bean	Prakash and Ram (2014)
		-	551.33-813.33	5582.53	4285.13	11.03	09.66	76.75	118.14	17.44	Winged bean	Prasanth and Sreelatha (2014)
		-	-	-	-	27.11	27.07	79.12	34.45	55.68	Pea	Singh *et al.* (2014a)
		85.62	63.91- 121.53	369.24	368.05	22.44	22.40	99.67	39.45	46.08	Dolicos bean	Verma *et al*. (2014a)
		171.6	102.64-282.00	-	-	23.62	23.42	00.98	-	47.84	French bean	Verma *et al*. (2014b)
		-	-	-	-	34.69	33.23	91.00	196.27	65.68	Jack bean	Lenkala *et al*. (2015)
		49.54	34.47- 128.21	41.71	40.92	41.71	40.92	96.50	40.98	82.72	French bean	Jayprakash *et al*. (2015)
		80.02	55.69- 109.02	-	-	17.54	15.84	81.50	23.58	29.46	Cluster bean	Kumar *et al*. (2015)
2.	**No of primary branches / plant**	46.69	-	14.00	10.65	08.01	06.99	76.07	586.3	-	French bean	Raffi and Nath (2004)
		3.68	2.40-6.33	0.49	0.48	19.07	18.96	98.90	1.43	38.86	Dolicos bean	Gnanesh *et al.* (2006)
		2.73	1.72-3.79	0.29	0.22	19.88	17.17	75.80	-	30.80	Pea	Tyagi *et al.* (2012)
		-	-	0.64	0.48	12.81	11.04	74.27	1.23	19.60	Dolicos bean	Magalingam *et al*. (2013)

Table 1. Continued.....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
A.	**Growth parameters**											
2.	**No of primary branches / plant**	7.05	5.03- 9.80	-	-	18.91	16.50	76.15	2.09	29.64	Pea	Sharma and Bora (2013)
		-	2.11-4.77	0.68	0.50	24.34	20.85	73.42	1.25	36.81	French bean	Kumar *et al.*(2014)
		-	-	0.328	0.202	17.81	13.98	61.00	0.72	22.61	Dolicos bean	Chaitanya *et al.*(2014)
		3.86	2.57- 5.11	-	-	19.85	15.40	60.20	0.95	24.61	French bean	Prakash and Ram (2014)
		-	6.33- 15.66	7.68	6.09	24.19	21.54	79.32	4.53	39.52	Winged bean	Prashanth and Sreelatha (2014)
		1.63	1.33-2.27	0.09	0.05	18.72	13.77	54.00	0.34	20.85	Pea	Saxesena *et al.*(2014)
		3.31	2.50- 4.30	0.32	0.31	17.10	16.85	97.19	1.13	34.23	Dolicos bean	Verma *et al.*(2014a)
		3.81	2.45-5.10	18.20	14.62	18.20	14.62	64.50	0.93	24.28	French bean	Jayprakash *et al*. (2015)
		-	-	-	-	36.65	35.26	92	2.25	69.88	Jack bean	Lenkala *et al*. (2015)
B.	**Earliness parameters**											
1.	**Days to first flowering**	85.14	42.33-105	320.92	320.47	21.04	21.02	99.86	36.85	43.28	Dolicos bean	Gnanesh *et al.* (2006)
		17.69	-	37.60	35.51	34.66	33.68	94.43	11.93	67.42	Bush bean	Roy *et al.* (2006)
		104.8	47.6-136.3	428.88	422.00	19.76	19.60	98.39	42.20	40.26	Dolicos bean	Islam *et al.* (2011)
		55.46	39.8-67.53	-	-	12.97	12.75	0.97	14.38	25.92	French bean	Syed Mudasir *et al*. (2012)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Earliness parameters**											
1.	**Days to first flowering**	67.06	58.66- 76.33	19.47	10.18	6.58	4.76	52.3	-	07.09	Pea	Tyagi *et al.* (2012)
		-	32- 60.33	38.33	36.75	15.36	15.04	95.89	12.23	30.35	French bean	Kumar *et al.*(2014)
		-	-	112.26	107.12	15.00	15.35	95	20.82	30.18	Dolicos bean	Chaitanya *et al.*(2014)
		36.84	30.33-43.50	-	-	11.51	10.54	83.80	7.32	19.86	French bean	Prakash and Ram (2014)
		-	75.05- 178.8	853.91	799.98	25.72	24.88	93.68	56.39	49.62	Winged bean	Prashanth and Sreelatha (2014)
		-	-	-	-	14.36	14.20	80.25	14.42	28.94	Pea	Singh *et al.* (2014a)
		52.06	40.26-66.88	73.01	72.42	16.41	16.34	99.20	17.46	33.53	Dolicos bean	Verma *et al.*(2014a)
		37.72	28.05-42.00	-	-	8.76	8.68	0.98	-	17.73	French bean	Verma *et al.*(2014b)
		36.56	29.67-43.33	11.36	10.37	11.36	10.37	83.30	7.13	19.50	French bean	Jayprakash *et al.* (2015)
		-	-	-	-	6.29	5.31	71.00	5.06	9.24	Jack bean	Lenkala *et al.* (2015)
		110.26	33.00-136.60	-	-	18.30	18.29	99.90	41.52	37.65	Dolicos bean	Rai *et al.* (2015)
		22.16	0.97-19.77	-	-	6.48	3.60	30.90	0.91	4.10	Cluster bean	Kumar *et al.* (2015)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Earliness parameters**											
2.	**Days to 50 per cent flowering**	-	-	16.130	15.74	8.180	8.081	97.59	8.074	16.445	Dolicos bean	Magalingam *et al.* 2013)
		98.68	39.33- 147.33	-	-	16.26	15.76	93.91	31.05	31.46	Dolicos bean	Parmar *et al*. (2013)
		34.64	29.33- 46.33	-	-	15.09	14.50	92.25	9.94	28.69	Pea	Sharma and Bora (2013)
		-	-	11.081	10.573	7.64	7.46	0.954	6.54	15.02	Mung bean	Ahmad *et al.* (2014)
		-	-	120.65	110.74	14.97	14.34	91	20.76	28.30	Dolicos bean	Chaitanya *et al.*(2014)
		41.79	36- 48.50	-	-	8.54	7.42	75.50	5.55	13.28	French bean	Prakash and Ram (2014)
		-	84.71- 187.23	987.94	954.39	25.11	24.67	96.60	62.55	49.95	Winged bean	Prashanth and Sreelatha (2014)
		34.64	29.33- 47.33	-	-	16.09	14.50	82.25	8.94	28.69	French bean	Kumar *et al*. (2014)
		67.10	53.67- 77.67	57.86	54.83	11.34	11.04	95.00	14.85	22.13	Pea	Saxesena *et al.*(2014)
		54.65	42.38- 68.90	79.30	78.53	16.29	16.21	99.02	18.16	33.24	Dolicos bean	Verma *et al.* (2014)
		40.97	35.33- 47.67	8.50	7.02	8.50	7.02	68.00	4.88	11.91	French bean	Jay prakash *et al*. (2015)
		-	-	-	-	6.86	6.17	80.0	6.90	11.44	Jack bean	Lenkala *et al.* (2015)
		34.10	31.64- 37.79	-	-	4.54	3.61	63.60	2.02	5.92	Cluster bean	Kumar *et al.* (2015)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Earliness parameters**											
3.	**Days to first pod picking**	133.29	91.66- 157.00	295.64	295.29	12.90	12.89	99.88	35.37	26.54	Dolicos bean	Gnanesh *et al.* (2006)
		92.99	80-109.00	-	-	8.28	8.23	98.6	15.65	16.83	French bean	Rai *et al.* (2010)
		127.87	67.00-148.00	457.70	439.86	16.73	16.40	96.1	42.9	33.55	Dolicos bean	Islam *et al.* (2011)
		115.43	71.81- 152.67	-	-	16.45	16.30	0.97	38.21	33.10	French bean	Syed mudasir *et al.* (2012)
		79.36	64.95- 88.62	78.14	22.13	11.14	5.93	28.30	5.16	6.50	Dolicos bean	Chaudhari *et al.* (2013)
		72.60	55.97- 93.08	-	-	8.52	7.11	0.639	9.63	23.72	Pea	Karnwal *et al.* (2013)
		97.86	49- 140.33	-	-	13.59	12.70	87.38	23.94	24.46	Dolicos bean	Parmar *et al.* (2013)
		62.66	56- 87.00	-	-	13.51	13.23	2.76	95.80	16.71	Pea	Sharma and Bora (2013)
		-	45.33- 76.33	48.96	44.39	12.74	12.13	90.65	13.06	23.80	French bean	Kumar *et al.* (2014)
		-	-	142.49	131.57	12.35	11.87	92	22.70	23.50	Dolicos bean	Chaitanya *et al.* (2014)
		-	97.13- 192.67	724.03	688.97	19.64	19.16	95.15	52.74	38.50	Winged bean	Prashanth and Sreelatha (2014)
		78.45	68.46- 90.16	59.69	58.57	9.84	9.75	98.12	15.61	19.00	Dolicos bean	Verma *et al.* (2014a)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
3.	**Days to first pod picking**	-	-	-	-	6.49	4.79	54	5.09	7.29	Jack bean	Lenkala *et al.* (2015)
		141.82	55- 165	-	-	12.03	12.00	99.4	34.95	24.64	Dolicos bean	Rai *et al.* (2015)
C.	**Yield parameters**											
1.	**Pod length (cm)**	9.41	-	-	-	13.74	12.70	85.40	2.27	24.12	Dolicos bean	Pan *et al.* (2004)
		7.93	-	2.30	1.84	19.12	17.10	80.00	249.9	-	French bean	Raffi and Nath (2004)
		4.77	4.07- 5.51	0.07	0.07	5.82	5.75	97.90	0.56	11.71	Dolicos bean	Gnanesh *et al.* (2006)
		12.48	8.89- 16.38	-	-	12.75	12.71	99.4	3.24	25.96	French bean	Rai *et al.* (2006)
		9.25	-	2.54	2.37	17.21	16.63	93.33	3.06	33.10	Bush bean	Roy *et al.* (2006)
		9.96	7.20- 13.37	-	-	13.19	13.14	99.2	2.68	26.91	French bean	Rai *et al.* (2010)
		12.73	10.33- 15.0	-	-	14.92	9.57	41.17	1.61	12.65	French bean	Kamaluddin and Ahmed (2011)
		5.61	4.44- 10.30	2.5	2.44	28.04	27.83	98.5	-	3.19	Cluster bean	Rai *et al.* (2012)
		6.07	4.37- 11.20	1.77	1.17	21.90	17.84	66.40	1.82	29.96	Dolicos bean	Chaudhari *et al.* (2013)
		-	-	2.779	2.626	21.475	20.87	94.50	3.245	41.80	Dolicos bean	Magalingam *et al.*(2013)
		8.83	6.92- 10.32	-	-	9.47	8.14	74.69	1.28	14.49	Pea	Sharma and Bora (2013)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Yield parameters**											
1.	**Pod length (cm)**	-	7.76- 15.62	4.08	3.59	18.12	17.00	87.98	3.66	32.85	French bean	kumar *et al.* (2014)
		-	-	3.085	2.93	23.72	23.14	95	3.44	46.48	Dolicos bean	Chaitanya et al. (2014)
		11.14	8.33- 13.76	-	-	16.42	14.67	79.80	3.01	27.01	French bean	Prakash and Ram (2014)
		-	14.84- 21.89	4.81	3.76	11.61	10.25	78.11	3.53	18.67	Dolicos bean	Prashanth and Sreelatha (2014)
		-	-	-	-	8.12	8.02	79.12	1.43	16.24	Pea	Singh *et al.* (2014a)
		-	-	5.26	4.67	18.00	16.97	88.85	4.20	32.95	French bean	Singh *et al.* (2014b)
		6.07	4.73- 8.55	1.46	1.34	19.92	19.10	91.94	2.29	37.74	Dolicos bean	Verma *et al.* (2014a)
		11.01	8.14- 17.15	-	-	16.55	16.38	0.98	-	33.37	French bean	Verma *et al.* (2014b)
		11.03	8.32- 13.86	16.12	14.44	16.12	14.44	80.20	2.94	26.65	French bean	Jayprakash *et al.* (2015)
		-	-	-	-	15.46	15.04	94	4.95	30.13	Jack bean	Lenkala *et al.* (2015)
		9.78	7.28- 12.82	-	-	14.05	14.02	99.5	2.82	28.83	Dolicos bean	Rai *et al.* (2015)
		5.72	4.52- 6.90	-	-	10.53	7.52	51.00	0.63	11.01	Cluster bean	kumar *et al.* (2015)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Yield parameters**											
2.	**Pod width (cm)**	1.21	0.78- 1.46	-	-	11.51	10.80	87.90	0.25	20.66	French bean	Rai *et al.* (2006)
		1.11	0.92- 1.43	-	-	11.17	8.97	64.6	0.17	15.32	French bean	Rai *et al.* (2010)
		7.18	5.58- 10.17	0.66	0.7	12.36	10.92	89.4	-	1.27	Cluster bean	Rai *et al.* (2012)
		1.30	1.11- 1.49	-	-	7.45	7.09	90.74	10.19	13.92	Pea	Davendra *et al.* (2013)
		-	-	0.203	0.185	25.76	24.56	90.94	0.845	48.26	Dolicos bean	Magalingam *et al.*(2013)
		-	7.76- 15.62	4.08	3.59	18.12	17.00	87.98	3.66	32.85	French bean	Kumar *et al.* (2014)
		-	-	0.060	0.053	13.45	12.71	89	0.44	24.74	Dolicos bean	Chaitanya *et al.* (2014)
		0.68	0.49- 0.95	-	-	20.64	17.76	74	0.21	30.88	French bean	Prakash and Ram (2014)
		-	-	-	-	4.82	3.23	87.71	1.12	4.45	Pea	Singh *et al.* (2014a)
		1.82	1.52- 2.08	0.41	0.03	11.19	10.00	79.86	0.33	18.41	Dolicos bean	Verma *et al*. (2014a)
		0.66	0.48- 0.95	-	-	19.34	17.62	83	0.22	33.33	French bean	Jayprakash *et al*. (2015)
		-	-	-	-	11.07	9.32	70	0.30	16.16	Jack bean	Lenkala *et al.* (2015)
		2.15	0.50- 3.23	-	-	29.30	28.67	95.8	1.25	58.03	Dolicos bean	Rai *et al.* (2015)
		5.97	5.70- 6.34	-	-	5.67	0.53	9.00	0.01	0.16	Cluster bean	Kumar *et al.* (2015)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Yield parameters**											
3.	**No. of seeds per pod**	4.84	-	-	-	11.12	7.50	45.58	0.50	10.53	Dolicos bean	Pan *et al.* (2004)
		3.75	-	1.41	1.13	31.72	28.36	79.90	1.96	52.21	Bush bean	Roy *et al*. (2006)
		4.59	3- 5.67	-	-	15.85	14.67	8.59	1.29	28.10	French bean	Rai *et al.* (2010)
		4.56	3.6- 5.87	0.28	0.20	11.6	9.8	71.4	0.87	19.07	Dolicos bean	Islam *et al.* (2011)
		4.26	4- 5.0	-	-	10.86	9.98	84.48	0.81	18.91	French bean	Kamaluddin and Ahmed (2011)
		4.58	3.33- 5.56	-	-	18.66	11.52	0.38	-	14.64	Dolicos bean	Sankaran *et al.* (2011)
		6.37	5.30- 8.10	0.6	0.48	11.98	11.33	78	-	1.58	Cluster bean	Rai *et al.* (2012)
		4.48	3.13- 6.67	0.61	0.35	17.45	13.25	57.70	0.93	20.74	Dolicos bean	Chaudhari *et al*. (2013)
		4.06	2.6- 6.9	-	-	13.71	13.26	0.93	-	26.75	Pea	Dar *et al*. (2013)
		-	2.99- 7.99	1.39	1.11	24.62	22.05	80.22	1.95	40.69	French bean	kumar *et al.* (2014)
		-	-	0.426	0.361	15.96	14.68	84	1.138	27.81	Dolichos bean	Chaitanya *et al.* (2014)
		4.81	3.64- 5.96	-	-	14.53	10.05	47.80	0.69	14.34	French bean	Prakash and Ram (2014)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Yield parameters**											
3.	**No. of seeds per pod**	-	-	-	-	12.42	12.15	86.70	1.94	24.50	Pea	Singh *et al.* (2014a)
		-	-	1.93	1.85	20.16	19.76	96.01	2.75	39.88	French bean	Singh *et al.* (2014b)
		3.86	3.35- 4.65	0.19	0.18	11.40	11.24	97.09	0.88	22.81	Dolichos bean	Verma *et al*. (2014a)
		5.64	3.08- 7.77	-	-	25.03	24.29	0.94	-	48.58	French bean	Verma *et al*. (2014b)
		4.76	3.58- 5.72	13.46	7.36	13.46	7.36	29.9	0.40	8.40	French bean	Jayprakash *et al*. (2015)
		-	-	-	-	21.39	20.09	88	36.5	38.89	Jack bean	Lenkala *et al.* (2015)
		4.522	3.67- 5.67	-	-	13.78	10.33	56.2	0.72	15.92	Dolichos bean	Rai *et al.* (2015)
		6.72	5.93- 7.53	-	-	8.57	5.75	45.00	0.53	7.88	Cluster bean	Kumar *et al.* (2015)
4.	**No. of clusters per plant**	28.19	12.80-49.67	96.5	82.47	34.85	32.22	85.5	-	17.3	Cluster bean	Rai *et al.* (2012)
		-	-	1.806	1.568	14.157	13.527	86.83	2.404	25.966	Dolichos bean	Magalingam *et al.* (2013)
		-	-	0.288	0.199	8.89	7.38	0.689	0.76	12.63	Mung bean	Ahmed *et al.* (2014)
		5.56	4- 7.60	1.29	0.97	20.31	17.61	75.00	1.76	31.47	Pea	Saxesena *et al.*(2014)
		12.02	7.00- 31.13	-	-	43.03	41.99	95.30	10.15	84.44	Cluster bean	Kumar *et al.* (2015)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Yield parameters**											
5.	**No. of pods per cluster**	7.23	5.40- 14.10	2.9	2.75	23.6	22.94	89.7	-	3.32	Cluster bean	Rai *et al.* (2012)
		9.42	5.76- 19.66	9.50	8.76	32.71	31.40	92.10	5.85	62.09	Dolicos bean	Chaudhari *et al*. (2013)
		-	-	5.318	4.911	29.65	28.49	92.35	4.387	56.416	Dolicos bean	Magalingam *et al.*(2013)
		7.01	3.66- 12.93	-	-	32.02	24.60	59.02	2.73	38.93	Dolicos bean	Parmar *et al.* (2013)
		-	-	0.153	0.133	13.53	12.60	0.867	0.70	24.17	Mung bean	Ahmad *et al.* (2014)
		7.91	2.93- 21.47			62.31	61.52	97.50	9.90	125.15	Cluster bean	Kumar *et al.* (2015)
6.	**No. of pods per plant**	5.23	-	1.97	1.08	26.75	19.81	54.82	158.5	-	French bean	Raffi and Nath (2004)
		55.64	31.06-94.53	195.64	195.2	25.13	25.11	99.79	28.75	51.67	Dolicos bean	Gnanesh *et al.* (2006)
		19.58	6.14- 95	-	-	64.16	63.38	97.6	25	1.27	French bean	Rai *et al.* (2006)
		9.8	-	22.51	20.43	48.43	46.14	90.76	8.87	90.55	Bush bean	Roy *et al.* (2006)
		39.95	13.33-79.67	-	-	41.03	40.81	98.9	33.41	83.63	French bean	Rai *et al.* (2010)
		256.6	122- 425	6776.9	4736.2	32.08	26.82	79.88	132.58	51.66	Dolicos bean	Islam *et al.* (2011)
		9.73	8.33- 13.33	-	-	20.91	18.83	43.74	1.83	18.84	French bean	Kamaluddin and Ahmed (2011)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Yield parameters**											
6.	**No. of pods per plant**	117.53	75.50- 185.00	757.2	679.37	23.41	22.18	94.5	-	50.86	Cluster bean	Rai *et al.* (2012)
		8.80	5.14- 13.76	-	-	23.00	19.42	0.71	2.96	33.63	French bean	Syed mudasir *et al.* (2012)
		11.15	2.39- 19.44	21.49	19.00	41.55	39.10	88.4	-	75.71	Pea	Tyagi *et al.* (2012)
		65.68	18.33- 158.62	1164.8	1120.65	51.96	50.97	96.20	67.64	102.99	Dolicos bean	Chaudhari *et al.* (2013)
		7.39	5- 10.13	-	-	21.90	12.03	0.30	-	13.16	Pea	Dar *et al*. (2013)
		8.78	5.33- 15	-	-	27.56	21.02	78.28	3.36	38.28	Pea	Sharma and Bora (2013)
		-	-	19.495	18.605	24.57	24.00	0.954	8.68	48.30	Mung bean	Ahmad *et al.* (2014)
			12.90-104.03	344.28	329.00	43.22	42.25	95.56	36.52	85.09	French bean	Kumar *et al.* (2014)
		-	-	8219.7	1900.69	134.24	64.55	23	43.18	63.94	Dolicos bean	Chaitanya *et al*. (2014)
		20.96	10.46- 30.22	-	-	23.72	22.94	93.60	9.58	45.70	French bean	Prakash and Ram (2014)
		-	44.98- 154.49	1313.8	673.47	41.86	29.97	51.26	38.27	44.20	Dolicos bean	Prashanth and Sreelatha (2014)
		16.07	10.47- 21.73	9.57	5.91	19.24	15.12	62.00	3.94	24.49	Pea	Saxesena *et al.*(2014)

Table 1. Continued...

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Yield parameters**											
6.	**No. of pods per plant**	-	-	-	-	20.82	20.68	87.60	13.37	42.32	Pea	Singh *et al.* (2014a)
		-	-	7.10	5.95	18.63	17.06	83.82	4.60	32.17	French bean	Singh *et al.* (2014b)
		58.43	20.50- 93.12	547.05	546.60	40.02	40.00	99.92	48.14	82.38	Dolichos bean	Verma *et al.* (2014a)
		15.61	5.30- 27.00	-	-	43.43	43.32	0.99	-	89.02	French bean	Verma *et al.* (2014b)
		20.75	10.11- 29.87	23.54	22.91	23.54	22.91	94.70	9.53	45.92	French bean	Jayprakash *et al.* (2015)
		-	-	-	-	21.56	20.92	94.00	10.27	41.80	Jack bean	Lenkala *et al.* (2015)
		231.57	45.33- 689.67	-	-	64.04	63.99	99.9	305.0	131.73	Dolichos bean	Rai *et al.* (2015)
		5.97	41.07- 76.73	-	-	15.20	13.50	78.90	13.89	24.70	Cluster bean	Kumar *et al.* (2015)
7.	**Pod weight (g)**	7.52	-	-	-	24.12	23.91	98.32	3.67	48.80	Dolichos bean	Pan *et al.* (2004)
		63.88	23.37- 108.65	-	-	33.98	33.79	98.9	43.80	68.56	French bean	Rai *et al.* (2006)
		8.26	1.47- 12.30	4.66	4.15	26.13	24.66	89.05	4.12	49.9	Dolichos bean	Islam *et al.* (2011)
		6.96	4.44- 12.70	-	-	28.12	26.93	0.91	-	53.14	Dolichos bean	Sankaran *et al.* (2011)
		-	1.95- 7.97	1.99	1.93	31.15	30.71	97.16	2.82	62.36	French bean	Kumar *et al.* (2014)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Yield parameters**											
7.	**Pod weight (g)**	-	-	2.59	3.43	36.08	34.99	94	3.11	69.92	Dolichos bean	Chaitanya *et al*. (2014)
		6.21	4.56- 7.94	-	-	13.86	11.12	64.40	1.14	18.35	French bean	Prakash and Ram (2014)
		-	10.13- 22.62	11.24	8.86	15.55	17.52	78.79	5.44	28.43	Dolichos bean	Prashanth and Sreelatha (2014)
		-	-	11.51	11.31	43.87	43.49	98.28	6.87	88.81	French bean	Singh *et al.* (2014b)
		7.31	4.45- 12.19	-	-	28.60	28.29	0.98	-	57.65	French bean	Verma *et al*. (2014b)
		-	-	-	-	24.28	23.50	93	7.19	46.89	Jack bean	Lenkala *et al.* (2015)
8.	**Pod yield per plant (g/ plant)**	152.4	63.49- 270.35	1978.0	1977.4	29.17	29.16	99.97	91.59	60.07	Dolichos bean	Gnanesh *et al.* (2006)
		92.76	5.13- 388.11	-	-	68.80	68.74	99.8	130.15	140.3	French bean	Rai *et al.* (2006)
		122.9	57.74- 222.3	1522.4	1319.9	31.73	29.55	86.7	-	69.69	Cluster bean	Rai *et al.* (2012)
		-	-	827.57	797.64	20.37	20.00	96.38	57.11	40.45	Dolichos bean	Magalingam *et al.*(2013)
		66.74	25.00- 129.0	-	-	34.56	33.35	93.10	44.24	66.28	Pea	Sharma and Bora (2013)
			-	9665.5	8492.2	44.06	41.30	87	177.94	79.75	Dolichos bean	Chaitanya *et al*. (2014)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Yield parameters**											
8.	**Pod yield per plant (g/ plant)**	92.37	55.06- 149.11	-	-	28.85	27.55	91.20	50.05	54.18	French bean	Prakash and Ram (2014)
		-	696.6- 2703.3	434395.2	235907.6	42.33	31.19	54.30	737.3	47.36	Dolicos bean	Prashanth and Sreelatha (2014)
		10.70	7.62- 15.09	4.39	3.88	19.58	18.40	88.00	3.81	35.62	Pea	Saxesena *et al.*(2014)
		190.49	86.30- 300.83	5434.42	5410.42	38.69	38.61	99.56	151.1	79.36	Dolicos bean	Verma *et al.* (2014a)
		68.68	22.52- 128.53	-	-	41.36	33.63	0.66	-	56.35	French bean	Verma *et al.* (2014b)
		92.16	54.91- 148.87	28.33	27.21	28.33	27.21	92.30	49.62	53.84	French bean	Jayprakash *et al.* (2015)
		-	-	-	-	40.31	39.51	96.00	306.7	79.76	Jack bean	Lenkala *et al.* (2015)
		97.15	0.41- 0.78	-	-	13.11	12.61	92.50	24.28	24.99	Cluster bean	kumar *et al.* (2015)
9.	**Pod yield per plant (t/ ha)**	13.89	9.02-19.29	8.6	8.08	21.12	20.47	93.90	-	5.68	Cluster bean	Rai *et al.* (2012)

Table 1. Continued....

Sl. No	Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)	Crop	References
B.	**Yield parameters**											
10.	**No of root nodules per plant**	-	-	8135.59	8074.09	83.07	82.76	99.24	184.4	169.83	French bean	Singh *et al.* (2014b)
11.	**Dry matter content per plant (g/ plant)**	19.87	11.13- 30.83	-	-	29.29	29.13	0.99	-	59.67	French bean	Verma *et al.* (2014b)
D.	**Quality parameters**											
1	**Protein content per plant (g/ 100g)**	24.25	18.51- 28.14	5.07	4.92	9.29	9.15	97.03	4.50	18.57	Dolicos bean	Gnanesh *et al.* (2006)
		18.45	-	9.72	9.70	16.90	16.88	99.78	6.41	34.74	Bush bean	Roy *et al.* (2006)
		21.36	17.13- 25.01	-	-	9.50	7.68	0.70	2.81	13.15	French bean	Syed mudasir *et al.* (2012)
		16.78	11.76- 21.73	9.42	8.90	18.29	17.78	94.50	5.98	35.61	Dolicos bean	Chaudhari *et al.* (2013)
		-	-	4.313	4.258	23.102	22.95	98.73	4.224	46.98	Dolicos bean	Magalingam *et al.*(2013)
		19.84	16.26- 22.13	-	-	7.30	7.12	95.09	2.84	25.32	Dolicos bean	Parmar *et al.* (2013)
		-	15.58- 34.74	24.25	22.19	19.67	19.15	94.78	9.61	38.41	French bean	Kumar *et al.* (2014)
		23.35	17.15- 30.53	-	-	18.65	18.05	93.60	8.40	35.97	French bean	Prakash and Ram (2014)
		23.21	17.74- 27.66	13.09	13.00	15.58	15.53	99.34	7.40	31.89	Dolicos bean	Verma *et al.* (2014a)

used to find the relative contribution of component characters directly on the main characters and indirectly through other characters to increase the efficiency in selection programmes. The correlation between dependent and independent characters is due to the direct effect of the characters, it reflects a true relationship between them and selection can be practiced for such a character in order to improve dependent variable. Otherwise, broadly speaking a breeder has to select for the later through which the indirect effect is exerted.

Govanakoppa (2001) noticed that pod yield per plant was positively correlated with plant height (0.191), number of primary branches (0.151) and number of secondary branches (0.111). Plant height had significant and positive correlation with number of pods per plant (0.330). Number of primary branches showed negative correlation with plant height (-0.090), pod breadth (-0.109) and pod width (-0.015). Number of secondary branches is significant and positively correlated with plant height (0.223) and pod length (0.300) and pod width was negatively correlated with plant height, number of primary branches and number of secondary branches at genotypic level in French bean.

In dolicos bean Rai *et al.* (2003) found that pod yield per plant was significant and positively correlated with no of pods per plant at both genotypic and phenotypic levels. The path analysis revealed that number of pods per plant and weight of ten pods showed maximum direct effect on pod yield per plant. Whereas, pod length (0.469) followed by pod width (0.403) showed high positive indirect effect on pod yield per plant.

Yadav *et al.* (2003) reported positive and significant association of green pod yield per plant with plant height, pods per cluster, pod length, pods per plant, seeds per pod and pod dry matter in Cowpea. The path analysis revealed that dry matter in pod, pods per plant, seeds per pod and plant height are main components of green pod yield per plant in cowpea.

Nath and Korla (2004) reported that, green pod yield per plant was negatively correlated with plant height (-0.025), pod length (-0.521) and number of pods per plant (-0.934) and days to first flowering was positively correlated with number of green pods per plant (0.087) and negatively correlated with plant height (-0.456) at genotypic level in 28 genotypes of french bean.

Nigude *et al.* (2004) observed that green pod yield per plant was significantly and positively associated with all the characters except pod length at both genotypic and phenotypic levels in cowpea.

Rai *et al.* (2004) reported that pod yield per plant showed significant positive correlation with pod weight and pod length, whereas significant negative correlations were observed in between pod width and number of pods per plant in french bean.

In dolicos bean Ali *et al.* (2005) reported pod weight at harvest showed significant positive correlation with pod diameter and with yield per plant both at phenotypic and genotypic levels. Similarly, pod length displayed positive significant phenotypic and genotypic correlation with the yield per plant.

Singh *et al.* (2005) carried out correlation coefficient analysis in 24 advanced cluster bean genotypes. High estimates of the phenotypic and genotypic coefficients of variation were obtained for pod yield per plant, pods per plant, clusters per plant, days to flowering and branches per plant.

Lovely and Radhadevi (2006) observed that pod yield per plant had strong positive correlation with pods per cluster, pods per plant, pod weight, pod length, pod breadth and seeds per pod. Path analysis revealed that the maximum positive direct effect on pod yield was observed for pods per plant followed by pod weight, pods per cluster, pod length, seeds per pod and pod breadth in yard long bean.

In french bean Rai *et al.* (2006) reported that genotypic correlations were observed to be higher than the corresponding phenotypic correlation for all the characters. Pod yield per plant was positively and significantly associated with pod length and pod weight at both phenotypic and genotypic levels. The path analysis revealed that pod weight and number of pods per plant exhibited maximum positive direct effect on pod yield per plant.

Bhushan *et al.* (2007) reported that, days to 50 per cent flowering showed negative non significant correlation with number of pods per plant (-0.041) and pod length (0.038), while significant positive correlation with days to maturity (0.538) and plant height (0.479). Pod length showed positive and significant correlation with plant height (0.179), whereas positive but non- significant with days to maturity (0.0101) in french bean.

Nawab *et al.* (2008) revealed that, days to emergence showed a positive and significant association with number of pods per plant (0.446), whereas negative and significant correlation of days to emergence was observed with pod length (-0.402) and green pod yield per plot (-0.489) in pea.

Anjani *et al.* (2009) reported that green pod yield per plant showed positive and significant association with number of pods per plant and pod length in french bean.

Usha Kumari *et al.* (2010) carried out the correlation studies in cowpea and the results of genotypic correlation revealed that days to fifty per cent flowering had highly positive significant correlation with days to maturity. Plant height was highly positively significant with branches per plant and pods per plant.

Aditya *et al.* (2011) opined that at genotypic and phenotypic level, yield per plant showed highly significant positive correlation with number of pods per plant, dry matter weight per plant, harvest index and number of primary branches per plant in soya bean.

Islam *et al.* (2011) conducted correlation studies in 44 genotypes of french bean and reported that there was positive correlation between pod yield with individual pod weight, number of pods per plant and harvesting duration. And also significant negative correlation was observed between days to first flower with harvesting duration and number of pods per plant at phenotypic level.

Sharma *et al.* (2011) analysed 23 genotypes of dolicos bean for the correlation study and reported that highly significant and positive correlation of pod yield per plant was recorded with number of spikes per plant, days taken to first flowering, days taken to 50 per cent flowering, days taken to first pod harvest, pod weight, pod length and pod width, whereas negative and significant association was recorded with number of flowers per cluster at both genotypic and phenotypic levels.

Singh *et al.* (2011) studied correlation and path analysis with seventy three genotypes of dolicos bean. Pod yield per plant showed maximum positive significant association with number of pods per plant (0.708) at both genotypic and phenotypic levels. Path analysis resulted positive direct effect with number of pods per plant, pod length, pod width, while, days to first flowering had negative direct effect on pod yield per plant.

Twelve genotypes of french bean were assessed for character association. Pod yield per hectare had positive and highly significant association with pod yield per plant, pod length, weight of pod, plant height, leaf area, leaf area index, ovule number per pod and number of seeds per pod at both phenotypic and genotypic level (Angadi *et al.*, 2012).

In french bean Mehra and Singh (2012) carried out path analysis and reported that 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 per cent maturity (0.0566), number of primary branches per plant(0.0461) and number of pods per plant(0.0102). Pod length (-0.941), days to 50 per cent flowering (-0.0540) and plant height (-0.0376) exhibited negative direct effect on pod yield per hectare.

A study conducted by Pal and Singh (2012) revealed that, days to maturity of green pods had highest positive and direct effect (38.05) on green pod yield per plant followed by pod width (6.466), number of primary branches per plant (4.666), days to first flower emergence (2.98). Days to 50 per cent flower emergence (-23.501) had highest negative effect on green pod yield per plant followed by days to first pod set (-13.438), pod length (-6.246), number of pods per plant (-4.189) at genotypic level in pea.

Kamaluddin and Ahmed (2011) studied path analysis in 57 germplasm lines of rajmash beans for yield and yield contributing traits. Significant variations were observed for plant height, number of pods per plant and yield. They noticed that, days to 50 per cent flowering, number of pods per plant and pod length had maximum positive direct effect on yield, whereas plant height had negative direct effect on yield.

Magalingam *et al.* (2013) evaluated 23 dolicos bean accessions and found that pod yield per plant was positively and significantly associated with green pod width, number of flowers per cluster, pod length and individual green pod weight at both genotypic and phenotypic levels, whereas, negative correlation was observed for days to 50 per cent flowering and days to maturity. Path analysis revealed that individual green pod weight exhibited very high direct positive effect on pod yield per plant. In addition, percent pod set, number of clusters per plant, pods per plant and flowers per cluster and days to 50 percent flowering also showed very high direct positive effect on pod yield.

Kumar *et al.* (2014) studied correlation and path analysis in 44 accessions of french bean. Marketable pod yield per plant had highly significant and positive association with length of inflorescence, number of inflorescence per plant, number of flowers per inflorescence, pod length, pod weight, number of pods per plant, pod width and number of seeds per pod. Path analysis for green pod yield per plant revealed that traits like number of pods per plant and pod weight exhibited high positive direct effects on green pod yield per plant.

Chaitanya *et al.* (2014) evaluated 48 dolicos bean genotypes for thirteen yield and yield contributing characters and found that pod yield per plant showed positive and significant correlation with number of pods per plant, days to last pod harvest, number of inflorescences per plant, pod length, pod width, pod weight, number of seeds per pod and protein content, whereas, significant negative correlation with days to first flowering, days to 50 per cent flowering and days to first pod harvest at both phenotypic and genotypic levels. Path analysis revealed that number of pods per plant exhibited high positive direct effect on pod yield per plant followed by pod weight at both genotypic and phenotypic levels. The direct negative effects on pod yield were observed by number of inflorescences per plant, pod length, pod width and protein content.

In cluster bean Rai *et al.* (2014) reported the positive associations of pod yield per hectare (t) with plant height (0.315, 0.309), pods per cluster (0.322, 0.298), pods per plant (0.443, 0.389) and pod yield per plant (0.905, 0.787) at genotypic and phenotypic levels respectively. The genotypic path analysis revealed that yield per plant exhibited positive direct effect (1.138) and had strong positive association with yield per hectare. Phenotypic path coefficient showed that yield per plant had high positive direct effect (0.879) and strong degree of association (0.787) for pod yield per hectare.

Singh *et al.* (2014b) carried out correlation and path analysis in evaluation study of french bean genotypes and reported that pod yield per plant had significant positive correlation with vine length, inter-nodal length, pod length, single pod weight, number of seeds per pod, number of locules per pod and number of pods per plant at genotypic levels. The path analysis revealed that positive direct effect on the pod yield was highest for single pod weight followed by number of pods per plant, inter-nodal length and nodule fresh weight while, pod length, days to 50 per cent flowering, and vine length recorded a negative direct effect on pod yield.

In dolicos bean Ravinaik *et al.* (2014) reported pod yield per plant was significant and positively correlated with plant height, number of branches per plant, number of flowers per cluster, number of pods per cluster, average weight of pod, pod length, pod width, number of seeds per pod and number of pods per plant at both phenotypic and genotypic levels, but days to 50 per cent flowering showed negative correlation with pod yield per plant. Path coefficient analysis revealed that pod yield per plant had highest positive direct effect on number of flowers per cluster followed by number of pods per cluster, pod width and days to 50 per cent flowering, whereas, number of pods per plant, plant height, average weight of pod and number of seeds per pod had negative effect on pod yield per plant at genotypic levels.

In french bean Verma *et al.* (2014b) observed that yield per plant was positively correlated with all traits except days to 50 per cent flowering, pod diameter and vitamin C content. Leaf length and pod length had negative direct effect on yield per plant but its positive effect through number of pods per plant, average pod weight and number of seeds per pod made its association with yield per plant significantly positive. The path analysis revealed that number of pods per plant exhibited maximum direct effect followed by average pod weight and number of seeds per pod.

In french bean Jyotidevi *et al.* (2015) reported that pod yield per plant had positive and significant correlation with days to flowering, average pod weight, branches per plant, pods per plant and pod height. The path analysis study revealed that the pods per plant and average pod weight have highest positive direct effect on pod yield per plant.

In jack bean Lenkala *et al.* (2015) evaluated 15 jackbean genotypes and found that pod weight and number of pods per plant was positively and significantly associated with pod yield per plant. While, the significant and negative association was observed in days to 50 per cent flowering, plant height and days to first fruit set on pod yield per plant.

Rai *et al.* (2015) carried out correlation and path analysis with 24 genotypes of dolicos bean and indicated that pod length, number of seeds per pod, number of pods per plant and pod yield per plant had positive and significant correlation with pod yield. The Path analysis revealed maximum direct effect of days to 50 per cent flowering, pod width, number of pods per plant and pod yield per plant on pod yield.

In dolicos bean Singh *et al.* (2015) reported pod yield per plant was positively and significantly correlated with pod length, number of seeds per pod and number of pods per plant at genotypic and phenotypic levels, while plant height negatively and significantly correlated with pod yield. The path analysis revealed that the traits like pod yield per plant, number of pods per plant, pod width and days to 50 per cent flowering exercised maximum direct effect on pod yield (q/ha) at genotypic and phenotypic levels.

A study with dolichos bean by Verma *et al.* (2015) revealed that number of secondary branches per plant, number of inflorescences per plant, number of pods per inflorescence, number of pods per plant, number of seeds per pod, pod width and days to last harvest had the significant positive correlation with marketable green pod yield per plant. The path analysis revealed true relationship between yield and number of secondary branches per plant, number of pods per inflorescence and number of pods per plant and direct selection for these traits will be rewarding for yield improvement as correlation was due to direct effect of the characters.

2.3 Genetic divergence

The magnitude of divergence between two groups under consideration is provided by D^2 statistic developed by Mahalanobis (1936).

The technique in the form of generalized distance was first used by Mahalanobis in an anthropometric survey of the United Province in India. For the first time D^2 statistic was applied for biological population by Nair and Mukherjee (1960) to classify the natural and plantation teak tree types. Its application was extended later to taxonomic studies. Murthy and Pavate (1962) observed that D^2 analysis can be extended to the situations where overlapping species need to be discriminated and also when the discrimination at subspecies level is needed.

Several methods of divergence analysis based on quantitative traits have been proposed to suit various objectives, of which Mahalanobis generalised distance technique (Mahalanobis, 1936) occupy a unique place in plant breeding. It is a very sensitive and potent biometrical tool in quantifying the degree of divergence between biological populations and also to assess the relative contribution of different components to the total divergence both at inter and intra cluster levels (Khanna and Misra, 1977: Suyambhulingam and Jobarani, 1978). The concept of Mahalanobis D^2 statistic is based on the technique of utilising the measurements in respect of aggregate of characters.

Nandi *et al.* (2000) studied the genetic divergence in 28 genotypes of indian bean for eight characters. On the basics of Mahalanobis's D^2 analysis the genotypes were grouped into five clusters. Cluster I was the largest containing twenty two genotypes followed by Cluster III with three genotypes. Remaining three Clusters (II, IV and V) had a single genotype each. Clusters II and V showed maximum divergence followed by Clusters I and V and clusters I and IV. Minimum divergence was observed between Clusters II and III followed by Clusters II and IV. Cluster I had higher intracluster D^2 value followed by Cluster III.

Govanakoppa *et al.* (2002) conducted genetic diversity study with 62 french bean genotypes. From D2 statistic method, sixty two genotypes were grouped in to eleven clusters. The maximum divergence was found between cluster X and cluster XI (D^2 =130.15), while the minimum was recorded between cluster II (21.04) followed by cluster III (20.32) and cluster I (19.82). The green pod yield per plant contributed highest towards genetic advance

Hanchinamani *et al.* (2003) reported genetic divergence in 80 genotypes of cluster bean for seventeen characters. On the basics of Mahalanobis's D^2 analysis the genotypes were grouped into 12 clusters. The cluster IX showed maximum intra-cluster distance. The maximum inter cluster distance was observed between cluster III and I. Number of leaves per plant contributed maximum to genetic diversity followed by vegetable pod yield per plant and plant height.

Rai *et al.* (2003) studied genetic divergence in 45 genotypes of indian bean. On the basis of D^2 values, the genotypes were grouped in to 5 clusters. The maximum genetic distance was observed between clusters I and cluster V followed by cluster I and cluster IV. Whereas, cluster II and cluster III displayed lowest degree of divergence. The maximum intra cluster distance was exhibited by cluster V followed by cluster III. The numbers of pod per plant followed by pod thickness contributed maximum towards divergence.

Gnanesh *et al.* (2007) studied genetic divergence in 64 genotypes of field bean. On the basis of Mahalanobis D^2 statistics, the genotypes were grouped into 11 clusters. Cluster I was the largest with 27 genotypes followed by cluster IV, III, IV and IX with 12, 10, 7 and 2 genotypes, respectively and rest of the clusters- II, V,VII, VIII, X and XI contained a single genotype each. The maximum intracluster distance was observed in cluster IV (46.10).Whereas, the minimum intracluster distance observed in cluster IX (34.17). The maximum intercluster distance was recorded between clusters IV and IX (159.09) followed by clusters X and XI (145.00). Based on cluster mean values, the genotypes of cluster XI exhibited superiority for plant height, no. of inflorescence per plant, pod length and seeds per pod. Whereas the genotypes of clusters III, VII and IX showed superiority for pod yield per plant, protein content and vitamin C content. Hence, pod yield per plant and plant height were important traits contributing towards genetic divergence in field bean.

Golani *et al.* (2007) studied genetic divergence in 18 accessions of dolichos bean. The genotypes were grouped into eight clusters. Among the eight clusters, cluster I had maximum number of genotypes, cluster II to cluster V each had two genotypes each, while cluster VI to VIII had solitary genotype. The maximum genetic distance was observed between cluster III and cluster V followed by cluster V and cluster VII. Cluster I and cluster VII exhibited lowest degree of divergence. The maximum intra cluster distance was exhibited by cluster IV followed by cluster V. The cluster mean value for most of the traits was highest in cluster VIII. Pod width followed by number of branches per plant, plant spread, number of seeds per pod contributed higher towards total divergence

Rai *et al.* (2009) studied genetic divergence in 37 dolichos bean genotypes for fifteen characters. On the basis of D^2 statistic method, the genotypes were grouped into three clusters. Cluster I, II and III had 5, 18 and 14 genotypes respectively. The intra cluster distance ranged from 103.93 (cluster III) to 464.19 (cluster I). The maximum inter cluster distance was recorded between cluster II and cluster I (4362.99) followed by cluster III and cluster I (1645.55), whereas, the lowest intercluster distance was observed between cluster III and II (845.38). The contribution of various characters towards genetic divergence indicated that number of seeds per pod (26.05%), and number of fruit set (22.29%) contributed maximum towards divergence.

Mishra *et al.* (2010) studied genetic divergence in 51 genotypes of french bean for fourteen characters. By using D^2 values, the genotypes were grouped into 8 clusters. A very large majority of genotypes were found in cluster VII and VIII, followed by cluster V and cluster IV. The highest genetic divergence occurred between clusters IV and V (D^2 = 86.56), followed closely by that between clusters V and VI (D^2 = 84.560) and the lowest divergence was between clusters VII and VIII (D^2 = 22.75). Cluster IV had maximum cluster mean performance to days to first flowering, Number of pods per cluster and number of seeds per pod. Similarly, cluster VI had genotypes with desirable number of pods per plant and days to marketable maturity.

Patel *et al.* (2011) studied genetic divergence in 63 genotypes of dolichos bean. On the basis of D^2 statistics, the genotypes were grouped in to six clusters. Maximum number of genotypes (17) was retained by cluster III followed by cluster VI (15) genotypes, cluster I and IV almost equal (11) genotypes, cluster V with 5 genotypes and cluster II with 4 genotypes. Among six cluster the maximum inter cluster distance was observed between cluster III and I (4.984), followed by cluster III and VI (2.585), cluster III and I (1.998), cluster IV and III (1.617), cluster V and III (1.781) and cluster VI and II (1.420). The genotypes IS-02, IS-04, IS-28 and IS-38 were highly divergent and used as parents in breeding programme.

Huque *et al.* (2012) studied genetic divergence in 13 yard long bean genotypes. On the basis of D^2 statistics, the genotypes were grouped into four clusters. Cluster III had the maximum (5) and cluster I had the minimum (1) number of genotypes. Cluster III (D^2 = 1.439) had highest intra-cluster distance and the lowest in cluster I (D^2 = 0.000). The inter-cluster divergence ranged from 4.160 to 15.515 between clusters II and III and clusters I and II, respectively.

Syed Mudasir *et al.* (2012) studied genetic divergence in 71 french bean genotypes for ten characters. On the basis of D^2 statistics, the genotypes were grouped into three clusters. The clustering pattern showed cluster II had 51 genotypes, cluster I had 23 genotypes and the third cluster had only one genotype. Analysis of the traits contributing maximum to the divergence in the pooled analysis revealed the traits like days to maturity (22.52%), protein content (12.605), and days to 50 per cent flowering (10.46%) to contributed maximum to the divergence.

Mahalanobis D^2 statistics was used to study the genetic divergence for 19 characters among 48 genotypes of Indian bean. Genotypes were grouped in to eight clusters. The highest number of genotypes (14) appeared in cluster III. The maximum inter cluster distance was observed between cluster IV and cluster VI followed by cluster IV and VIII. The minimum inter cluster distance was observed between cluster I and cluster IV. Maximum intra cluster distance was in cluster V followed by cluster III. The mean cluster value for most of the traits was highest in cluster VIII. Among the yield contributing characters, the maximum contribution towards divergence was made by protein content followed by number of flowers per inflorescence, pod length and number of pods per plant (Chaitanya *et al.*, 2013).

Pawar *et al.* (2013) evaluated 58 genotypes of lablab bean. The genotypes were grouped into seven clusters on the basis of relative magnitude of D^2 values. The maximum genetic distance was observed between cluster IV and cluster VII (45.798) followed by cluster IV and cluster VI (42.723) and cluster III and cluster VII (40.680). Cluster II and cluster III displayed lowest degree of divergence. The maximum intra cluster distance was exhibited by cluster I (22.432) followed by cluster VI (17.807) and cluster V (16.872), whereas minimum was recorded by cluster III. The maximum cluster mean value for grain yield per plant was recorded in cluster III due to maximum number of inflorescences per plant. Protein content followed by days to 50 per cent flowering and days to maturity contributed maximum towards total divergence

Salim *et al.* (2013) studied genetic divergence in 66 genotypes of lablab bean for eleven characters. On the basis of D^2 statistics, the genotypes were grouped into seven clusters. The highest number of genotypes 15 was included in cluster V followed by cluster II, which contained 13 genotypes. Cluster III, I, VI, IV and VII contained 12, 11, 6, 5 and 4 genotypes, respectively. The highest amount of genetic divergence within the cluster group was noticed in the cluster VII having only 4 genotypes. The inter-cluster D2 values varied from 2059.094 to 19302.6. The distances between the cluster VII and V; VII and VI; VII and II and VII and I were comparatively high than the other inter-cluster distances. The intracluster distance (8502.795) observed in cluster VII revealed maximum diversity among genotypes. The number of pods per plant contributed maximum (34.033%) to the genetic divergence followed by pod yield per plant.

Gangadhara *et al.* (2014) studied genetic divergence in 66 genotypes of french bean for eleven characters. On the basis of D^2 statistics, the genotypes were grouped into two clusters. Cluster II was the largest, consisting of forty eight genotypes, while cluster I contained eighteen genotypes. Days to fifty per cent flowering (43.86%) contributed maximum to the total genetic diversity among the genotypes followed by green pod yield (11.79%), pod weight (11.04%) and pod length (6.71%). The maximum inter cluster distance was recorded to be 148.840 between cluster I and cluster II. Cluster I showed maximum intra-cluster distance (122.419). Whereas, the lowest intra cluster distance was in the cluster II (D^2 = 86.14). Cluster I having maximum mean values for plant height, pod weight, pod length and green pod yield per plant. Cluster II having maximum mean values for number of pods per plant, number of seeds per plant and days to 50 per cent flowering.

3. MATERIAL AND METHODS

The investigation on variability and genetic diversity studies in french bean was undertaken during the *Rabi* season of 2015-2016. The details of the experiment, material used and techniques adopted in the present investigation are presented in this chapter.

3.1 Experimental site

The experiment on variability and genetic diversity studies in French bean was conducted at the Research Block of Vegetable Section in Sector No. 1 under the University of Horticultural Sciences, Bagalkot (Karnataka). The soil of the experimental site was medium black. The chemical properties of the soil are presented in Appendix I.

3.2 Location and climate

Bagalkot is situated in Northern dry zone of Karnataka State at 16^o 46’ North latitude, 74^o 59’ East longitude and an altitude of 533.0 meters above the mean sea level.

During crop period *i.e.,* from November 2015 to January 2016 the rainfall received was low (36 mm).Mean maximum and minimum relative humidity were 64.70 and 79.25 per cent, respectively. The minimum and maximum temperature was 18.33 and 30.33^0C.The meteorological data recorded at MHREC, Bagalkot during 2015-2016 is presented in Appendix II.

3.3 Experimental details

3.3.1 Experimental material

The experimental material comprised of 36 genotypes collected from Indian Institute of Horticulture Research, Hesaraghatta, Bangalore. The list of genotypes with their sources of collection is given in Table 2.

Table 2. Details of French bean genotypes with their sources

Sl. No	Genotypes	IC- No.	Sl. No	Genotypes	IC- No.
1.	IIHR- 6	525211	19.	IIHR- 53	525258
2.	IIHR- 7	525212	20.	IIHR- 62	525267
3.	IIHR- 9	525214	21.	IIHR- 67	525272
4.	IIHR- 13	525218	22.	IIHR- 70	525275
5.	IIHR- 16	525221	23.	IIHR- 76	525281
6.	IIHR- 21	525226	24.	IIHR- 87	-
7.	IIHR- 23	525228	25.	IIHR- 119	-
8.	IIHR- 27	525232	26.	IIHR- 232	-
9.	IIHR- 29	525234	27.	IIHR- 234	-
10.	IIHR- 32	525237	28.	IIHR- 237	-
11.	IIHR- 34	525239	29.	IIHR- 244	
12.	IIHR- 35	525240	30.	IIHR- 245	-
13.	IIHR- 36	525241	31.	Arka Komal	-
14.	IIHR- 37	525242	32.	Arka Anoop	-
15.	IIHR- 40	525245	33.	Arka Suvidha	-
16.	IIHR- 44	525249	34.	Arka Sharath	-
17.	IIHR- 47	525252	35.	Arka Arjun	-
18.	IIHR- 48	525253	36.	Bagalkot Local	-

3.3.2 Layout of the experiment

Number of treatments	: 36 genotypes
Experimental design	: RCBD
Replications	: 2
Spacing	: 60 X 15 cm
Season	: *Rabi* 2015
No of plants per row	: 50 plants

3.4 Cultural operations

The cultural operations constituted the following sequence of work.

3.4.1 Preparation of experimental plot

The land was brought to a fine tilth by repeated ploughing and harrowing. The plot of requisite dimension was prepared as per the plan. A gap of 1.0 m between two replications was provided for laying out the irrigation channels and working space.

3.4.2 Sowing and Gap filling

Seeds collected from different sources were used for sowing. The ridges and furrows were opened at 60 cm and two to three seeds per hill were sown by dibbling on one side of the ridge at 15 cm distance. The sowing was done on November 2nd 2015 in *rabi* season and irrigation was given after the sowing. Thinning of excess seedlings and gap filling was done one week after sowing.

3.4.3 Fertilizer application

Recommended dose (63:100:75 kg/ha, FYM-25 t/ha) of nitrogen, phosphorus and potassium were applied in the form of urea, diammonium phosphate and muriate of potash respectively at the time sowing, half the dose of N and full dose of P and K were applied as basal dose and remaining half dose of N was applied as a top dress at 30 days after sowing.

3.4.4 Weeding and irrigation

The plots were kept weed free by 3- 4 hand weeding. Irrigation was given at an interval of 6-7 days during experimentation, depending on the soil moisture status and climatic conditions.

3.4.5 Harvesting

French bean pods were harvested at tender stage. The pickings were done and pod yield per plot of each treatment was recorded.

3.5 Observations recorded

For recording various observations, five plants in each experimental plot were randomly selected by avoiding border plants. The selected plants were tagged for taking observations on various growth and yield parameters.

3.5.1 Vegetative parameters

1. Plant height (cm)

The plant height was measured from ground level to the tip of the plant at 25 and 50 day after sowing. The plant height was measured with the help of meter scale and average was computed and expressed in centimetres.

2. Plant spread (cm)

With the help of meter scale, the spread of plant was measured in centimetre in North- South and East –West direction at 25 and 50 days after sowing.

3. Number of primary branches per plant

Number of primary branches arising from main stem were counted at 50 days after sowing and the average was worked out.

3.5.2 Earliness parameters

1. Days to first flowering

The day on which the first flower appeared was noted on the five randomly selected plants and the days to first flowering were counted from the date of sowing and the average was calculated and expressed as days to first flowering.

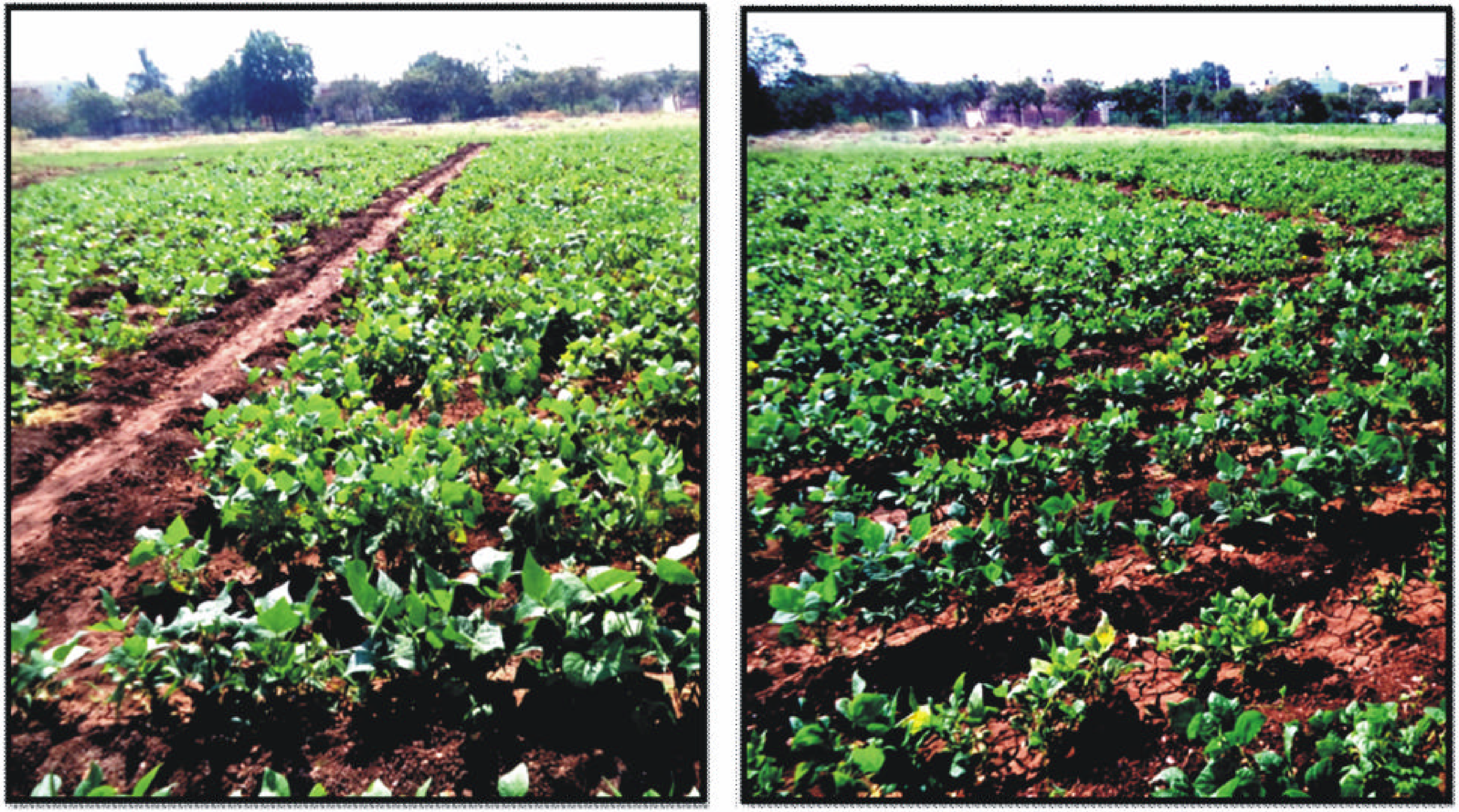

Plate 1. General view of experimental plot

2. Days to 50 per cent flowering

Days to 50 per cent flowering was recorded from the five randomly tagged plants and the average was worked out from date of sowing and expressed in days.

3. Days to first pod picking

The days from the date of sowing to date of first vegetable pod picking were counted and recorded.

3.5.3 Yield parameters

1. Pod Length

Pod length (cm) was measured on randomly selected ten pods at the time of harvest and expressed in centimetres.

2. Pod width

The width of the ten selected pods was measured at the centre of pods and average was worked out and expressed in centimetres.

3. Pod flesh thickness

The flesh thickness was measured in ten randomly selected pods by taking cross section at centre and average was computed and expressed in centimetres.

4. Number of seeds per pod

Number of seeds per pod was taken as a mean number of seeds of ten randomly selected pods at the time of harvest.

5. Number of pods per clusters

Number of pods produced on pod bearing cluster of tagged plants in each experimental plot was counted and average was worked out.

6. Number of clusters per plant

The number of clusters produced by the tagged plants in each experimental plot was counted and average was worked out.

7. Number of pods per plant

The number of marketable green pods harvested in successive harvest were pooled and expressed as total number of pods per plant.

8. Weight of ten pods

Ten green vegetable pods harvested from the tagged plants were selected randomly and weight was recorded in grams.

9. Vegetable pod yield per plant

The weight of green vegetable pods harvested from the tagged plants was recorded separately and the sum of all harvests was used to work out the vegetable pod yield per plant and expressed as grams.

10. Vegetable pod yield per hectare (t/ha)

The vegetable pod yield per plot was computed by summing up pod yield of all the harvests in each treatment and from these data yield per hectare in tonnes was computed.

$$\text{Yield /ha (t)} = \frac{\text{Yield /plot (kg)} \times 10{,}000}{\text{Plot area} \times 1{,}000}$$

Plot area= 4.50 square meter

11. Number of root nodules per plant

Number of nodules produced on roots of tagged plants in each experimental plot was counted and average was worked out.

12. Dry matter in leaves, stem and roots (g/plant)

At the harvesting stage, five tagged plants were carefully uprooted in each treatment and were separated into leaves, root and stem. The separated plant parts were oven dried at a temperature of 65^0C ± 5^0 C for 24 hours after removing the soil adhered to the root zone. The dried plant parts were cooled in the ambient conditions for two hours. The dry weight was recorded the average was computed and expressed as grams.

13. Dry matter in pods (g/plant)

The 100g fresh pod sample was collected from the pods harvested from tagged plants. This sample was oven dried at a temperature of $65^0 \pm 5^0$ C for 24 hours. The dried pod sample was cooled in ambient conditions for two hours. The dry weight of the sample was recorded. From this data the dry weight in pods (g) per plant was worked by using the following formula.

$$\text{Dry weight in pods per plant (g)} = \frac{\text{Dry weight of 100 g sample x total weight of pods per plant}}{100}$$

3.5.4 Quality parameters

1. Protein content in pods

Protein content of fresh pods from each variety was estimated as per the Lowry's method and expressed in g/100 g of pods.

2. Pod colour

The colour of the pod harvested for vegetable purpose was observed for twelve varieties under natural day light and grouped into dark green, medium green and light green.

3. Pod curvature

The pod curvature was observed and recorded at edible stage for all twelve varieties and were grouped into straight, slightly curved and highly curved.

4. Pod shape

The pod shapes was observed and recorded at edible stage for all twelve varieties and were grouped into circular and elliptic shapes.

5. Stringlessness

The pod stringlessness was observed by visually at edible stage for all the twelve genotypes and grouped into stringness and stringlessness.

3.6 Statistical and Biometrical analysis

The data collected from the experiment was subjected to various statistical analysis to draw the suitable inference. The details of the statistical procedure followed are given below.

3.6.1 Analysis of variance (ANOVA)

Analysis of variance was carried out as per the procedure given by Panse and Sukhatme (1967). Using the mean values of randomly selected plants in each replication from all treatments to find out the significance of treatment effects. The details of analysis of variance are as follows

Source of variation	**Degrees of freedom (d. f)**	**S.S.**	**M.S.S.**	**F ratio (Cal. F)**
Replication	(r-1)	RSS	Mr (M1)	Mr/ Me
Genotype	(g-1)	GSS	Mg (M2)	Mg/ Me
Error	(r-1) (t-1)	ESS	Me (M3)	-
Total	(rt-1)	-	-	-

Where,

r = Number of replication Mr= Mean sum of square of replication

g = Number of genotypes Mg = Mean sum of square of genotypes

Me = Mean sum of square of error.

Statistical significance of variation due to genotype was tested by comparing calculated values to table F values at one per cent and five per cent level of probability.

3.6.2 Estimation of genetic parameters

1. Genotypic and phenotypic variance

The genotypic and phenotypic variances were computed based on the expected mean sum of squares from ANOVA table as follows:

$$\text{Genotypic variance } (\sigma^2 g) = \frac{\text{Genotype MSS (Mg) - Error MSS (Me)}}{r}$$

Phenotypic variance (σ^2 P) = $\sigma^2 g + \sigma^2 e$

Environmental variance (σ^2 e) = Me

2. Coefficient of variations

Genotypic and phenotypic coefficients of variations were computed according to Burton and Devane (1953) based on the estimate of genotypic and phenotypic variances as follows.

3. Genotypic co-efficient of variation (GCV)

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sigma_g}{\bar{x}} \times 100$$

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sigma_p}{\bar{x}} \times 100$$

Where,

$\bar{X}$ = General mean

σ g = Genotypic standard deviation

σ p = Phenotypic standard deviation

GCV and PCV were classified as suggested by Sivasubramanian and Menon (1973).

0 - 10%	: Low
10-20%	: Moderate
20% and above	: High

4. Heritability

Broad sense heritability was estimated as the ratio of genotypic variance to the phenotypic variance and expressed in percentage (Falconer, 1981).

$$\text{Heritability } (h^2) = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,

σ^2 g = Genotypic Variance

σ^2 p = Phenotypic Variance

Heritability percentage was categorised as demonstrated by Robinson *et al.* (1949).

0-30% : Low

31-60% : Moderate

>60% : High

5. Genetic advance (GA)

Genetic advance (GA) was computed using the formula given by Robinson *et al.* (1949).

GA = i.P.h2

Where,

i = Selection differential (2.06) at 5 per cent selection intensity

P = Phenotypic standard deviations

h2 = Heritability at broad sense

6. Genetic advance as percentage over mean (GAM)

Genetic advance as percentage over mean was worked out as suggested by Johnson *et al.* (1955).

$$GAM = \frac{GA}{\bar{x}} \times 100$$

Where,

GA = Genetic advance

X = General mean of the character

The GAM was categorized as suggested by Johnson *et al.* (1955).

0-10% : Low

11-20% : Moderate

>20% : High

3.6.3 Correlation

The correlation co-efficient among all important character combinations at phenotypic (rp) and genotypic (rg) level were estimated by employing formula given by Al-Jibouri *et al.* (1958).

$$\text{Phenotypic correlation} = r_{xy}(P) = \frac{\text{Cov}_{xy}(P)}{\sqrt{[V_X(P) \times V_Y(P)]}}$$

$$\text{Genotypic correlation} = r_{xy}(G) = \frac{\text{Cov}_{xy}(G)}{\sqrt{[VX(g) \times VY(g)]}}$$

Where,

$COV_{XY}(P)$ = Phenotypic co-variance between X and Y characters

$COV_{XY}(G)$ = Genotypic co-variance between X and Y characters

$V_x(p)$ = Phenotypic variance of X characters

$V_x(_g)$ = Genotypic variance of X characters

$V_Y(_p)$ = Phenotypic variance of Y characters

$V_Y(_g)$ = Genotypic variance of Y characters

The test of significance for association between characters was done by comparing table ‘r’ values at n-2 error degrees of freedom for phenotypic and genotypic correlations with estimated values, respectively.

3.6.4 Path co-efficient analysis

Path co-efficient analysis suggested by Wright (1921) and Dewey and Lu (1957) was carried out to know the direct and indirect effect of the morphological traits on plant yield. The following set of simultaneous equations were formed and solved for estimating various direct and indirect effects.

$r_{1y} = a + r_{12}b + r_{13}c + \ldots\ldots\ldots\ldots\ldots\ldots.... + r_{1Ii}$

$r_{2y} = a + r_{21}a + b + r_{23}c + \ldots\ldots\ldots\ldots\ldots.. + r_{2Ii}$

$r_{3y} = r_{31}a + r_{32}b + c + \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. + r_{3Ii}$

$r_{1y} = r_{11}a + r_{12}b + r_{13}c + \ldots\ldots\ldots\ldots\ldots.. + I$

Where,

r_{1y} to 1_{1y} = Co-efficient of correlation between causal factors 1 to I with

dependent characters y.

r_{12} to r_{1I} = Co-efficient of correlation among causal factors

a, b, c…i = Direct effects of characters 'a' to 'I' on the dependent character 'y'

Residual effect (R) was computed as follows.

Residual effect (R) = $1- \sqrt{a^2 + b^2 + c^2 + \ldots\ldots\ldots i^2 + 2abr_{12} + 2acr_{13} + \ldots.}$

Lenka and Mishra (1973) have suggested scales for path coefficients analysis.

0.00-0.09	: Negligible
0.10-0.19	: Low
0.20-0.29	: Moderate
0.30-0.99	: High
>1.00	: Very high

3.6.5 Genetic divergence

3.6.5.1 Mahalanobis D2 analysis

Mahalanobis (1936) D^2 statistic was used for assessing the genetic divergence between different populations. The D^2 analysis was carried out using the data recorded on germplasms. Mahalanobis generalized distance (D^2) between any two populations is given by the formula.

$$D^2 = \sum \lambda^{ij} \sigma^i \sigma^j$$

Where,

D^2 = Square of generalized distance

λ^{ij} = Reciprocal of the common dispersal index

$\sigma^i = \mu i1 - \mu i2$

$\sigma^j = \mu j1 - \mu j2$

μ = General mean

Since, the formula for computation requires inversion of higher order determinants, transformation of the original correlated unstandardised character mean (Xs) to standardise uncorrelated variable (Ys) was done to simplify the computational procedure. The D2 values were obtained as the corresponding uncorrelated (Ys) values of any two uncorrelated genotypes (Rao, 1952).

3.6.5.2 Clustering of genotypes

Using all the n (n-1)/2D2 values were grouped into cluster using Toucher’s method as described by Rao (1952).

3.6.5.3 Intra and inter-cluster distance

The intra and inter-cluster distances were calculated by following the formula described by Singh and Choudhary (1976).

$$\text{Square of intra-cluster distance} = \frac{\Sigma Di^2}{N}$$

Where,

Di^2 = Sum of distances between all possible combinations of the entries included in the cluster

N = Number of all possible combinations

$$\text{Square of inter-cluster distance} = \frac{\Sigma Dij^2}{n_i nj}$$

Where,

Dij^2 = Sum of distances between all possible combinations ($n_i n_j$) of the entries included in the cluster

n_i = Number of entries in the cluster i

n_j = Number of entries in the cluster j

4. EXPERIMENTAL RESULTS

The present investigation on Variability and genetic diversity studies were carried out using 36 genotypes of french bean (*Phaseolus vulgaris* L.) at the Research Block of Vegetable Section in Sector No. 1 under the University of Horticultural Sciences, Bagalkot during 2015-2016. The results obtained are presented in this chapter.

4.1 Genetic variability

4.1.1 Analysis of variance

The results of the analysis of variance for 27 characters under study are summarised in Tables 3 and 4. The variance due to treatments (genotypes) was significant for all 27 characters *viz.,* plant height (25 and 50 DAS), plant spread (25 and 50 DAS), number of primary branches (50 DAS), days to first flowering, days to 50 per cent 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, average pod weight, pod yield per plant, pod yield per plot, pod yield per hectare, number of root nodules per plant, dry matter content (leaves, stem, pod and roots) and protein content.

4.1.2 Genetic variability, heritability and genetic advance

The estimates of mean, range, genotypic variance (GV), phenotypic variance (PV), genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), heritability (h^2), genetic advance (GA) and genetic advance as per cent over mean (GAM) were worked out for 27 plant traits and are presented in Tables 5 and 7.

4.1.2.1 Plant height

Plant height at 25 DAS (Tables 5 and 6) ranged from 18.75 cm (IIHR-244) to 37.90cm (Arka Sharath) with a mean value of 29.83 cm. The GV (18.53) was moderate and PV (26.35) was high. The moderate GCV (17.20%) and PCV (14.43%) were observed. High heritability (70.33%) along with high genetic advance over mean (24.93%) was noticed for this trait.

Table 3. Analysis of variance (mean sum of squares) for growth, earliness and yield parameters in French bean genotypes

Sl. No.	Source of variation/ Character	Replication	Genotype (treatment)	Error	CD @ 5%	CD @1%
	Degrees of freedom	**1**	**35**	**35**		
A.	**Growth parameters**					
1.	Plant height at 25 DAS (cm)	24.85	44.89**	7.82	5.67	7.61
2.	Plant height at 50 DAS (cm)	105.12	77.57**	11.92	7.01	9.40
3.	Number of primary branches at 50 DAS	0.21	1.03**	0.199	0.90	1.21
4.	Plant spread (N-S) at 25 DAS	7.36	29.21**	3.21	4.51	6.06
5.	Plant spread (N-S) at 50 DAS	62.94	40.69**	4.95	5.13	6.88
6.	Plant spread (E-W) at 25 DAS	4.06	33.29**	3.52	4.88	6.26
7.	Plant spread (E-W) at 50 DAS	1.30	33.70**	4.76	4.43	5.94
B.	**Earliness parameters**					
8.	Days to first flowering	17.01	14.26**	2.87	3.43	4.61
9.	Days to 50 percent flowering	22.89	26.47**	3.61	3.86	5.18
10.	Days to first pod picking	24.15	30.56**	5.02	4.54	6.10
C.	**Yield parameters**					
11.	Pod length (cm)	9.46	4.21**	0.94	1.97	2.64
12.	Pod width (cm)	0.001	0.019**	0.001	0.08	0.12
13.	Pod flesh thickness (cm)	0.005	0.010**	0.001	0.08	0.11

Table 4. Analysis of variance (mean sum of squares) for growth, earliness and yield parameters in French bean genotypes

Sl. No.	Source of variation/ Character	Replication	Genotype (treatment)	Error	CD @ 5%	CD @1%
	Degrees of freedom	**1**	**35**	**35**		
C.	**Yield parameters**					
14.	Number of seeds/ pod	0.22	0.70**	0.10	0.64	0.86
15.	Number of clusters per plant	12.33	5.49**	0.94	1.97	2.64
16.	Number of pods per cluster	0.055	0.19**	0.04	0.41	0.56
17.	Number of pods per plant	169.17	67.12**	13.09	7.34	9.86
18.	Average pod weight	90.74	103.92**	21.83	9.47	12.73
19.	Yield per plant	8867.922	3481.91**	377.55	39.38	52.93
20.	Yield per plot	22.16	8.70**	0.94	1.97	2.65
21.	Yield per hectare	109.69	42.96**	4.64	4.37	5.87
22.	Number of root nodules per plant	17.11	18.14**	1.43	2.43	3.26
23.	Dry matter content of leaves	8.92	16.89**	2.82	3.41	4.58
24.	Dry matter content of stem	15.35	100.41**	18.62	8.75	11.76
25.	Dry matter content of pod	6.67	16.21**	2.546	3.23	4.34
26.	Dry matter content of roots	0.01	2.99**	0.35	1.21	1.63
D.	**Quality parameters**					
27.	Protein content	0.040	0.275**	0.001	5.47	4.07

****- Significant at P= 0.01**

Table 5. Estimates of range, mean, components of variance, heritability and genetic advance for growth, earliness and yield parameters in French bean

Sl. No.	Character	Range	Mean ±S.Em	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)
A.	**Growth parameters**									
1.	Plant height at 25 DAS (cm)	18.75-37.90	29.83 ±1.97	26.35	18.53	17.20	14.43	70.33	7.43	24.93
2.	Plant height at 50 DAS (cm)	31.50-53.50	44.87±2.44	44.75	32.82	14.90	12.76	73.35	10.10	22.52
3.	Number of primary branches at 50 DAS	4.80-7.10	6.09 ±0.31	0.61	0.41	12.91	10.63	67.78	1.09	18.03
4.	Plant spread (N-S) at 25 DAS	29.50-48.00	37.27±1.57	22.79	17.83	12.80	11.32	78.26	7.69	20.64
5.	Plant spread (N-S) at 50 DAS	38.25-60.00	45.94±1.7	28.10	21.72	11.53	10.14	77.27	8.43	18.36
6.	Plant spread (E-W) at 25 DAS	26.50-48.00	33.75±1.54	19.23	14.46	12.99	11.26	75.23	6.79	20.13
7.	Plant spread (E-W) at 50 DAS	29.50-47.00	38.87±1.62	18.62	13.33	11.10	9.39	71.59	6.36	16.37
B.	**Earliness parameters**									
8.	Days to first flowering	28.50-39.50	33.04±1.19	8.56	5.69	8.85	7.22	66.50	4.01	12.13
9.	Days to 50 percent flowering	34.50-48.50	40.41±1.34	15.04	11.43	9.59	8.36	75.96	6.07	15.02
10.	Days to first pod picking	43.50-59.00	51.62±1.58	17.79	12.77	8.17	6.92	71.77	6.23	12.07
C.	**Yield Parameters**									
11.	Pod length (cm)	8.25-15.50	13.39±0.68	2.57	1.63	11.99	10.00	63.32	2.09	15.64
12.	Pod width (cm)	0.61-1.27	0.82±0.03	0.010	0.008	12.42	11.21	81.37	0.17	20.83
13.	Pod flesh thickness (cm)	0.42-0.73	0.61±0.030	0.006	0.004	13.01	10.47	71.08	0.11	19.05

GV = Genotypic variance PV = Phenotypic variance GCV = Genotypic coefficient of variance GA= Genetic advance h^2 = Heritability (broad sense)
PCV =Phenotypic coefficient of variance GAM = Genetic advance (per cent mean), DAS= Days after sowing.

Table 6. ***Per se*** **performance of french bean (** ***Phaseolus vulgaris*** **)genotypes for growth and earliness parameters**

Sl. No.	Character	Range	Mean ±S.Em	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)
C.	**Yield parameters**									
14.	Number of seeds per pod	4.40-7.20	6.02±0.22	0.40	0.29	10.50	9.09	74.84	0.97	16.20
15.	Number of clusters per plant	10.50-15.90	13.67±0.69	2.27	3.21	13.12	11.03	70.74	2.61	19.12
16.	Number of pods per cluster	1.95-3.13	2.61±0.14	0.11	0.075	13.14	10.55	64.48	0.45	17.45
17.	Number of pods per plant	20.93-46.29	35.77±2.56	27.01	40.11	17.70	14.52	67.35	8.78	24.56
18.	Average pod weight	30.65-66.00	51.97±3.30	41.04	62.87	15.25	12.32	65.27	10.66	20.51
19.	Yield per plant	110.65-268.50	185.09±13.74	1552.18	1929.73	23.73	21.28	80.43	72.78	39.32
20.	Yield per plot	5.53-13.43	9.25±0.69	3.88	4.82	23.74	21.29	80.43	3.63	39.32
21	Yield per hectare	12.29-29.83	20.56±1.52	19.15	23.80	23.72	21.28	80.48	8.08	39.33
22	Number of root nodules per plant	11.40-22.60	16.16±0.84	9.79	8.35	19.38	17.87	85.36	5.50	34.02
23.	Dry matter content of leaves	18.85-32.75	27.58±1.19	7.03	9.85	11.38	9.61	71.36	4.61	16.73
24.	Dry matter content of stem	60.60-86.50	71.45±3.05	40.89	59.52	10.79	8.95	68.71	10.91	15.28
25.	Dry matter content of pods	15.95-26.25	19.40±1.13	6.83	9.38	15.48	13.47	72.85	4.59	23.68
26.	Dry matter content of roots	7.15-11.75	9.54±0.42	1.31	1.61	13.57	12.03	78.68	2.09	21.99
D.	**Quality parameters**									
27.	Protein content	0.94-2.42	1.62±0.03	0.1385	0.1365	22.88	22.72	98.56	0.75	46.46

GV = Genotypic variance PV = Phenotypic variance GCV = Genotypic coefficient of variance GA= Genetic advance h^2 = Heritability (broad sense)
PCV =Phenotypic coefficient of variance GAM = Genetic advance (per cent mean) , DAS= Days after sowing.

Plant height at 50 DAS (Tables 5 and 6) ranged from 31.50 (IIHR-35) to 53.50 cm (IIHR-34) with a mean value of 44.87cm. The GV (32.82) and PV (44.75) were high. The moderate GCV (12.76%) and PCV (14.90%) were observed. High heritability (73.35) along with high genetic advance over mean (22.52%) and moderate genetic advance (10.10) were noticed for this trait

4.1.2.2 Plant spread (North-South)

Plant spread (N-S) at 25 DAS (Tables 5 and 6) ranged from 29.50cm (IIHR-87) to 48.00cm (Arka Arjun)) with a mean value of 37.28 cm. The GV (17.83) was moderate and PV (22.79) was high. The moderate genotypic coefficient of variation (11.32%) and phenotypic coefficient of variation (12.80%) with high heritability (78.26%) and low genetic advance (7.69) with high GAM (20.64%) were noticed for this trait.

Plant spread (N-S) at 50 DAS (Tables 5 and 6) ranged from 38.25cm (IIHR-87) to 60.00cm (IIHR-29) with a mean value of 45.95 cm. The estimates of genotypic variance (21.72) and phenotypic variance (28.10) were high. The moderate genotypic coefficient of variation (10.14%) and phenotypic coefficient of variation (11.53%) with high heritability (77.27%) and low genetic advance (8.43) with moderate GAM (18.36 %) were recorded.

4.1.2.3 Plant spread (East-West)

The range for plant spread (E-W) at 25 DAS (Tables 5 and 6) was 26.50 cm (IIHR-87) to 45.50 cm (Arka Arjun) with a mean value of 33.75cm. The GV (14.46) and PV (19.23) were moderate. The moderate genotypic coefficient of variation (12.99%) and phenotypic coefficient of variation (14.46%) with high heritability (75.23%) and low genetic advance (6.79) with high GAM (20.13%) were observed.

Plant spread (E-W) at 50 DAS (Tables 5 and 6) ranged from 32.50cm (IIHR-87) to 47.00cm (IIHR-27) with a mean value of 38.87 cm. The moderate genotypic variance (13.33) and phenotypic variance (18.62) were observed. The low to moderate genotypic coefficient of variation (9.39%) and phenotypic coefficient of variation (11.10%) with high heritability (71.59%) low Genetic advance (6.36) with moderate GAM (16.37 %) were noticed for this trait.

4.1.2.4 Number of primary branches per plant

At 50 DAS (Tables 5 and 6) number of primary branches ranged from 4.80 (IIHR-13) to 7.10 (Arka Sharath) with a mean value of 6.09.The estimates of GV (0.41) and PV (0.61) were very low. The estimates genotypic coefficient of variation (10.63%) and phenotypic coefficient of variation (12.91%) were moderate. High heritability (67.78%) with low genetic advance (1.09) and moderate GAM (18.03%) were noticed for this trait.

4.1.2.5 Days to first flowering

For appearance of first flower, the genotype IIHR-62 took least number of days (28.50) and IIHR-70 took maximum number of days (39.50) with mean value of days 33.04 (Tables 5 and 6). The estimates of genotypic variances (5.69) and phenotypic variances (8.56) were low. The low GCV (7.22%) and PCV (8.85%) were observed. The high heritability (66.50%) with moderate GAM (12.13%) was observed.

4.1.2.6 Days to 50 per cent flowering

The genotype IIHR-21 took least number of days (34.50) for 50 per cent flowering, while Bagalkot local took maximum number of days (48.50), on an average genotypes took 40.41 days for appearance of 50 per cent flowering (Tables 5 and 6). The estimates of genotypic variances (11.43) and phenotypic variances (15.04) were moderate. The low genotypic coefficient of variation (8.36%) and phenotypic coefficient of variation (9.59%) with high heritability (75.96%) and low genetic advance (6.07) with moderate GAM (15.02%) were recorded.

4.1.2.7 Days to first pod picking

The genotype (IIHR-53) took least number of days (43.50) for 50 per cent flowering, while (IIHR-16 and IIHR-36) took maximum number of days (59.00), on an average genotypes took 51.62 days to reach first pod maturity (Tables 5 and 6). The estimates of genotypic variance (12.77) and phenotypic variance (17.79) were moderate. The low genotypic coefficient of variation (6.92%) and phenotypic coefficient of variation (8.17%) with high heritability (71.77%) and low genetic advance (6.23) with moderate GAM (12.07%) were observed.

4.1.2.8 Pod length

Pod length (Tables 5 and 8) was maximum in IIHR-76 (15.50 cm) while it was minimum in IIHR-244 (8.25 cm) to 15.50 cm (IIHR-76) with a mean value of 13.39 cm. The low genotypic variance (1.63) and phenotypic variance (2.57) were observed. The low estimates of genotypic coefficient of variation (9.54%) with moderate phenotypic coefficient of variation (11.99%) and high heritability (74.07%) and low genetic advance (2.46) with moderate GAM (18.36%) were observed for this trait.

4.1.2.9 Pod width

Pod width (Tables 5 and 8) ranged from 0.62 cm (Arka Komal) to 1.27cm (IIHR-244) with a mean value of 0.82 cm. The estimates of GV (0.008) and PV (0.01) were very low. The moderate genotypic coefficient of variation (11.21 %) and phenotypic coefficient of variation (12.42%) with high heritability (81.37%) and low genetic advance (0.17) with high GAM (20.83%) were noticed for this trait.

4.1.2.10 Pod flesh thickness

Pod flesh thickness (Tables 5 and 8) ranged from 0.43 cm (IIHR-244) to 0.74cm (IIHR-234) with a mean value of 0.62 cm. The estimates of GV (0.004) and PV (0.006) were very low. The moderate genotypic coefficient of variation (10.97%) and phenotypic coefficient of variation (13.01%) with high heritability (71.08%) and low genetic advance (0.11) with moderate GAM (19.05 %) were recorded.

4.1.2.11 Number of seeds per pod

Number of seeds per pod (Tables 7 and 8) ranged from 4.40 (IIHR-244) to 7.20 (IIHR-232) with a mean value of 6.03 cm. The estimates of GV (0.29) and PV (0.40) were very low. The low genotypic coefficient of variation (9.09%) with moderate phenotypic coefficient of variation (10.50%) was observed. High heritability (74.84%) and low genetic advance (0.97) with moderate GAM (16.20%) were noticed for number of seeds per pod.

Table 7. Estimates of range, mean, components of variance, heritability and genetic advance for yield parameters in French bean

Sl. No.	Genotypes	Plant height		Number of primary branches	Plant spread		Plant spread		Days to first flowering Days to	50 per cent flowering	Days to first pod picking
		25 DAS	50 DAS	50 DAS	25 DAS	50 DAS	25 DAS	50 DAS			
1	IIHR- 6	28.50	40.50	6.10	35.85	45.50	31.75	36.75	30.00	36.00	50.00
2.	IIHR- 7	29.00	42.50	5.40	34.60	46.25	34.75	38.00	32.00	37.50	51.00
3.	IIHR- 9	31.25	42.00	5.60	35.00	41.50	31.15	36.50	34.50	40.00	54.50
4.	IIHR- 13	30.25	49.50	4.80	32.00	38.50	27.75	37.00	34.00	39.50	53.00
5.	IIHR- 16	24.75	39.75	5.90	35.00	41.50	31.75	37.00	37.00	42.00	59.00
6.	IIHR- 21	34.00	52.20	5.80	41.13	52.00	37.50	44.50	29.00	34.50	49.00
7.	IIHR- 23	28.75	38.00	5.00	36.00	46.75	32.50	38.50	33.50	37.10	51.00
8.	IIHR- 27	34.18	53.00	6.70	47.13	50.50	41.00	47.00	31.00	36.50	55.50
9.	IIHR- 29	27.50	37.50	7.00	37.00	60.00	33.00	45.00	35.00	40.50	53.50
10.	IIHR- 32	30.50	51.00	6.60	35.75	41.50	31.50	37.50	32.00	42.50	55.00
11.	IIHR- 34	28.25	53.50	5.90	39.15	45.30	32.00	37.00	35.00	40.50	56.00
12.	IIHR- 35	21.50	31.50	5.10	37.60	43.65	34.50	39.35	37.00	45.00	57.50
13.	IIHR- 36	28.75	34.25	6.30	40.00	46.15	35.95	41.50	36.00	46.50	59.00
14.	IIHR- 37	19.25	37.75	5.00	32.45	41.50	30.00	34.80	35.50	41.50	48.50
15.	IIHR- 40	29.13	45.00	5.15	32.50	38.35	30.00	34.00	34.50	38.50	47.75
16.	IIHR- 44	29.00	48.00	5.40	38.00	43.00	35.00	35.50	36.00	40.50	52.50
17.	IIHR- 47	31.00	46.00	6.40	36.70	44.10	32.50	40.75	30.50	47.50	45.50
18.	IIHR- 48	35.50	53.25	6.30	41.50	49.35	38.65	43.00	29.50	37.50	47.75
19.	IIHR- 53	35.43	51.75	6.75	44.25	55.76	39.25	42.50	31.50	35.80	43.50
20.	IIHR- 62	28.50	43.75	6.60	43.00	51.50	39.00	44.00	28.50	36.50	50.00

Continued ....

Sl. No.	Genotypes	Plant height		Number of primary branches	Plant spread		Plant spread		Days to first flowering Days to	Days to 50 % flowering	Days to first pod picking
		25 DAS	50 DAS	50 DAS	25 DAS	50 DAS	25 DAS	50 DAS			
21.	IIHR- 67	27.00	41.25	7.05	33.50	40.25	30.50	34.00	31.00	43.50	49.75
22.	IIHR- 70	29.10	44.50	6.70	31.75	43.75	30.25	39.50	39.50	41.50	47.25
23.	IIHR- 76	33.00	48.50	5.25	32.00	45.50	29.00	33.00	35.50	42.00	55.50
24.	IIHR- 87	28.75	43.75	5.90	29.50	38.25	26.50	32.50	31.00	38.00	57.00
25.	IIHR- 119	30.75	42.75	6.90	37.50	44.00	33.50	39.50	35.50	41.00	52.50
26.	IIHR- 232	36.75	51.75	6.95	44.50	50.50	37.25	45.00	29.50	35.50	49.40
27.	IIHR- 234	29.90	47.75	5.40	38.79	44.25	35.50	40.00	30.50	40.00	53.00
28.	IIHR- 237	23.00	38.75	6.25	35.15	47.50	31.50	37.50	34.00	45.00	54.50
29.	IIHR- 244	18.75	35.80	4.85	32.00	40.75	29.00	33.50	31.00	45.50	54.00
30.	IIHR- 245	32.25	43.00	6.25	32.15	43.50	30.25	37.15	33.50	45.00	50.25
31.	A. Komal	37.50	51.75	6.65	39.35	50.25	35.15	41.50	30.50	37.00	45.00
32.	A. Suvidha	31.50	47.50	7.00	41.50	47.75	37.50	40.75	35.50	41.00	49.00
33.	A. Anoop	33.88	47.75	6.30	39.00	48.65	33.50	33.50	34.50	40.50	51.00
34.	A. Sharath	37.90	53.00	7.10	37.50	49.75	39.25	41.00	32.50	36.50	49.50
35.	A. Arjun	35.50	51.50	7.00	48.00	53.50	45.50	46.00	30.50	38.50	47.00
36.	Bagalkot Local	23.50	35.50	5.90	35.25	43.25	31.50	35.00	33.00	48.50	54.50
	Mean	**29.83**	**44.88**	**6.09**	**37.28**	**45.95**	**33.75**	**38.88**	**33.04**	**40.41**	**51.63**
	CV	9.37	7.69	7.32	5.97	5.50	6.46	5.91	5.12	4.70	4.34
	SE	1.97	2.44	0.31	1.57	1.78	1.54	1.6	1.19	1.34	1.58
	CD @ 5%	5.67	7.09	0.9	4.51	5.13	4.43	4.66	3.43	3.86	4.54
	CD@ 1%	7.61	9.40	1.21	6.06	6.88	5.94	6.26	4.61	5.18	6.10

Table 8. ***Per se*** **performance of French bean (** ***Phaseolus vulgaris*** **)genotypes for yield parameters**

Sl. No.	Genotypes	Pod length (cm)	Pod width (cm)	Pod flesh thickness (cm)	No. of seeds / pod	No. of clusters/ plant	No. of pods/ cluster	No. of pods/ plant	Average pod weight	Yield / plant (g)	Yield/ plot (kg)
1	IIHR- 6	12.00	0.82	0.62	6.1	14.75	2.70	39.80	43.83	174.91	8.75
2.	IIHR- 7	13.53	0.79	0.55	5.6	13.75	2.70	37.05	48.49	179.43	8.97
3.	IIHR- 9	12.15	0.82	0.63	6.2	12.25	2.88	35.24	52.85	187.42	9.37
4.	IIHR- 13	15.00	0.80	0.51	5.5	13.25	2.60	34.50	44.15	148.17	7.41
5.	IIHR- 16	13.68	0.78	0.58	4.8	14.25	2.75	39.18	50.40	197.44	9.87
6.	IIHR- 21	14.93	0.89	0.72	5.9	12.75	2.95	37.80	57.16	225.33	11.27
7.	IIHR- 23	11.75	0.75	0.64	5.7	13.50	2.70	36.50	51.81	188.92	9.45
8.	IIHR- 27	14.88	0.86	0.67	6.3	14.90	2.75	40.96	56.50	231.72	11.59
9.	IIHR- 29	12.15	0.82	0.71	5.6	12.75	2.65	33.83	48.41	164.14	8.21
10.	IIHR- 32	14.55	0.89	0.59	5.9	15.50	2.45	37.95	44.03	167.07	8.35
11.	IIHR- 34	12.75	0.81	0.65	6.5	13.75	2.50	34.35	50.10	171.72	8.59
12.	IIHR- 35	13.15	0.84	0.52	5.7	13.80	3.00	41.84	37.88	160.25	8.01
13.	IIHR- 36	13.25	0.92	0.65	5.1	13.25	2.25	29.93	48.51	145.29	7.26
14.	IIHR- 37	11.85	0.88	0.54	6.3	10.50	3.13	32.75	51.91	169.99	8.50
15.	IIHR- 40	13.63	0.81	0.53	5.3	12.15	2.30	28.05	48.82	135.69	6.78
16.	IIHR- 44	12.80	0.82	0.53	5.7	14.95	2.00	29.79	46.63	138.89	6.94
17.	IIHR- 47	12.85	0.89	0.70	5.5	15.90	2.35	37.38	52.43	196.19	9.81
18.	IIHR- 48	14.10	0.82	0.62	6.7	15.10	2.75	41.39	64.26	247.50	12.38
19.	IIHR- 53	13.63	0.82	0.61	6.6	15.75	2.95	46.29	54.06	250.27	12.51
20.	IIHR- 62	13.55	0.82	0.71	6.5	15.15	2.75	41.72	65.75	268.50	13.43

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Sl. No.	Genotypes	Pod length (cm)	Pod width (cm)	Pod flesh thickness (cm)	No. of seeds / pod	No. of clusters/ plant	No. of pods/ cluster	No. of pods/ plant	Average pod weight	Yield / plant (g)	Yield/ plot (kg)
21.	IIHR- 67	11.00	0.91	0.53	5.5	12.75	2.00	25.65	49.54	125.64	6.28
22.	IIHR- 70	13.65	0.87	0.53	5.5	14.70	2.45	36.03	50.38	181.58	9.08
23.	IIHR- 76	15.50	0.84	0.56	6.4	10.75	2.00	21.35	53.80	114.21	5.71
24.	IIHR- 87	15.20	0.75	0.71	6.3	10.75	1.95	20.93	58.78	123.07	6.15
25.	IIHR- 119	12.75	0.85	0.59	7.1	15.50	2.50	38.80	56.02	217.53	10.88
26.	IIHR- 232	15.40	0.81	0.65	7.2	15.90	2.65	42.25	58.43	245.41	12.27
27.	IIHR- 234	13.25	0.69	0.73	6.5	15.15	2.45	37.14	52.96	196.64	9.83
28.	IIHR- 237	13.20	0.72	0.61	6.3	15.70	2.50	39.28	49.94	196.28	9.81
29.	IIHR- 244	8.25	1.27	0.42	4.4	11.63	3.10	35.98	30.65	110.65	5.53
30.	IIHR- 245	12.55	0.81	0.68	6.1	12.00	2.50	30.20	51.78	156.44	7.82
	A. Komal	13.10	0.62	0.54	6.0	13.48	2.85	42.47	49.63	210.86	10.54
	A. Suvidha	14.05	0.84	0.70	6.5	14.40	2.80	37.44	51.83	194.00	9.70
	A. Anoop	14.10	0.80	0.73	6.3	15.15	2.50	36.71	63.19	230.83	11.54
	A. Sharath	15.15	0.78	0.68	6.3	11.00	2.90	32.00	59.00	185.24	9.26
	A. Arjun	15.40	0.77	0.70	6.8	14.45	2.70	42.61	66.00	258.68	12.93
	Bagalkot Local	13.35	0.80	0.69	6.2	11.00	3.00	32.80	50.97	167.23	8.36
	Mean	**13.39**	**0.82**	0.62	6.03	**13.67**	**2.61**	**35.77**	**51.97**	**185.09**	**9.25**
	CV	7.26	6.86	4.79	2.92	7.10	7.83	10.12	8.99	10.50	10.50
	SE	0.68	0.03	0.02	0.12	0.69	0.14	2.56	3.30	13.74	0.69
	CD @ 5%	1.97	0.09	0.06	0.36	1.97	0.41	7.34	9.47	39.38	1.97
	CD@ 1%	2.65	0.12	0.08	0.48	2.64	0.56	9.86	12.73	52.93	2.65

4.1.2.12 Number of clusters per plant

Numbers of cluster per plant was maximum in genotype IIHR-47 and IIHR-232 (15.90) followed by and it was minimum in IIHR-37 (10.50) with a mean value of13.67. The estimates of GV (2.27) and PV (3.21) were very low. The moderate genotypic coefficient of variation (11.03 %) and phenotypic coefficient of variation (13.02%) were observed. High heritability (70.74%). with high genetic advance over mean (19.12%) was noticed for this trait.

4.1.2.13 Number of pods per cluster

Number of pods per plant (Tables 7 and 8) was maximum in IIHR-37 (3.13) while it was minimum in IIHR-87 (1.95) with a mean value of 2.61. The GV (0.075) and PV (0.11) were very low. The estimates of GCV and PCV were moderate (10.55 and 13.14%, respectively). High heritability (64.48%) along with high genetic advance over mean (17.45%) were observed for this trait.

4.1.2.14 Weight of ten pods

Weight of ten pods (Tables 7 and 8) was maximum in genotype Arka Arjun (66.00 g) and it was minimum in IIHR-244 (30.65 g) with a mean value of 51.97. The GV (41.04) and PV (62.87) were high. The moderate genotypic coefficient of variation (12.32%) and phenotypic coefficient of variation (15.25%) with high heritability (65.27%) and moderate genetic advance (10.66) with high GAM (20.51%) were observed for this trait.

4.1.2.15 Number of pods per plant

Number of pods per plant (Tables 7 and 8) was maximum in IIHR-53 (46.29) and it was minimum in IIHR-87 (20.93) with a mean value of 35.77. The GV (27.01) and PV (40.11) were very high. The estimates of GCV and PCV were moderate (14.52% and 17.70%, respectively). High heritability (67.35%) along with very high genetic advance over mean (24.56%) and low GA (8.78) were observed for number of pods per plant.

4.1.3.16 Pod yield per plant

Pod yield per plant (Tables 7 and 8) ranged from 110.65 g (IIHR-244) to 268.50 g (IIHR-62) with a mean value of 185.09 g. The GV (1552.18) and PV (1929.73) were very high. The estimates of genotypic coefficient of variation and phenotypic coefficient of variation were high (21.28% and 23.73%, respectively). High heritability (80.43%) along with high genetic advance over mean (39.32%) and high genetic advance (72.78) were observed for yield per plant.

4.1.2.17 Pod yield per plot

Pod yield per plot (Tables 7 and 8) ranged from 5.53 kg (IIHR-244) to 13.43 kg (IIHR-62) with a mean value of 9.25 kg. The estimates of GV (3.88) and PV (4.82) were low. The high genotypic coefficient of variation (21.29%) and phenotypic coefficient of variation (23.74%) were observed. High heritability (80.43%) and low genetic advance (3.63) with high GAM (39.32%) were noticed for number of seeds per pod.

4.1.3.18 Pod yield per hectare

The highest yield per hectare (Tables 7 and 9) was recorded in genotype IIHR-62 (29.83 t) and the lowest yield was recorded in IIHR-244 (12.29 t) with a mean value of 12.29 tonnes. The moderate GV (19.15) with high PV (23.80) were recorded. The moderate estimates of genotypic coefficient of variation (21.28%) with high phenotypic coefficient of variation (23.72%) and high heritability (80.48%) and low genetic advance (8.08) with high GAM (39.33%) were noticed for this trait.

4.1.3.19 Number of root nodules per plant

Number of root nodules per plant (Tables 7 and 9) was maximum in genotype IIHR-27 (22.60) while it was minimum in IIHR-76 (11.40) with a mean value of 16.16. The GV (8.35) and PV (9.79) were low. The estimates of GCV and PCV were moderate (17.87% and 19.38%, respectively). Very high heritability (85.36%) along with very high genetic advance over mean (34.02%) and less genetic advance (5.50) was recorded for this trait.

Table 9. ***Per se*** **performance of French bean (** ***Phaseolus vulgaris*** **)genotypes for yield and quality parameters**

Sl. No.	Genotypes	Yield/ ha	No. of root nodules/ plant	Dry matter content of leaves	Dry matter content of stem	Dry matter content of pods	Dry matter content of roots	Protein content (g $100g^{-1}$)
1	IIHR- 6	19.43	16.00	28.05	69.00	17.85	10.15	2.10
2.	IIHR- 7	19.94	14.80	30.15	73.50	19.50	9.05	1.62
3.	IIHR- 9	20.82	12.20	28.15	68.75	17.80	11.03	1.73
4.	IIHR- 13	16.46	16.40	25.20	67.50	23.75	10.15	1.58
5.	IIHR- 16	21.93	12.60	25.05	61.50	15.95	9.75	1.69
6.	IIHR- 21	25.03	18.40	32.75	80.00	24.75	11.15	1.61
7.	IIHR- 23	21.03	13.60	27.75	72.75	18.25	9.00	1.98
8.	IIHR- 27	25.74	22.60	31.50	83.00	22.75	10.75	1.87
9.	IIHR- 29	18.23	14.60	27.75	72.50	21.00	9.15	2.42
10.	IIHR- 32	18.56	12.70	30.00	72.00	17.60	10.15	1.20
11.	IIHR- 34	19.08	15.85	26.88	71.15	18.75	9.75	1.47
12.	IIHR- 35	17.80	13.55	25.95	66.63	16.75	8.75	2.26
13.	IIHR- 36	16.16	16.70	26.85	58.50	17.50	8.00	1.84
14.	IIHR- 37	18.88	13.55	24.75	66.75	16.75	7.65	1.76
15.	IIHR- 40	15.08	12.80	23.60	60.60	16.90	7.85	1.36
16.	IIHR- 44	15.43	16.70	24.75	69.25	18.75	8.50	1.39
17.	IIHR- 47	21.80	15.90	28.75	69.00	17.65	9.05	1.61
18.	IIHR- 48	27.50	19.80	31.25	80.00	21.75	11.00	1.49
19.	IIHR- 53	27.81	18.90	29.75	82.00	24.25	11.00	1.44
20.	IIHR- 62	29.83	20.75	31.25	61.50	25.25	11.15	1.64

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Sl. No.	Genotypes	Yield/ ha	No. of root nodules/ plant	Dry matter content of leaves	Dry matter content of stem	Dry matter content of pods	Dry matter content of roots	Protein content (g $100g^{-1}$)
21.	IIHR- 67	13.97	21.40	29.75	67.00	18.25	9.25	1.98
22.	IIHR- 70	20.17	15.85	18.85	79.50	19.75	8.90	2.42
23.	IIHR- 76	12.69	11.40	25.60	66.00	17.50	7.85	1.36
24.	IIHR- 87	13.67	11.50	24.65	62.75	19.75	7.15	1.30
25.	IIHR- 119	24.17	16.05	28.75	69.75	17.55	8.95	1.49
26.	IIHR- 232	27.26	20.05	31.75	82.50	26.25	12.25	2.10
27.	IIHR- 234	21.85	12.80	26.75	69.00	20.04	9.65	0.95
28.	IIHR- 237	21.81	16.15	27.50	72.25	18.50	9.50	1.53
29.	IIHR- 244	12.29	15.35	27.00	64.20	16.65	8.50	1.88
30.	IIHR- 245	17.38	16.75	26.30	73.30	17.75	9.25	1.46
31.	A. Komal	23.42	16.80	28.75	71.15	18.65	8.85	1.50
32.	A. Suvidha	21.55	21.75	29.50	76.00	17.50	8.75	0.94
33.	A. Anoop	25.64	16.05	29.05	80.75	16.00	10.50	1.17
34.	A. Sharath	20.58	18.25	30.65	79.00	20.50	10.65	1.20
35.	A. Arjun	28.74	19.60	32.25	86.50	23.75	11.75	1.25
36.	Bagalkot Local	18.58	13.90	23.75	66.75	16.75	8.75	2.03
	Mean	**20.56**	**16.17**	**27.80**	**71.45**	**19.41**	**9.54**	**1.62**
	CV	10.48	7.41	6.09	6.04	8.22	6.27	2.74
	SE	1.52	0.85	1.19	3.05	1.13	0.42	0.03
	CD @ 5%	4.37	2.43	3.41	8.75	3.23	1.21	0.09
	CD @ 1%	5.87	3.26	4.58	11.76	4.34	1.63	0.12

4.1.2.20 Dry matter partitioning

4.1.2.20.1 Dry matter in stem

Dry matter in stem (Tables 7 and 9) was maximum in genotype IIHR-27 (83.00g) and it was minimum in IIHR-40 (60.60) with a mean value of 71.45 g. The GV (40.89) and PV (59.52) were very high. The low estimates of genotypic coefficient of variation (8.95%) with moderate phenotypic coefficient of variation (10.79%) are observed. High heritability (68.71%) along with moderate genetic advance over mean (15.28%) and moderate genetic advance (10.91) were observed for dry matter in stem.

4.1.2.20.2 Dry matter in leaves

Dry matter in leaves (Tables 7 and 9) was maximum in genotype IIHR-21 (32.75g) and it was minimum in IIHR-70 (18.85g) with a mean value of 27.58 g. The GV (7.03) and PV (9.52) were very low. The estimates of GCV and PCV were low (9.85%and 11.38 % respectively). High heritability (71.36%) along with moderate genetic advance over mean (16.73%) and low genetic advance (4.61) was observed for dry matter in leaves.

4.1.2.20.3 Dry matter in pods

Dry matter in pods (Tables 7 and 9) was maximum in genotype IIHR-232 (26.25g) and it was minimum in IIHR-16 (15.95g) with a mean value of 19.41g. The GV (6.83) and PV (9.38) were very low. The estimates of GCV and PCV were moderate (13.47% and 15.48% respectively). High heritability (72.85%) along with high genetic advance over mean (23.68%) and low genetic advance (4.59) were recorded for dry matter in pods.

4.1.2.20.4 Dry matter of roots

Dry matter inn roots (Tables 7 and 9) was maximum in genotype Arka Arjun (11.75g) and it was minimum in IIHR-87 (7.15g) with a mean value of 9.54g. The GV (1.31) and PV (1.67) were very low. The estimates of GCV and PCV were moderate (12.03%and 13.57% respectively). High heritability (78.68%) along with high genetic advance over mean (21.99%) and low genetic advance (2.09) were recorded for dry matter in pods.

4.1.2.21 Protein content in pods

Protein content in pods (Tables 7 and 9) ranged from 0.94g per 100g (Arka Anup) to 2.42g per 100g (IIHR-70 & IIHR-29) with a mean value of 1.62g per 100g. The estimates of GV (0.13and PV (0.13) were very low. The high genotypic coefficient of variation (22.72%) and phenotypic coefficient of variation (22.88%) with high heritability (98.56%) and low genetic advance (0.75) with high GAM (46.46%) were noticed for this trait.

4.1.2.22 Pod colour

The dark green pods were observed in genotypes (Table10) IIHR-21, IIHR-23, IIHR-36, IIHR-44, IIHR-47, IIHR-48, IIHR-53, IIHR-62, IIHR-67, IIHR-76, IIHR-232, IIHR-234, Arka Komal and Arka Sharath. The light green pods were observed in genotypes IIHR-13, IIHR-16, IIHR-27, IIHR-35, IIHR-37, Arka Anup, Arka Suvidha, Arka Arjun and Bagalkot local. Whereas the medium green pods were observed in genotypes IIHR-6, IIHR-7, IIHR-9, IIHR-29, IIHR-32, IIHR-34, IIHR-40, IIHR-70, IIHR-87, IIHR-119, IIHR-237 and IIHR-245.While, the genotype IIHR-244 exhibited medium green with red stripes.

4.1.2.23 Pod shape

The elliptic shaped pods were observed in genotypes (Table10) IIHR-6, IIHR-7,IIHR-9, IIHR-13, IIHR-21, IIHR-27, IIHR-32, IIHR-35, IIHR-36, IIHR-37, IIHR-44, IIHR-53, IIHR-67, IIHR-70, IIHR-119, IIHR-237, IIHR-244, Arka Komal, Arka Anup, Arka Suvidha and Bagalkot local. While, the circular shaped pods were observed in genotypes IIHR-16, IIHR-23, IIHR-29, IIHR-34, IIHR-40, IIHR-47, IIHR-48, IIHR-62, IIHR-76, IIHR-87, IIHR-232, IIHR-234, IIHR-245, Arka Sharath and Arka Arjun.

4.1.2.24 Pod curvature

The slightly curved pods were observed in genotypes (Table10) IIHR-6, IIHR-7, IIHR-13, IIHR-16, IIHR-21, IIHR-23, IIHR-27, IIHR-29, IIHR-34, IIHR-35, IIHR-36, IIHR-37, IIHR-40, IIHR-44, IIHR-47, IIHR-48, IIHR-53, IIHR-67, IIHR-76, IIHR-87, IIHR-119, IIHR-232, IIHR-234, IIHR-237, IIHR-244, IIHR-245,

Table 10. Qualitative traits of French bean (*Phaseolus vulgaris*) genotypes

Sl. No.	Genotypes	Pod colour	Pod shape	Pod curvature	Pod stringness
1.	IIHR- 6	Medium green	Elliptic	Slightly curved	Stringlesss
2.	IIHR- 7	Medium green	Elliptic	Slightly curved	Stringless
3.	IIHR- 9	Medium green	Elliptic	Straight	Stringed
4.	IIHR- 13	Light green	Elliptic	Slightly curved	Stringed
5.	IIHR- 16	Light green	Circular	Slightly curved	Stringless
6.	IIHR- 21	Dark green	Elliptic	Slightly curved	Stringed
7.	IIHR- 23	Dark green	Circular	Slightly curved	Stringed
8.	IIHR- 27	Light green	Elliptic	Slightly curved	Stringed
9.	IIHR- 29	Medium green	Circular	Slightly curved	Stringless
10.	IIHR- 32	Medium green	Elliptic	Straight	Stringless
11.	IIHR- 34	Medium green	Circular	Slightly curved	Stringless
12.	IIHR- 35	Light green	Elliptic	Slightly curved	Stringed
13.	IIHR- 36	Dark green	Elliptic	Slightly curved	Stringed
14.	IIHR- 37	Light green	Elliptic	Slightly curved	Stringed
15.	IIHR- 40	Medium green	Circular	Slightly curved	Stringed
16.	IIHR- 44	Dark green	Elliptic	Slightly curved	Stringed
17.	IIHR- 47	Dark green	Circular	Slightly curved	Stringless
18.	IIHR- 48	Dark green	Circular	Slightly curved	Stringed
19	IIHR- 53	Dark green	Elliptic	Slightly curved	Stringless
20.	IIHR- 62	Dark green	Circular	Straight	Stringless
21.	IIHR- 67	Dark green	Elliptic	Slightly curved	Stringed
22.	IIHR- 70	Medium green	Elliptic	Straight	Stringed
23.	IIHR- 76	Dark green	Circular	Slightly curved	Stringless
24.	IIHR- 87	Medium green	Circular	Slightly curved	Stringless
25.	IIHR- 119	Medium green	Elliptic	Slightly curved	Stringed
26.	IIHR- 232	Dark green	Circular	Slightly curved	Stringeless
27.	IIHR- 234	Dark green	Circular	Slightly curved	Stringless
28.	IIHR- 237	Medium green	Elliptic	Slightly curved	Stringed
29.	IIHR- 244	Mediuum green with red stripes	Elliptic	Slightly curved	Stringless
30.	IIHR- 245	Medium green	Circular	Slightly curved	Stringless
31.	A. Komal	Dark green	Circular	Slightly curved	Stringed
32.	A. Suvidha	Light green	Elliptic	Slightly curved	Stringless
32.	A. Anoop	Light green	Elliptic	Slightly curved	Stringless
34.	A. Sharath	Dark green	Circular	Slightly curved	Stringless
35.	A. Arjun	Light green	Circular	Straight	Stringless
36.	Bagalkot Local	Light green	Elliptic	Slightly curved	Stringed

Arka Anup, Arka Suvidha, Arka Sharath, Arka Komal and Bagalkot local. While, the straight pods were observed in genotypes IIHR-9, IIHR-32, IIHR-62, IIHR-70 and Arka Arjun.

4.1.2.25 Pod stringlessness

The pod stringlessness were observed in genotypes (Table10) IIHR-6, IIHR-7, IIHR-16, IIHR-29, IIHR-32, IIHR-34, IIHR-47, IIHR-53, IIHR-62, IIHR-76, IIHR-87, IIHR-232, IIHR-234, IIHR-244, IIHR-245, Arka Anup, Arka Suvidha, Arka Sharath and Arka Arjun. While, the stringed pods were observed in genotypes IIHR-9, IIHR-13, IIHR-21, IIHR-23, IIHR-27, IIHR-35, IIHR-36, IIHR-37, IIHR-40, IIHR-44, IIHR-48, IIHR-67, IIHR-70, IIHR-119, IIHR-237, Arka Komal and Bagalkot local.

4.2 Correlation studies

The phenotypic and genotypic correlation coefficients were determined to know the nature of relationship existing between yield and its component characters as well as the association among component characters themselves. The degrees of association of growth, yield and quality characters with yield per plant and also among themselves at genotypic and phenotypic level are depicted in Tables 11 and 12, respectively.

4.2.1 Correlation of different characters with yield per plant

Total yield per plant was found to be positively and significantly (at p=0.01) associated with plant height at 25 DAS (r_g= 0.585 and rp= 0.439), plant height at 50 DAS (r_g= 0.552 and rp= 0.373), number of primary branches at 50 DAS (r_g= 0.525 and rp = 0.396), plant spread (N- S) at 50 DAS (r_g= 0.707 and rp= 0.593), plant spread (E-W) at 50 DAS (r_g= 0.857 and rp= 0.615), plant spread (N- S) at 25 DAS (r_g= 0.815 and rp= 0.714), plant spread (E-W) at 25 DAS (r_g= 0.807 and rp= 0.651),pod length (r_g =0.499 and rp= 0.256), pod flesh thickness ($r_{g=}$ 0.594 and rp= 0.435), number of seeds per pod(r_g= 0.614 and rp=0.465), number of clusters per plant (r_g= 0.648 and rp= 0.612), number of pods per cluster (r_g=0.481 and rp= 0.434), number of pods per plant (r_g = 0.809 and rp= 0.771), weight of ten pods (r_g = 0.717 and rp= 0.638), dry matter content of pods (r_g =0.700 and rp= 0.519) and number of root nodules per plant (r_g= 0.601 and rp= 0.476), whereas days to first flowering (r_g= -0.499 and rp= -0.385), days to 50 per cent flowering (r_g = -0.573 and rp= -0.479), days to first pod maturity (r_g = -0.517and rp= -0.370) and pod width (r_g = -0.354and rp= -0.245) showed negative and significant association both at genotypic and phenotypic level.

4.2.2 Genotypic correlation

Plant height at 25 DAS (Table 11) had positive and significant correlation at p=0.01 with plant height at 50 DAS (0.957), number of primary branches at 50 DAS (0.645), plant spread (N-S) at 50 DAS (0.553,) plant spread (E-W) at 50 DAS (0.613), plant spread (N-S) at 25DAS (0.622,) plant spread (E-W) at 25 DAS (0.685), pod length (0.794), pod flesh thickness (0.661), number of seeds per pod(0.621),number of clusters per plant (0.374), weight of ten pods (0.793), dry matter content of pods (0.576), number of root nodules (0.496) and yield per plant (0.585), while it showed significant and negative correlation with days to first flowering (-0.492), days to 50 per cent flowering (-0.692), days to first pod maturity (-0.575) and pod width (-0.485).

A significant (at p= 0.01) and positive correlation of plant height at 50 DAS (Table 11) was observed with number of primary branches at 50 DAS (0.447), plant spread (N-S) at 50 DAS (0.342) plant spread (E-W) at 50 DAS (0.486), plant spread (N-S) at 25 DAS (0.582) plant spread (E-W) at 25 DAS (0.552), Pod length (0.682), pod flesh thickness (0.448), number of seeds per pod(0.537), number of clusters per plant (0.421), number of pods per plant (0.314) weight of ten pods (0.573), dry matter content of pods (0.673), number of root nodules (0.471) and yield per plant (0.552), whereas it had significant and negative correlation with days to first flowering (-0.422), days to 50 per cent flowering (-0.684), days to first pod maturity (-0.530) and pod width (-0.304).

Number of primary branches at 50 DAS (Table 11) had positive and significant association at p= 0.01 with plant spread(N-S) at 50 DAS (0.661), plant spread (E-W) at 50 DAS (0.641), plant spread (N-S) at 25 DAS (0.584), plant spread (E-W) at 25 DAS (0.642), pod length (0.298), pod flesh thickness (0.519), number of seeds per pod (0.462), number of clusters per plant (0.389), weight of ten pods

Table 11. Genotypic correlation coefficient among growth, earliness and yield parameters in french bean genotypes

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
1	**1.000**	0.957**	0.645**	0.553**	0.613**	0.622**	0.685**	-0.492**	-0.692**	-0.575**	0.794**	-0.485**	0.661**	0.621**	0.374**	-0.177	0.198	0.793**	0.576**	0.496**	0.585**
2		**1.000**	0.447**	0.342**	0.486**	0.582**	0.552**	-0.422**	-0.684**	-0.530**	0.682**	-0.304**	0.448**	0.537**	0.421**	-0.030	0.314**	0.573**	0.673**	0.471**	0.552**
3			**1.000**	0.661**	0.641**	0.584**	0.642**	-0.341**	-0.184	-0.342**	0.298*	-0.151	0.519**	0.462**	0.389**	-0.100	0.236*	0.622**	0.465**	0.707**	0.525**
4				**1.000**	0.895**	0.822**	0.830**	-0.370**	-0.465**	-0.428**	0.328**	-0.266*	0.470**	0.429**	0.371**	0.448**	0.596**	0.465**	0.617**	0.543**	0.707**
5					**1.000**	0.917**	0.904**	-0.431**	-0.490**	-0.304**	0.376**	-0.176	0.551**	0.386**	0.639**	0.441**	0.793**	0.493**	0.802**	0.665**	0.857**
6						**1.000**	0.997**	-0.477**	-0.483**	-0.310**	0.470**	-0.212	0.571**	0.568**	0.542**	0.329**	0.631**	0.625**	0.694**	0.774**	0.815**
7							**1.000**	-0.396**	-0.503**	-0.374**	0.469**	-0.244*	0.532**	0.499**	0.413**	0.433**	0.603**	0.631**	0.679**	0.757**	0.807**
8								**1.000**	0.479**	0.476**	-0.022	0.023	-0.407**	-0.292*	-0.272*	-0.230	-0.373**	-0.377**	-0.677**	-0.416**	-0.499**
9									**1.000**	0.452**	-0.507**	0.390**	-0.277*	-0.438**	-0.243*	-0.231*	-0.375**	-0.510**	-0.743*	-0.324**	-0.573**
10										**1.000**	-0.020	0.109	-0.096	-0.268*	-0.291*	-0.315**	-0.426**	-0.363**	-0.447**	-0.478**	-0.517**
11											1.000	-0.539**	0.612**	0.536**	0.247*	-0.196	0.107	0.796**	0.614**	0.110	0.499**
12												**1.000**	-0.436**	-0.477**	-0.210	0.140	-0.092	-0.549**	-0.189	0.108	-0.354**
13													**1.000**	0.641**	0.253*	-0.079	0.149	0.885**	0.315**	0.293*	0.594**
14														**1.000**	0.227	0.085	0.240*	0.790**	0.493**	0.317**	0.614**
15															1.000	0.031	0.760**	0.153	0.366**	0.410**	0.648**
16																**1.000**	0.667**	0.038	0.269*	0.234*	0.481**
17																	**1.000**	0.164	0.484**	0.465**	0.809**
18																		**1.000**	0.611**	0.433**	0.717**
19																			1.000	0.639**	0.700**
20																				**1.000**	0.601**
21																					**1.000**

Critical r_g value at 1 percent - 0.301 critical r_g value at 5 percent – 0.231 ****- indicates significant at P=0.01 *- indicates significant at P= 0.05**

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 per cent 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

(0.622), dry matter content of pods (0.465), number of root nodules (0.707) and yield per plant (0.525). It showed significant and negative correlation with days to first flowering (-0.341) and days to first pod maturity (-0.342). This trait had positive and significant (at p=0.05) association with number of pods per plant (0.236).

A significant (at p=0.01) and positive correlation of plant spread (N-S) at 50 DAS (Table 11) was observed with plant spread (E-W) at 50 DAS (0.895), plant spread (N-S) at 25 DAS (0.822), plant spread (E-W) at 25 DAS (0.830), pod length (0.328), pod flesh thickness (0.470), number of seeds per pod (0.429), number of clusters per plant (0.371), number of pods per cluster(0.448), number of pods per plant (0.596), weight of ten pods (0.465), dry matter content of pods (0.617), number of root nodules (0.543) and yield per plant (0.707). It showed significant and negative correlation with days to first flowering (-0.370), days to 50 per cent flowering (-0.465), days to first pod maturity (-0.428). Whereas positive and significant (at p=0.05) association was found with pod width (-0.266).

Plant spread (E-W) at 50 DAS (Table 11) was positively and significantly (at p=0.01) associated with plant spread (N-S) at 25 DAS (0.917), plant spread (E-W) at 25 DAS (0.904), Pod length (0.376), pod flesh thickness (0.551), number of seeds per pod (0.386), number of clusters per plant (0.639), number of pods per cluster(0.441), number of pods per plant (0.793), weight of ten pods (0.493), dry matter content of pods (0.802), number of root nodules (0.665) and yield per plant (0.857). It showed significant and negative correlation with days to first flowering (-0.431), days to 50 per cent flowering (-0.490), days to first pod maturity (-0.304).

A significant (at p=0.01) and positive association of plant spread (N-S) at 25 DAS (Table 11) was noticed with plant spread (E-W) at 25 DAS (0.997), pod length (0.470), pod flesh thickness (0.571), number of seeds per pod (0.568), number of clusters per plant (0.542), number of pods per cluster (0.329), number of pods per plant (0.631), weight of ten pods (0.625), dry matter content of pods (0.694), number of root nodules (0.774) and yield per plant (0.815). But it showed significant and negative correlation with days to first flowering (-0.477), days to 50 per cent flowering (-0.483), days to first pod maturity (-0.310).

Plant spread (E-W) at 25 DAS (Table 11) was positively and significantly (at p=0.01) associated with pod length (0.469), pod flesh thickness (0.532), number of seeds per pod (0.499), number of clusters per plant (0.413), number of pods per cluster (0.433), number of pods per plant (0.603), weight of ten pods (0.631), dry matter content of pods (0.679), number of root nodules per plant (0.757) and yield per plant (0.807). But it showed significant and negative correlation with days to first flowering (-0.396), days to 50 per cent flowering (-0.503), days to first pod maturity (-0.374), whereas positive and significant (at p=0.05) association was found with pod width (-0.244).

A significant (at p=0.01) and positive association of days to first flowering (Table 11) was noticed with days to 50 per cent flowering (0.479), days to first pod maturity (0.476). It showed significant and negative correlation with pod flesh thickness (-0.407), number of pods per plant (-0.373), weight of ten pods (-0.377), dry matter content of pods (-0.677), number of root nodules (-0.416) and yield per plant (-0.499) whereas, negative and significant (at p=0.05) association was found with number of seeds per pod (-0.292), number of clusters per plant (-0.272).

Days to 50 per cent flowering (Table 11) was positively and significantly (at p=0.01) correlated with days to first pod maturity (0.452), pod width (0.390). But it showed significant and negative correlation with pod length (-0.507), number of seeds per pod (-0.438), number of pods per plant (-0.375), weight of ten pods (-0.510), dry matter content of pods (-0.743), number of root nodules (-0.324) and yield per plant (-0.573) whereas, negative and significant (at p=0.05) association was noticed with pod flesh thickness (-0.277) number of clusters per plant (-0.243) and number of pods per cluster (-0.231).

A significant (at p=0.01) and negative association of days to first pod maturity (Table 11) was observed with number of pods per cluster (-0.315), number of pods per plant (-0.426), weight of ten pods (-0.363), dry matter content of pods (-0.447), number of root nodules (-0.478) and yield per plant (-0.517) while, number of seeds per pod (-0.268) and number of clusters per plant (-0.291) were found significant (at p=0.05) but negatively correlated with this trait.

Pod length (Table 11) had positive and significant (at p=0.01) association with pod flesh thickness (0.512), number of seeds per pod (0.608), number of clusters per plant (0.631), number of pods per cluster (0.572), number of pods per plant (0.589), weight of ten pods (0.591) and yield per plant (0.553). It showed significant and negative correlation with pod width (-0.499).

Pod width (Table 11) had negative and significant (at p=0.01) correlation with pod flesh thickness (-0.436), number of seeds per pod (-0.477), weight of ten pods (-0.549) and yield per plant (-0.354).

The positive and significant (at p=0.01) correlation of pod flesh thickness (Table 11) was observed with number of seeds per pod (0.641), weight of ten pods (0.885), dry matter content of pods (0.315) and yield per plant (0.594). While number of clusters per plant (0.253) and number of root nodules per plant (0.293) were found significant (at p=0.05) but negatively associated with this trait.

Number of seeds per pod (Table 11) had positive and significant (at p=0.01) association with weight of ten pods (0.790), dry matter content of pods (0.493), number of root nodules per plant (0.317) and yield per plant (0.614).

The positive and significant (at p=0.01) correlation of number of clusters per plant (Table 11) was observed with number of pods per plant (0.760), dry matter content of pods (0.366), number of root nodules per plant (0.410) and yield per plant (0.648).

Number of pods per cluster (Table 11) had positive and significant (at p=0.01) association with number of pods per plant (0.667) and yield per plant (0.481). While dry matter content of pods (0.269) and number of root nodules per plant (0.234) were found significant (at p=0.05) and positively associated with this trait.

The positive and significant (at p=0.01) correlation of number of pods per plant (Table 11) was observed with yield per plant (0.809), dry matter content of pods (0.484) and number of root nodules per plant (0.465).

Weight of ten pods exhibited the positive and significant (at p=0.01) association with pod yield (0.717), dry matter content of pods (0.611) and number of root nodules per plant (0.433). Dry matter content of pods had positive and significant (at p=0.01) association with number of root nodules per plant (0.639) and yield per plant (0.717). Number of root nodules per plant exhibited the positive and significant association with pod yield (0.601).

4.2.3 Phenotypic correlation

A significant (at p=0.01) and positive correlation of plant height at 25 DAS (Table 12) with plant height at 50 DAS (0.702), number of primary branches at 50 DAS (0.432), plant spread (N-S) at 50 DAS (0.419) plant spread (E-W) at 50 DAS (0.417), plant spread (N-S) at 25 DAS (0.453) plant spread (E-W) at 25 DAS (0.439), pod length (0.510), pod flesh thickness (0.419), number of seeds per pod (0.420), weight of ten pods (0.492), dry matter content of pods (0.463) and yield per plant (0.439). It showed significant and negative correlation with days to first flowering (-0.504) and days to first pod maturity (-0.369). While number of clusters per plant (0.233) was found significant (at p=0.05) but negatively correlated with this trait.

Plant height at 50 DAS (Table 12) had positive and significant correlation at p=0.01 with plant spread (N-S) at 25 DAS (0.386), plant spread (E-W) at 25 DAS (0.360), pod length (0.541), pod flesh thickness (0.337), number of seeds per pod (0.441), weight of ten pods (0.454), dry matter content of pods (0.448), number of root nodules (0.375) and yield per plant (0.373). It showed significant and negative correlation with days to first flowering (-0.360), days to 50 per cent flowering (-0.515) and days to first pod maturity (-0.340). Whereas, it had positive and significant (p=0.05) correlation with number of primary branches at 50 DAS (0.272), plant spread (N-S) at 50 DAS (0.272), plant spread (E-W) at 50 DAS (0.276) and number of clusters per plant (0.257).

A significant (at p=0.01) and positive correlation of number of primary branches at 50 DAS (Table 12) was observed with plant spread (N-S) at 50 DAS (0.476), plant spread (E-W) at 50 DAS (0.492), plant spread (N-S) at 25 DAS (0.460), plant spread (E-W) at 25 DAS (0.415), pod flesh thickness (0.349), number of seeds per pod (0.375), weight of ten pods (0.382), number of root nodules (0.549) and yield per plant (0.396).It showed significant and negative correlation with days to first pod maturity (-0.298). Whereas positive and significant (at p=0.05) association was found with number of clusters per plant (0.261).

Table 12. Phenotypic correlation coefficient among growth, earliness and yield parameters in french bean genotypes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	**1.000**	0.702**	0.432**	0.419**	0.417**	0.453**	0.439**	-0.274*	-0.504**	-0.369**	0.510**	-0.345**	0.419**	0.420**	0.233*	-0.050	0.167	0.492**	0.463**	0.372**	0.439**
2		**1.000**	0.272*	0.272*	0.276*	0.386**	0.360**	-0.360**	-0.515**	-0.340**	0.541**	-0.279*	0.337**	0.441**	0.257*	-0.125	0.114	0.454**	0.448**	0.375**	0.373**
3			**1.000**	0.476**	0.492**	0.460**	0.415**	-0.116	-0.114	-0.298*	0.254*	-0.177	0.349**	0.375**	0.261*	0.005	0.200	0.382**	0.206	0.549**	0.396**
4				**1.000**	0.687**	0.647**	0.642**	-0.238*	-0.397**	-0.280*	0.176	-0.168	0.319**	0.337**	0.291*	0.273*	0.422**	0.429**	0.52**	0.455**	0.593**
5					**1.000**	0.736**	0.752**	-0.296*	-0.352**	-0.291*	0.320**	-0.168	0.303**	0.273*	0.372**	0.323**	0.506**	0.350**	0.635**	0.571**	0.615**
6						**1.000**	0.877**	-0.337**	-0.362**	-0.210	0.268*	-0.125	0.417**	0.421**	0.463**	0.318**	0.571**	0.414**	0.509**	0.610**	0.714**
7							**1.000**	-0.366**	-0.386**	-0.305**	0.305**	-0.132	0.399**	0.363**	0.327**	0.322**	0.466**	0.464**	0.486**	0.606**	0.651**
8								**1.000**	0.392**	0.296*	-0.128	0.001	-0.284*	-0.232*	-0.205	-0.128	-0.264*	-0.292*	-0.453**	-0.392**	-0.385**
9									**1.000**	0.329**	-0.312**	0.317**	-0.227	-0.338**	-0.244*	-0.131	-0.312**	-0.412**	-0.571**	-0.288*	-0.479**
10										**1.000**	-0.030	0.153	-0.077	-0.218	-0.186	-0.145	-0.227	-0.292*	-0.265*	-0.392**	-0.370**
11											**1.000**	-0.500**	0.390**	0.451**	0.046	-0.135	-0.031	0.460**	0.377**	0.172	0.256*
12												**1.000**	-0.339**	-0.448**	-0.136	0.124	-0.034	-0.379**	-0.141	0.069	-0.245*
13													**1.000**	0.449**	0.155	-0.057	0.096	0.571**	0.263*	0.203	0.435**
14														**1.000**	0.137	0.040	0.142	0.576**	0.311**	0.269*	0.465**
15															**1.000**	-0.031	0.727**	0.085	0.310**	0.312**	0.612**
16																**1.000**	0.655**	-0.099	0.115	0.124	0.434**
17																	**1.000**	0.014	0.340**	0.319**	0.771**
18																		**1.000**	0.387**	0.333**	0.638**
19																			**1.000**	0.509**	0.519**
20																				**1.000**	0.476**
21																					**1.000**

Critical r_g value at 1 percent - 0.301 critical r_g value at 5 percent – 0.231 ****- indicates significant at P=0.01 *- indicates significant at P= 0.05**

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 per cent 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

Plant spread (N-S) at 50 DAS (Table 12) was positively and significantly (at p=0.01) associated with plant spread (E-W) at 50 DAS (0.687), plant spread (N-S) at 25 DAS (0.647), plant spread (E-W) at 25 DAS (0.642), pod flesh thickness (0.319), number of seeds per pod (0.375), weight of ten pods (0.382), number of root nodules (0.549) and yield per plant (0.593). It showed significant and negative correlation with days to 50 per cent flowering (-0.397). Whereas, number of clusters per plant (0.291), number of pods per cluster (0.273) exhibited positive and significant (at p=0.05) association. Whereas, days to first flowering (-0.238) and days to first pod maturity (-0.280) had significant (at p=0.05) and negative correlation with this trait.

A significant (at p=0.01) and positive correlation of plant spread (E-W) at 50 DAS (Table 12) was observed with plant spread (N-S) at 25 DAS (0.736), plant spread (E-W) at 25 DAS (0.752), pod length (0.320), pod flesh thickness (0.303), number of clusters per plant (0.372), number of pods per cluster(0.323), number of pods per plant (0.506), weight of ten pods (0.350), dry matter content of pods (0.635), number of root nodules (0.571) and yield per plant (0.615). It showed significant (at p=0.05) and negative correlation with days to first flowering (-0.296) and days to first pod maturity (-0.291). Whereas positive and significant (at p=0.05) association was found with number of seeds per pod (0.273).

Plant spread (N-S) at 25 DAS (Table 12) was positively and significantly (at p=0.01) associated with plant spread (E-W) at 25 DAS (0.877), pod flesh thickness (0.417), number of seeds per pod (0.421), number of clusters per plant (0.463), number of pods per cluster (0.318), number of pods per plant (0.571), weight of ten pods (0.414), dry matter content of pods (0.509), number of root nodules (0.610) and yield per plant (0.714). While significantly negative association of this character with to first flowering (-0.337) and days to 50 per cent flowering (-0.362) was observed. Whereas, it had significant (at p=0.05) and positive association with pod length (0.263).

The positive and significant (at p=0.01) correlation of plant spread (E-W) at 25 DAS (Table 12) was observed with pod length (0.305), pod flesh thickness (0.399), number of seeds per pod (0.363), number of clusters per plant (0.327), number of pods per cluster (0.322), number of pods per plant (0.466), weight of ten pods (0.464), dry matter content of pods (0.486), number of root nodules (0.606) and yield per plant (0.651). Whereas, it had significant (at p=0.05) and negative association with days to first flowering (-0.366), days to 50 per cent flowering (-0.386) and days to first pod maturity (-0.305).

Days to first flowering (Table 12) was positively and significantly (at p=0.01) correlated with days to 50 per cent flowering (0.392). It showed negative and significant association with dry matter content of pods (-0.453), number of root nodules per plan (-0.392) and yield per plant (-0.385). At p=0.05, days to first pod maturity (0.296) showed significantly positive association with this trait.

Days to 50 per cent flowering (Table 12) was positively and significantly (at p=0.01) correlated with days to first pod maturity (0.329) and pod width (0.317). It showed significant and negative correlation with pod length (-0.312), number of seeds per pod (-0.338), number of pods per plant (-0.312), weight of ten pods (-0.412), dry matter content of pods (-0.571) and yield per plant (-0.479). Whereas negative and significant (at p=0.05) association was noticed with number of clusters per plant (-0.244) and number of root nodules per plant (-0.288).

A significant (at p=0.01) and negative association of days to first pod maturity (Table 12) was observed with number of root nodules (-0.392) and yield per plant (-0.370). Whereas, weight of ten pods (-0.292) and dry matter content of pods (-0.265) were found significant (at p=0.05) but negatively correlated with this trait.

Pod length (Table 12) had positive and significant (at p=0.01) association with pod flesh thickness (0.390), number of seeds per pod (0.608), weight of ten pods (0.460) and dry matter content of pods (0.377). It showed significant and negative correlation with pod width (-0.500). While, pod yield per plant (0.256) was found significant (at p=0.05) and positively associated with this trait.

A significant (at p=0.01) and negative correlation of pod width (Table 12) was noticed with pod flesh thickness (-0.339), number of seeds per pod (-0.448) and weight of ten pods (-0.379). Whereas, pod yield per plant (-0.245) found significant (at p=0.05) but negatively correlated with this trait.

Pod flesh thickness (Table 12) had positive and significant (at p=0.01) association with number of seeds per pod (0.449), weight of ten pods (0.571) and pod yield per plant (0.435). It showed significant (at p=0.05) and positive association with dry matter content of pods (0.263).

The positive and significant (at p=0.01) correlation of number of seeds per pod (Table 12) was noticed with weight of ten pods (0.576), dry matter content of pods (0.311), and yield per plant (0.435). While dry matter content of pods (0.269) was found significant (at p=0.05) and positively correlated with this trait.

Number of clusters per plant (Table 12) exhibited positive and significant (at p=0.01) association with number of pods per plant (0.727), dry matter content of pods (0.310), number of root nodules per plant (0.312) and yield per plant (0.612).

The positive and significant (at p=0.01) correlation of number of pods per cluster (Table 12) was noticed with number of pods per plant (0.655) and yield per plant (0.434).

Number of pods per plant (Table 12) had positive and significant (at p=0.01) association with dry matter content of pods (0.340), number of root nodules per plant (0.319) and yield per plant (0.771).

Weight of ten pods exhibited the positive and significant (at p=0.01) association with pod yield (0.638), dry matter content of pods (0.387) and number of root nodules per plant (0.333).

Dry matter content of pods had positive and significant (at p=0.01) association with number of root nodules per plant (0.509) and yield per plant (0.519). Number of root nodules per plant exhibited the positive and significant association with pod yield (0.476).

4.3 Path coefficient analysis

The correlation would only indicate the overall relationship of independent trait with dependent trait but does not provide cause and effect relationship. Using path analysis, it is possible to resolve the correlations, which provide clue about such relationship. 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 are presented in Tables 13 and 14, respectively.

4.3.1 Genotypic path co-efficient analysis

Plant height at 25 DAS (Table 13) had low and direct positive effect (0.114) on total yield per plant. It had negligible to low indirect and positive effects through plant height at 50 DAS (0.138), number of primary branches at 50 DAS (0.093), plant spread (N-S) at 50 DAS (0.079), plant spread (E-W) at 50 DAS (0.088), plant spread (N-S) at 25 DAS (0.08), plant spread (E-W) at 25 DAS (0.089), pod length (0.114), pod flesh thickness (0.095), number of seeds per pod (0.089), weight of ten pods (0.114), dry matter content of pods (0.089) and number of root nodules per plant (0.071). It also had low and indirect negative effects through days to first flowering (-0.071), days to 50 per cent flowering (-0.099), days to first pod maturity (-0.083) and pod width (-0.070).

Plant height at 50 DAS (Table 13) had high and direct negative effect (-0.352) on total yield per plant. It had moderate and indirect negative effects through plant spread (N-S) at 25 DAS (-0.205), pod length (-0.240), weight of ten pods (-0.202) and dry matter content of pods (-0.237). It also had low and indirect negative effect through number of primary branches at 50 DAS (-0.157), plant spread (E-W) at 50 DAS (-0.171), plant spread (E-W) at 25 DAS (0.194), pod flesh thickness (-0.158), number of seeds per pod (-0.189) and number of clusters per plant (-0.148) and also showed low to moderate indirect but positive effect through days to first flowering (0.149) and days to first pod maturity (0.187) and days to 50 per cent flowering (0.241).

Number of primary branches at 50 DAS (Table 13) had negligible and direct positive effect (0.030) on total yield per plant. It had negligible indirect and positive effects through plant spread (N-S) at 50 DAS (0.020), plant spread (E-W) at 50 DAS (0.019), plant spread (N-S) at 25 DAS (0.018), plant spread (E-W) at 25 DAS (0.019), pod flesh thickness (0.016), number of seeds per pod (0.014), weight of ten pods (0.019) and number of root nodules per plant (0.021).

Plant spread (N-S) at 50 DAS (Table 13) had low and direct negative effect (-0.160) on total yield per plant. It had low and indirect negative effect through plant

Table 13. Genotypic path coefficient analysis among growth, earliness and yield parameters in french bean genotypes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	rG
1	**0.144**	0.138	0.093	0.079	0.088	0.089	0.098	-0.071	-0.099	-0.083	0.114	-0.070	0.095	0.089	0.054	-0.025	0.028	0.114	0.083	0.071	0.585**
2	-0.337	**-0.352**	-0.157	-0.120	-0.171	-0.205	-0.194	0.149	0.241	0.187	-0.240	0.107	-0.158	-0.189	-0.148	0.010	-0.111	-0.202	-0.237	-0.166	0.552**
3	0.019	0.013	**0.030**	0.020	0.019	0.018	0.019	-0.010	-0.005	-0.010	0.009	-0.004	0.016	0.014	0.012	-0.003	0.007	0.019	0.014	0.021	0.525**
4	-0.088	-0.055	-0.106	**-0.160**	-0.143	-0.131	-0.133	0.059	0.074	0.068	-0.052	0.042	-0.075	-0.068	-0.059	-0.071	-0.095	-0.074	-0.099	-0.087	0.707**
5	0.007	0.005	0.007	0.010	**0.011**	0.011	0.010	-0.005	-0.005	-0.003	0.004	-0.002	0.006	0.004	0.007	0.005	0.009	0.005	0.009	0.008	0.857**
6	-0.063	-0.059	-0.059	-0.083	-0.093	**-0.102**	-0.101	0.048	0.049	0.031	-0.048	0.0216	-0.058	-0.058	-0.055	-0.033	-0.064	-0.063	0.070	-0.079	0.815**
7	0.151	0.121	0.141	0.183	0.199	0.219	**0.220**	-0.087	-0.110	-0.082	0.103	-0.053	0.117	0.110	0.091	0.095	0.133	0.139	0.149	0.166	0.807**
8	0.002	0.002	0.001	0.001	0.002	0.002	0.002	**-0.005**	-0.002	-0.002	0.0001	-0.0001	0.002	0.001	0.001	0.001	0.001	0.001	0.003	0.002	-0.499**
9	0.089	0.088	0.023	0.060	0.063	0.062	0.064	-0.061	**-0.128**	-0.058	0.065	-0.050	0.035	0.056	0.031	0.029	0.048	0.065	0.095	0.041	-0.573**
10	0.056	0.052	0.033	0.042	0.029	0.030	0.036	-0.046	-0.044	**-0.098**	0.002	-0.010	0.009	0.026	0.028	0.031	0.041	0.035	0.0440	0.047	-0.517**
11	0.096	0.082	0.036	0.039	0.045	0.056	0.056	-0.002	-0.061	-0.002	**0.121**	-0.065	0.074	0.064	0.029	-0.023	0.013	0.096	0.074	0.013	0.499**
12	-0.027	-0.017	-0.008	-0.015	-0.009	-0.011	-0.013	0.001	0.022	0.006	-0.030	**0.056**	-0.024	-0.026	-0.01	0.007	-0.005	-0.030	-0.010	0.006	-0.354**
13	0.047	0.032	0.037	0.033	0.039	0.040	0.038	-0.029	-0.019	-0.006	0.043	-0.031	**0.071**	0.045	0.018	-0.005	0.010	0.063	0.022	0.021	0.594**
14	0.051	0.044	0.038	0.035	0.031	0.047	0.041	-0.024	-0.036	-0.022	0.044	-0.039	0.053	**0.082**	0.018	0.007	0.019	0.065	0.040	0.026	0.614**
15	0.252	0.283	0.262	0.250	0.430	0.364	0.278	-0.183	-0.164	-0.195	0.166	-0.141	0.170	0.153	**0.673**	0.020	0.511	0.103	0.246	0.276	0.648**
16	-0.092	-0.016	-0.052	0.234	0.231	0.172	0.226	-0.120	-0.120	-0.164	-0.102	0.073	-0.041	0.044	0.016	**0.523**	0.349	0.020	0.141	0.122	0.481**
17	-0.035	-0.056	-0.042	-0.106	-0.142	-0.113	-0.108	0.066	0.067	0.076	-0.019	0.016	-0.026	-0.043	-0.136	-0.119	**-0.179**	-0.029	-0.086	-0.083	0.809**
18	0.274	0.197	0.215	0.160	0.170	0.216	0.218	-0.130	-0.176	-0.125	0.275	-0.189	0.305	0.273	0.053	0.013	0.056	**0.345**	0.211	0.149	0.717**
19	0.040	0.047	0.032	0.043	0.056	0.048	0.047	-0.047	-0.052	-0.031	0.043	-0.013	0.022	0.034	0.025	0.018	0.034	0.0429	**0.070**	0.044	0.700**
20	-0.001	-0.0009	-0.001	-0.001	-0.001	-0.001	-0.001	0.008	0.0006	0.0009	-0.000	-0.0002	-0.000	-0.000	-0.0008	-0.0005	-0.0009	-0.000	-0.001	**-0.001**	**0.601****

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 per cent 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

spread (E-W) at 50 DAS (-0.143), plant spread (N-S) at 25 DAS (-0.131) and plant spread (E-W) at 25 DAS (-0.133). It also had negligible and negative indirect effects through number of pods per plant (-0.095), pod flesh thickness (-0.075), weight of ten pods (-0.074), dry matter content of pods (-0.099) and number of root nodules per plant (-0.087) and negligible and positive indirect effects through days to 50 per cent flowering (0.074) and days to first pod maturity (0.068).

Plant spread (E-W) at 50 DAS (Table 13) 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).

Plant spread (N-S) at 25 DAS (Table 13) had low and direct negative effect (-0.102) on total yield per plant. It had low and indirect negative effect through plant spread (E-W) at 25 DAS (-0.101). It also had negligible and indirect negative effect through pod flesh thickness (-0.058), number of seeds per pod (-0.058), number of pods per plant (-0.064), weight of ten pods (-0.063) and number of root nodules per plant (-0.079). It had negligible and indirect positive effect through dry matter content of pods (0.070).

Plant spread (E-W) at 25 DAS (Table 13) had moderate and direct positive effect (0.220) on total yield per plant. It had low and indirect positive effects through number of pods per plant (0.133), weight of ten pods (0.139), dry matter content of pods (0.149), number of root nodules (0.166), pod length (0.103), pod flesh thickness (0.117) and number of seeds per pod (0.110). It also had low and indirect negative effect through days to 50 per cent flowering (-0.110).

Days to first flowering (Table 13) had negligible and direct negative effect (-0.005) on total yield per plant. It had negligible and indirect positive effect through pod flesh thickness (0.002), dry matter content of pods (0.003) and number of root nodules per plant (0.002).

Days to 50 per cent flowering (Table 13) 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), dry matter content of pods (0.095), weight of ten pods (0.065), number of seeds per pod (0.056) and number of pods per plant (0.048).

Days to first pod maturity (Table 13) had negligible and direct negative effect (-0.098) on total yield per plant. It had negligible and indirect positive effect through number of pods per plant (0.041), weight of ten pods (0.035), dry matter content of pods (0.044), number of root nodules per plant (0.047), number of seeds per pod (0.026) and number of clusters per plant (0.028) and number of pods per cluster (0.031).

Pod length (Table 13) 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).

Pod width (Table 13) 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).

Pod flesh thickness (Table 13) had negligible and direct positive effect (0.071) on total yield per plant. It had negligible and indirect positive effect through number of seeds per pod (0.045), number of clusters per plant (0.018), weight of ten pods (0.063), dry matter content of pods (0.022) and number of root nodules (0.021).

Number of seeds per pod (Table 13) 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), dry matter content of pods (0.040) and number of root nodules (0.026).

Number of clusters per plant (Table 13) 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).

Number of pods per cluster (Table 12) 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).

Number of pods per plant (Table 13) 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).

Weight of ten pods (Table 13) 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).

Dry matter content of pods (Table 13) had negligible and direct positive effect (0.070) on total yield per plant. It had negligible and indirect positive effect through number of root nodules per plant (0.044). Number of root nodules per plant negligible and direct negative effect (-0.001) on total yield per plant.

4.3.2 Phenotypic path co-efficient analysis

Plant spread (N-S) at 25 DAS (Table 14) had negligible and direct positive effect (0.087) on total yield per plant. It had negligible and indirect positive effect through plant spread (E-W) at 25 DAS (0.076), number of root nodules per plant (0.053), dry matter content of pods (0.044), number of pods per plant (0.049), number of clusters per plant (0.040), weight of ten pods (0.036), number of seeds per pod and pod flesh thickness (0.036).

Plant spread (E-W) at 25 DAS (Table 14) had negligible and direct negative effect (-0.066) on total yield per plant. It had low and indirect negative effects through number of pods per plant (-0.031), weight of ten pods (-0.031), dry matter content of pods (-0.032) and number of root nodules (-0.040). It also had low and indirect positive effect through days to first flowering (0.024) and days to 50 per cent flowering (0.025).

Table 14. Phenotypic path coefficient analysis among growth, earliness and yield parameters in french bean genotypes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	rP
1	**0.031**	0.009	0.005	0.005	0.005	0.005	0.005	-0.003	-0.006	-0.004	0.006	-0.004	0.005	0.005	0.0030	-0.0007	0.002	0.006	0.0061	0.004	0.439**
2	-0.012	**-0.017**	-0.004	-0.004	-0.004	-0.006	-0.006	0.006	0.009	0.006	-0.009	0.004	-0.005	-0.007	-0.004	0.002	-0.002	-0.008	-0.007	-0.006	0.373**
3	-0.0007	-0.004	**-0.018**	-0.008	-0.008	-0.008	-0.007	0.002	0.002	0.005	-0.004	0.003	-0.006	-0.006	-0.004	-0.0001	-0.003	-0.006	-0.003	-0.009	0.396**
4	-0.003	-0.001	-0.003	**-0.007**	-0.004	-0.004	-0.004	0.001	0.002	0.002	-0.001	0.001	-0.002	-0.002	-0.002	-0.001	-0.003	-0.003	-0.003	-0.003	0.593**
5	-0.004	-0.002	-0.004	-0.006	**-0.009**	-0.007	-0.007	0.002	0.003	0.002	-0.003	0.001	-0.002	-0.002	-0.003	-0.003	-0.004	-0.003	-0.006	-0.005	0.615**
6	0.039	0.033	0.040	0.056	0.064	**0.087**	0.076	-0.029	-0.031	-0.018	0.0234	-0.010	0.036	0.036	0.0405	0.027	0.049	0.036	0.0444	0.053	0.714**
7	-0.029	-0.024	-0.027	-0.042	-0.050	-0.058	**-0.066**	0.024	0.025	0.020	-0.020	0.008	-0.026	-0.024	-0.021	-0.021	-0.031	-0.031	-0.032	-0.0405	0.651**
8	-0.002	0.002	-0.0009	-0.001	-0.002	-0.002	-0.002	**0.007**	0.002	0.002	-0.0009	0.000	-0.002	-0.001	-0.001	-0.0009	-0.002	-0.002	-0.003	-0.002	-0.385**
9	-0.0013	-0.014	-0.003	-0.010	-0.009	-0.009	-0.010	0.010	**0.027**	0.008	-0.008	0.008	-0.006	-0.009	-0.006	-0.0036	-0.008	-0.011	-0.0155	-0.007	-0.479**
10	0.008	0.008	0.007	0.006	0.007	0.005	0.007	-0.007	-0.007	**-0.024**	0.0007	-0.003	0.001	0.005	0.004	0.0035	0.005	0.007	0.0064	0.009	-0.370**
11	0.001	0.0001	0.0001	0.000	0.0001	0.0001	0.0001	0.000	-0.000	0.000	**0.0003**	-0.000	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.000	0.256*
12	-0.001	-0.001	-0.0009	-0.0008	-0.000	-0.000	-0.0007	0.000	0.0001	0.0008	-0.0025	**0.005**	-0.001	-0.002	-0.0007	0.0006	-0.0002	-0.001	-0.0007	0.0003	-0.245*
13	0.004	0.003	0.003	0.003	0.002	0.003	0.003	-0.002	-0.002	-0.0007	0.003	-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	0.004	-0.004	-0.003	-0.005	-0.004	0.003	0.004	0.002	-0.005	0.005	-0.005	**-0.012**	-0.001	-0.0005	-0.001	-0.007	-0.0040	-0.003	0.465**
15	0.035	0.039	0.040	0.044	0.057	0.071	0.050	-0.031	-0.037	-0.028	0.007	-0.021	0.023	0.0211	**0.153**	-0.004	0.115	0.013	0.0475	0.048	0.612**
16	-0.007	-0.017	0.0008	0.038	0.045	0.045	0.045	-0.018	-0.018	-0.020	-0.019	0.017	-0.007	0.005	-0.004	**0.142**	0.093	-0.014	0.0164	0.017	0.434**
17	0.090	0.061	0.108	0.227	0.272	0.307	0.250	-0.142	-0.167	-0.122	-0.017	-0.018	0.051	0.076	0.390	0.352	**0.537**	0.008	0.182	0.1718	0.771**
18	0.310	0.286	0.241	0.270	0.220	0.261	0.293	-0.184	-0.260	-0.184	0.290	-0.239	0.360	0.363	0.053	-0.063	0.0093	**0.630**	0.244	0.210	0.638**
19	0.016	0.016	0.007	0.018	0.022	0.018	0.017	-0.16	-0.020	-0.009	0.013	-0.005	0.009	0.11	0.011	0.0041	0.012	0.0139	**0.036**	0.018	0.519**
20	0.007	0.007	0.011	0.009	0.011	0.012	0.012	-0.007	-0.005	-0.007	0.003	0.001	0.0041	0.005	0.006	0.002	0.006	0.006	0.010	**0.0200**	0.476**

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 per cent 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

Days to 50 per cent flowering (Table 14) had negligible and direct positive effect (0.027) on total yield per plant. It had negligible and indirect negative effects through weight of ten pods (-0.011) and dry matter content of pods (-0.015).

No of clusters per plant (Table 14) had low and direct positive effect (0.153) on total yield per plant. It had low to negligible and indirect positive effect through number of pods per plant (0.115), dry matter content of pods (0.047) and number of root nodules (0.048).

No of pods per clusters (Table 14) had low and direct positive effect (0.142) on total yield per plant. It had negligible and indirect positive effect through number of pods per plant (0.093), dry matter content of pods (0.016) and number of root nodules (0.017).

No of pods per plant (Table 14) had high and direct positive effect (0.537) on total yield per plant. It had low and indirect positive effect through dry matter content of pods (0.182) and number of root nodules (0.171).

Weight of ten pods (Table14) had high and direct positive effect (0.630) on total yield per plant. It had moderate and indirect positive effect through dry matter content of pods (0.244) and number of root nodules per plant (0.210).

Dry matter content of pods (Table 14) had negligible and direct positive effect (0.036) on total yield per plant. It had negligible and indirect positive effect through number of root nodules per plant (0.018). Number of root nodules per plant (Table 13) negligible and direct positive effect (0.02) on total yield per plant.

4.4 Genetic divergence

Thirty six genotypes of French bean were assessed for 21 characters and data obtained was subjected to D^2 statistics to assess the genetic diversity. Five clusters were constructed using Tocher's method.

4.4.1 Relative contribution of different characters towards divergence

The relative contribution of different characters for genetic divergence (D^2) is given in Table 15. Number of pods per plant (27.46%) contributed maximum to the

Table 15. Relative contribution of different characters to the total divergence in french bean Genotypes

Sl. No	Character or Source	No. of times ranked first	Per cent contribution
1.	Plant height at 25 DAS (cm)	2	0.32%
2.	Plant height at 50 DAS (cm)	6	0.95%
3.	Number of primary branches at 50 DAS	2	0.32%
4.	Plant spread (N-S) at 50 DAS	21	3.33%
5.	Plant spread (E-W) at 50 DAS	2	0.32%
6.	Plant spread (N-S) at 25 DAS	5	0.79%
7.	Plant spread (E-W) at 25 DAS	5	0.79%
8.	Days to first flowering	10	1.59%
9.	Days to 50 percent flowering	13	2.06%
10.	Days to first pod maturity	16	2.54%
11.	Pod length	9	1.43%
12.	Pod width	54	8.57%
13.	Pod flesh thickness	15	2.38%
14.	Number of seeds per pod	23	3.65%
15.	Number of clusters per plant	37	5.87%
16.	Number of pods per cluster	34	5.4%
17.	Number of pods per plant	173	27.46%
18.	Weight of ten pods	12	1.9%
19.	Dry matter content of pods	86	13.65%
20.	Pod yield per plant (g/plant)	88	13.97%
21.	Number of root nodules per plant	17	2.7%

genetic diversity followed by total yield per plant (13.97%), dry matter content of pods (13.65%), pod width (8.57%), number of clusters per plant (5.87%), number of pods per cluster (5.45%), number of seeds per pod (3.65%), plant spread (N-S) at 50 DAS (3.33%), number of root nodules (2.70%), Days to first pod maturity (2.54%), pod flesh thickness (2.38%), days to 50 per cent flowering (2.06%), weight of ten pods (1.90%), days to first flowering (1.59%) and pod length (1.43%). The contribution was less than one percent from the character *viz.*, plant height at 50 DAS (0.95%), plant spread (N-S) at 25 DAS (0.79%) and plant spread (E-W) at 25 DAS (0.79%).

4.4.2 Classification of French bean genotypes

By following Tocher's method, 36 genotypes were grouped into five clustering by treating estimated D^2 values as the square of the generalized distance. The distribution of entries into various clusters is given in Table 16.

Cluster I was the largest having 24 genotypes followed by cluster II (9), cluster III, cluster IV and cluster V which had one genotype (Table 17).

4.4.3 Inter cluster distance

The inter cluster D^2 values are given in Table 17. The nearest and farthest clusters from each cluster based on D^2 values were presented. The inter cluster D^2 value was maximum (395.94) between cluster II and cluster V followed by clusters I and V (D2=241.08), cluster II and III (D^2=223.39), cluster II and IV (D^2=171.48) and cluster IV and V (D^2=158.28). The cluster IV had the least inter-cluster distance (D^2=102.98) with the cluster V. Cluster V was the most diverse as many clusters showed maximum distance with it.

4.4.4 Intra cluster distance

Among the five clusters, cluster I with 24 genotypes showed maximum intra cluster diversity (D^2=69.06) followed by cluster II (48.21). The clusters III, IV and V had no intra-cluster distance (D^2=0.00) as they possessed single genotype.

Table 16. Classification of french bean genotypes in to different clusters based on D^2 value

Cluster number	Number of genotypes	Name of the genotypes
I	**24**	IIHR-9, IIHR-23, IIHR-6, IIHR-7, IIHR-40, IIHR-44, IIHR-34, IIHR-245, IIHR-237, IIHR-119, Arka Anup, IIHR-32, IIHR-234, IIHR-16, IIHR-76, IIHR-67, IIHR-29, IIHR-36, IIHR-35, Bagalkot local, IIHR-13, IIHR-47, IIHR-87 and Arka Suvidha
II	**9**	IIHR-48, IIHR-62, IIHR-232, Arka Arjun, IIHR-53, Arka Sharath, IIHR-21, IIHR-27 and Arka komal
III	**1**	IIHR-37
IV	**1**	IIHR- 67
V	**1**	IIHR-244

Table 17. Average intra and inter cluster D2 values for 5 clusters for 21 characters formed by 36 genotypes of french bean

Clusters	I	II	III	IV	V
I	69.06	146.06	116.20	127.39	241.08
II		48.21	223.39	171.48	395.94
III			0.00	133.13	102.98
IV				0.00	158.28
V					0.00

4.4.5 Cluster means

The mean values of 21characters for 5 clusters are summarized in Table 18.

4.4.5.1 Plant height at 25 DAS

Highest cluster mean for this character (Table 17) was observed in the cluster II (35.03 cm) followed by cluster I (28.91 cm), cluster IV (27.00 cm) and cluster III (19.25 cm) and the lowest cluster mean was observed in the cluster V (18.75 cm).

4.4.5.2 Plant height at 50 DAS

For this character highest cluster mean (Table 17) was observed in the cluster II (51.33 cm) followed by cluster I (43.28 cm), cluster IV (41.25 cm) and the lowest cluster mean was observed in the cluster V (35.80 cm).

4.4.5.3 Number of primary branches at 50 DAT

Highest cluster mean for number of primary branches at 50 DAS (Table 17) was observed in the cluster IV (7.05) followed by cluster II (6.65), cluster I (5.94) and cluster III (5.00) and the lowest cluster mean was observed in the cluster V (4.85).

4.4.5.4 Plant spread (N-S) at 50 DAS

The mean (Table 17) for plant spread (N-S) at 50 DAS was highest in the cluster II (51.46 cm) followed by cluster I (44.52cm), cluster III (41.50 cm) and cluster V (40.75 cm) and the lowest cluster mean was observed in the cluster IV (40.25 cm).

4.4.5.5 Plant spread (E-W) at 50 DAS

Highest cluster mean for plant spread (N-S) at 50 DAS (Table 17) was observed in the cluster II (43.83 cm) followed by cluster I (37.61 cm), cluster III (34.80cm) and cluster IV (34.00 cm) and the lowest cluster mean was observed in the cluster V (33.50).

Table 18. Mean values of 21 characters for 5 clusters formed by 36 genotypes in French bean

Sl. No.	Character	Clusters				
		I	II	III	IV	V
1.	Plant height at 25 DAS (cm)	28.91	35.03	19.25	27.00	18.75
2.	Plant height at 50 DAS (cm)	43.28	51.33	37.75	41.25	35.80
3.	Number of primary branches at 50 DAS	5.94	6.65	5.00	7.05	4.85
4.	Plant spread (N-S) at 50 DAS (cm)	44.52	51.46	41.50	40.25	40.75
5.	Plant spread (E-W) at 50 DAS (cm)	37.61	43.83	34.80	34.00	33.50
6.	Plant spread (N-S) at 25 DAS (cm)	35.74	42.93	32.45	33.50	29.00
7.	Plant spread (E-W) at 25 DAS (cm)	32.21	39.17	30.00	30.50	29.00
8.	Days to first flowering	34.15	30.28	35.50	31.00	31.00
9.	Days to 50 percent flowering	41.50	36.48	41.50	43.50	45.50
10.	Days to first pod maturity	52.91	48.52	48.50	49.75	54.00
11.	Pod length (cm)	13.37	14.46	11.85	11.00	8.25
12.	Pod width (cm)	0.81	0.80	0.88	0.91	1.28
13.	Pod flesh thickness (cm)	0.62	0.65	0.55	0.54	0.43
14.	Number of seeds per pod	5.94	6.44	6.30	5.50	4.40
15.	Number of clusters per plant	13.64	14.27	10.50	12.75	11.63
16.	Number of pods per cluster	2.52	2.80	3.13	2.00	3.10
17.	Number of pods per plant	34.42	40.83	32.75	25.65	35.98
18.	Weight of ten pods (g)	50.33	58.98	51.91	49.54	30.65
19.	Dry matter content of pods (g)	18.30	23.10	16.75	18.25	16.65
20.	Pod yield per plant (g/plant)	172.38	235.94	169.99	125.64	110.66
21.	Number of root nodules per plant	14.86	19.46	13.55	21.40	15.35

4.4.5.6 Plant spread (N-S) at 25 DAS

The mean (Table 17) for plant spread (N-S) at 25 DAS was highest in the cluster II (42.93 cm) followed by cluster I (35.74cm), cluster IV (33.50 cm) and cluster III (32.45 cm) and the lowest cluster mean was observed in the cluster V (29.00 cm).

4.4.5.7 Plant spread (E-W) at 25 DAS

For this character highest cluster mean (Table 17) was observed in the cluster II (39.17 cm) followed by cluster IV (30.50 cm), cluster III (30.00 cm) and the lowest cluster mean was observed in the cluster V (29.00 cm).

4.4.5.8 Days to first flowering

The mean (Table 17) for days to first flowering was highest in the cluster III (35.50 cm) followed by cluster I (34.15 cm), cluster IV (31.00cm) and cluster V (31.00 cm) and the lowest cluster mean was observed in the cluster II (30.28 cm).

4.4.5.9 Days to 50 per cent flowering

For this character highest cluster mean (Table 17) was observed in the cluster V (45.50) followed by cluster IV (43.50), cluster III and cluster I (41.50) and the lowest cluster mean was observed in the cluster II (36.48).

4.4.5.10 Days to first pod maturity

Highest cluster mean for Days to first pod maturity (Table 17) was observed in thecluster V (54.00) followed by cluster I (52.91), cluster III (49.75), cluster II (48.52) and the lowest cluster mean was observed in the cluster III (48.50).

4.4.5.11 Pod length

Highest cluster mean for pod length (Table 17) was observed in the cluster II (14.46) followed by cluster I (13.37), cluster III (11.85), cluster IV (11.00) and the lowest cluster mean was observed in the cluster V (8.25).

4.4.5.12 Pod width

The cluster means for pod width (Table 17) were 0.80, 0.81, 0.88 and 0.91 for clusters II I, III and IV, respectively and the highest cluster mean was observed in the cluster V (1.28).

4.4.5.13 Pod flesh thickness

Highest cluster mean for Pod thickness (Table 17) was observed in the cluster II (0.65) followed by cluster I (0.62), cluster III (0.55), cluster IV (0.54) and the lowest cluster mean was observed in the cluster V (0.43).

4.4.5.14 Number of seeds per pod

The cluster means for number of seeds per pod (Table 17) were 4.40, 5.50, 5.94 and 6.30 for clusters V, IV, I and III, respectively and the highest cluster mean was observed in the cluster II (6.44).

4.4.5.15 Number of clusters per plant

The highest cluster means (Table 17) was observed in the cluster II (14.27) followed by cluster I (13.64), cluster IV (12.75) and cluster V (11.63). The lowest cluster mean was observed in the cluster V (10.50).

4.4.5.16 Number of pods per cluster

The cluster means for number of pods per cluster (Table 17) were 2.00, 2.52, 2.80 and 3.10 for clusters IV, I, II and V, respectively and the highest cluster mean was observed in the cluster III (3.13).

4.4.5.17 Number of pods per plant

The highest cluster mean (Table 17) was observed in the cluster II (40.83) followed by cluster V (35.98), cluster I (34.42) and cluster III (32.75) and the lowest cluster mean was observed in the cluster V (25.65).

4.4.5.18 Weight of ten pods

The cluster means for Weight of ten pods (Table 17) were 30.65, 49.54, 50.33 and 51.91 for clusters V, IV, I and III, respectively and the highest cluster mean was observed in the cluster II (58.98).

4.4.5.19 Dry matter content of pods

For this character highest cluster mean (Table 17) was observed in the cluster II (23.10) followed by cluster I (18.30), cluster IV (18.25), cluster III (16.75) and the lowest cluster mean was observed in the cluster V (16.65).

4.4.5.20 Pod yield per plant

Highest cluster mean for pod yield per plant (Table 17) was observed in the cluster II (235.94) followed by cluster I (172.38), cluster III (169.99), cluster IV (125.64) and the lowest cluster mean was observed in the cluster V (110.66).

4.4.5.21 Number of root nodules per plant

The mean (Table 17) for number of root nodules per plant was highest in the cluster IV (21.40) followed by cluster II (19.46), cluster V (15.35) and cluster I (14.86) and the lowest cluster mean was observed in the cluster III (13.55).

5. DISCUSSION

The success of crop improvement programme depends on the extent of genetic variability existing in the germplasm. Magnitude of genetic variability can determine the pace and quantum of genetic improvement through selection or through hybridisation followed by selection. Therefore, in the present investigation, assessment of genetic variability in french bean was carried out during 2015-16 and the results of the experiments are discussed in this chapter.

5.1 Genetic variability, heritability, genetic advance and genetic advance over mean

Totally 36 genotypes were evaluated to know the amount of variability for yield and yield contributing characters. The analysis of variance (Tables 3 and 4) indicated highly significant (at p=0.01) difference among genotypes for most of the characters *viz.*, plant height (25 and 50 DAS), plant spread (25 and 50 DAS), number of primary branches (50 DAS), days to first flowering, days to 50 per cent flowering, days to first pod maturity, 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, average pod weight, pod yield per plant, pod yield per plot, pod yield per ha, number of root nodules per plant, dry matter content (leaves, stem, pod and roots) and protein content. It indicated that sufficient variability existed for all the characters and considerable improvement could be achieved in most of these characters by selection. However, the analysis of variance by itself is not enough and conclusive to explain all the inherent genotypic variance in the genotypes.

One of the ways in which the variability of these characters assessed is through a simple approach of examining the range of variation. Range of variation observed for all the traits in the present study (Tables 5 and 7) indicated the presence of sufficient amount of variation among the genotypes for all the characters studied. The range in the values reflects the amount of phenotypic variability which is not very reliable since it includes genotypic, environmental and genotype X environmental interaction components and does not reveal as which component is showing higher degree of variability. Further, the phenotype of crop is influenced by additive gene effect (heritable), dominance (non- heritable) and epistatic (non-allelic interaction).

Hence, it becomes necessary to split the observed variability into phenotypic variation (PV) and genotypic variation (GV) which indicates the extent of variability existing for various traits. However, these GV and PV estimates are influenced by the units of measurements of the various traits and even these estimates don't give a true picture.

The estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) will indicate the extent of variability existing for various traits irrespective of their units of measurements. However, even these don't give a correct picture about the extent of inheritance of the characters. Therefore, heritability of characters can be relied upon, as it enables the plant breeder to decide the extent of selection pressure to be applied under a particular environment, which separates out the environmental influence from the total variability. Nevertheless, its use would be limited as this is prone to change with environments and material. The estimation of heritability has a greater role to play in determining the effectiveness of selection for a character, provided it is considered in conjunction with the predicted genetic advance as suggested by Panse and Sukhatme (1957) and Johnson *et al.* (1955) as the heritability is influenced by biometrical method, generation of hybrid, sample size of experimental material and environment. With these points in view, the results of the variability observed in the 36 french bean genotypes evaluated in the present investigation are discussed here under.

5.1.1 Growth parameters

In the present investigation moderate estimates of genotypic coefficient of variation and phenotypic coefficient of variation (11-20%) were observed for plant height (25 and 50 DAS) and number of primary branches (50 DAS). Similar results were also obtained by Raffi and Nath (2004), Kumar *et al.* (2014), Prakash and Ram (2014), Verma *et al.* (2014a) and Kumar *et al.* (2015) in french bean, Gnanesh *et al.* (2006), Magalingam *et al.* (2013), Chaitanya *et al.* (2014) in dolicos bean, Tyagi *et al.* (2012) and Saxesena *et al.* (2014) in pea, Roy *et al.* (2006) in bush bean. It implied equal importance of additive and non additive gene action and substantial amount of variability for these traits.

It appears that phenotypic variability may be a good measure of genotypic variability for characters such as plant height and number of branches per plant as the

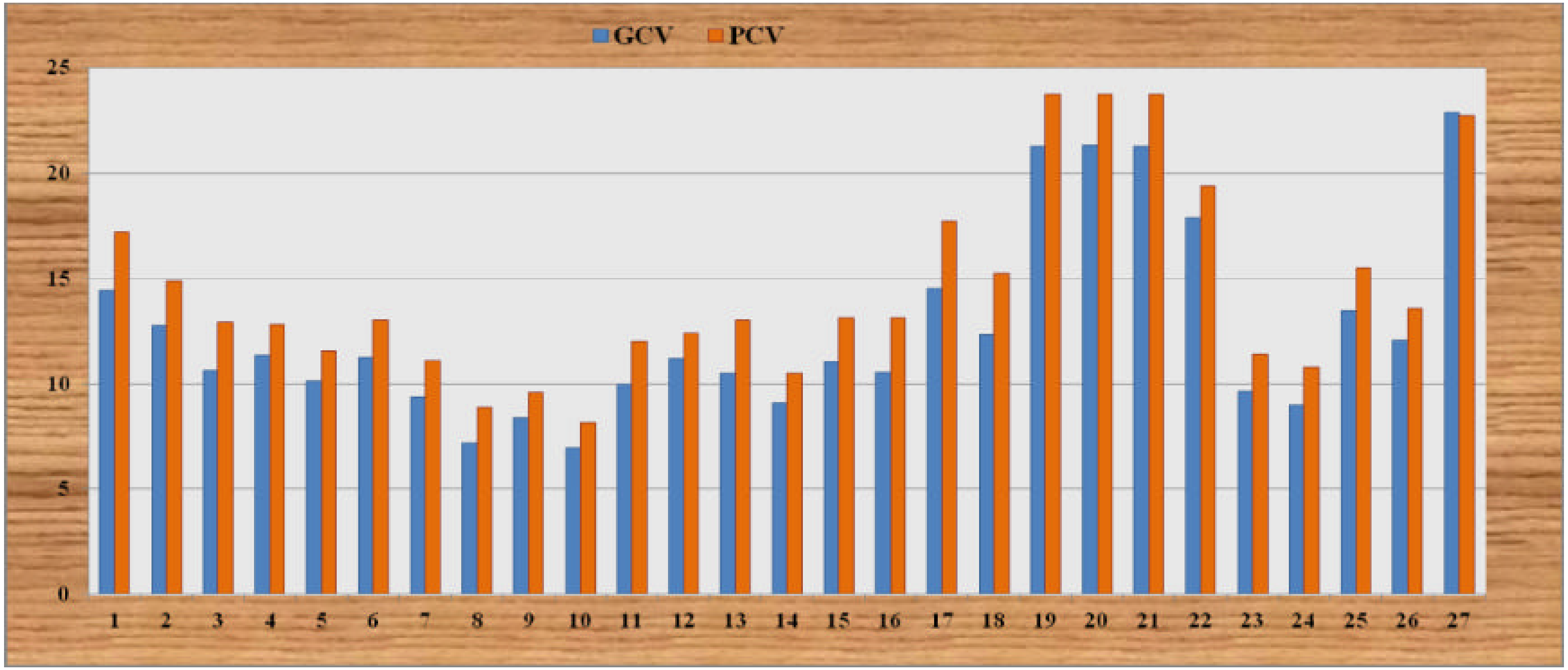

Fig. 1. Genotypic coefficient of variation and phenotypic coefficient of variation for different characters in french bean genotypes.

8. Plant height at 25 DAS
9. Plant height at 50 DAS
10. No. of primary branches at 50 DAS
11. Plant spread (N-S) at 50 DAS
12. Plant spread (E-W) at 50 DAS
13. Plant spread (N-S) at 25 DAS
14. Plant spread (E-W) at 25 DAS

8. Days to first flowering
9. Days to 50 per cent 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. Yield per plant
20. Yield per plot
21. Yield per hectare

22. No. of root nodules per plant
23. Dry matter content in leaves
24. Dry matter content in stem
25. Dry matter content in pods
26. Dry matter content in roots
27. Protein content in pods

estimates of GCV and PCV were closer and parallel indicating that they are comparatively least affected by environment and hence could be relied upon in the improvement of these parameters.

In the present study, very high heritability (>60%) along with high genetic advance as per cent over mean (>20%) was recorded for the plant height (25 and 50 DAS). These results suggested that the inheritance of character is governed mainly by additive gene effects and therefore, selection based on phenotypic performance may prove useful. Similar results were also reported by Raffi and Nath (2004), Kamaluddin and Ahmed (2011), Kumar *et al.* (2014) and Singh *et al.* (2014b) in french bean, Tyagi *et al.* (2012) in pea, Chaudari *et al.* (2013) and Magalingham *et al.* (2013) in dolicos bean, Lenkala *et al.* (2015) in jack bean and Roy *et al.* (2006) in bush bean.

High heritability (>60%) with moderate genetic advance (11-12%) was recorded for number of primary branches per plant at 50 DAS. It indicated the presence of dominance and epistatic gene action effects in controlling this character. Similar trends were observed by Magalingham *et al.* (2013) in dolicos bean.

5.1.2 Earliness parameters

Low genotypic coefficient of variation and phenotypic coefficient of variation were recorded for days to first flowering, days to 50 % flowering and days to first pod picking. These findings are in close agreement with the results obtained by Rai *et al.* (2010), Prakash and Ram (2014), Verma *et al.* (2014b) and Jayprakash *et al.* (2015) in french bean, Tyagi *et al.* (2012) and Karnwal *et al.* (2013) in pea, kumar *et al.* (2015) and Rai *et al.* (2012) in cluster bean, Chaudhari *et al.* (2013) in dolicos bean and Ahmed *et al.* (2014) in mung bean, Lenkala *et al.* (2015) in jack bean and low GCV and PCV for these characters indicated the narrow genetic base.

High heritability with moderate GAM observed for days to first flowering, days to 50 % flowering and days to first pod picking indicated the influence of non additive gene action and considerable influence of environment on the expression of these traits. These traits could be exploited through manifestation of dominance and epistatic components through hybridization followed by selection. These findings are similar to the reports of Rai *et al.* (2010), Prakash and Ram (2014), Verma *et al.* (2014b)

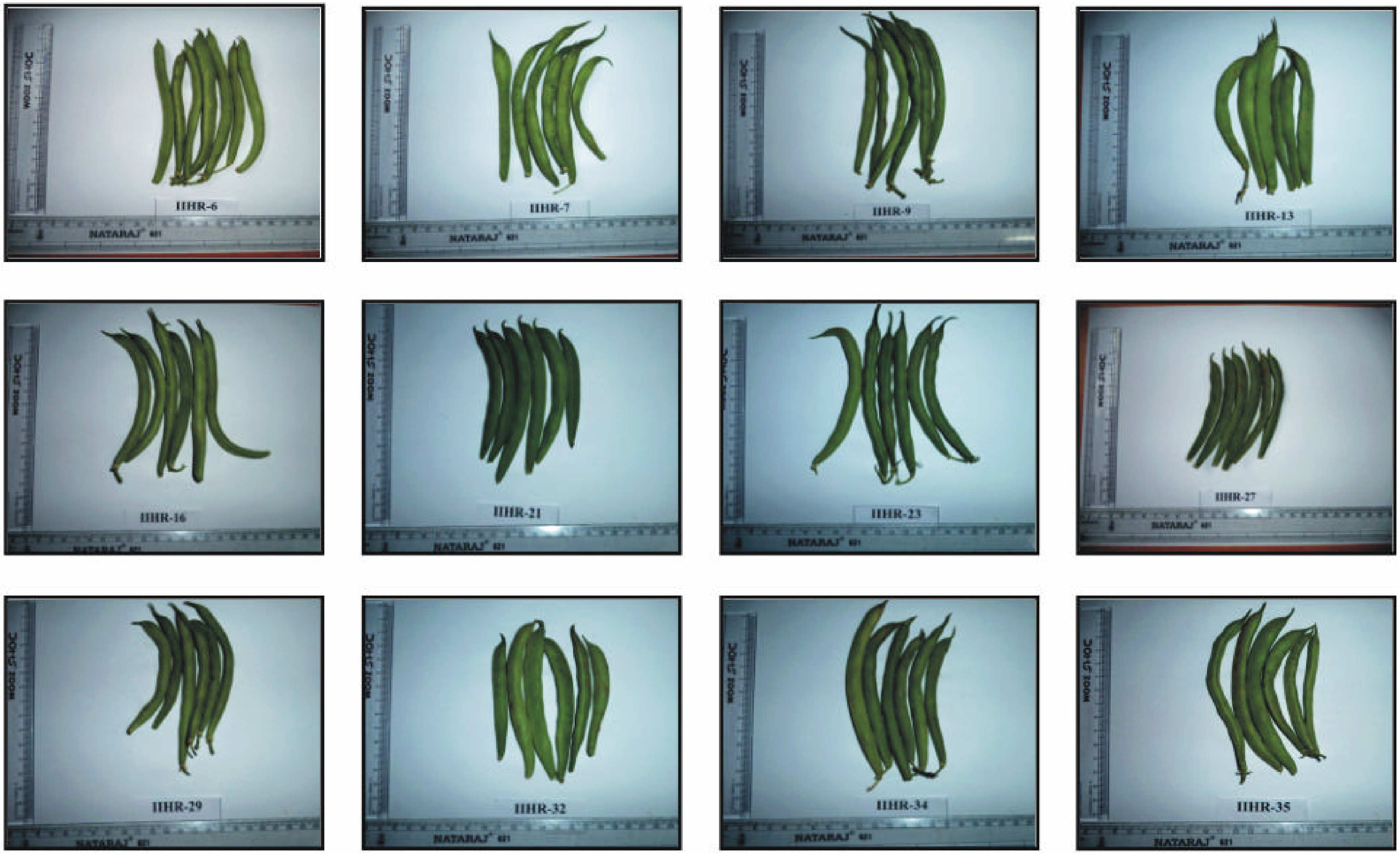

Plate 2a. Variability in pod shape, curvature and colour of the french bean genotypes

Plate 2b. Variability in pod shape, curvature and colour of the french bean genotypes

Plate 2c. Variability in pod shape, curvature and colour of the french bean genotypes

and Jayprakash *et al.* (2015) in french bean, Pan *et al.* (2004) and Magalingham *et al.* (2013) in dolicos bean and Ahmed *et al.* (2014)in mung bean, Lenkala *et al.* (2015) in jack bean.

5.1.3 Yield parameters

High (>20%) GCV and PCV were observed for most of yield traits *viz.*, yield per plant, yield per plot and yield per hectare. The results indicated the existence of sufficient variability in genetic stock studied and the traits are governed by additive genes. Hence, there is ample scope for improving these characters based on direct selection. The findings of Rai *et al.* (2006), Kumar *et al.* (2014), Singh *et al.* (2014a), Verma *et al.* (2014b) and Jayprakash *et al.* (2015) in french bean, Pan *et al.* (2004), Gnanesh *et al.* (2006), Islam *et al.* (2011), Sankaran *et al.* (2011), Chaitanya *et al.* (2014), Prashanth and Sreelatha (2014) and Verma *et al.* (2014a) in dolicos bean, Rai *et al.* (2012) in cluster bean and Sharma and Bora (2013) in pea.

Moderate (11-20%) GCV and PCV were observed for pod width, pod flesh thickness, number of clusters per plant, number of pods per cluster, number of pods per plant, weight of ten pods, number of root nodules per plant, dry matter content in pods and roots indicating the presence of moderate to good amount of variability for these traits in the genetic stock. These results are in accordance with Raffi and Nath (2004), Rai *et al.* (2006), Kumar *et al.* (2014), Prakash and Ram (2014), Prashanth and Sreelatha (2014), Singh *et al.* (2014a), Verma *et al.* (2014b) and Jayprakash *et al.* (2015) in french bean, Lenkala *et al.* (2015) in jack bean, Hanchimani (2003), Pan *et al.* (2004)), Ahmed *et al.* (2011), Magalingham *et al.* (2013) and Chaitanya *et al.* (2014) in dolicos bean, Roy *et al.* (2006) in bush bean, Rai *et al.* (2012) in cluster bean. Moderate PCV and low PCV were observed for number of seeds per pod, dry matter content in leaves and stem. Similar result was reported by Jayprakash *et al.* (2015) in french bean. This indicated the moderate to good amount of variability.

High heritability (>60%) estimates along with high GAM (>20%) was recorded for pod width, number of pods per plant, weight of ten pods, yield per plant, yield per plot, yield per hectare, number of root nodules per plant, dry matter content of pods and roots. These results indicated the presence of additive gene effects. Thus, there is an ample scope for improving these characters with direct selection. Similar

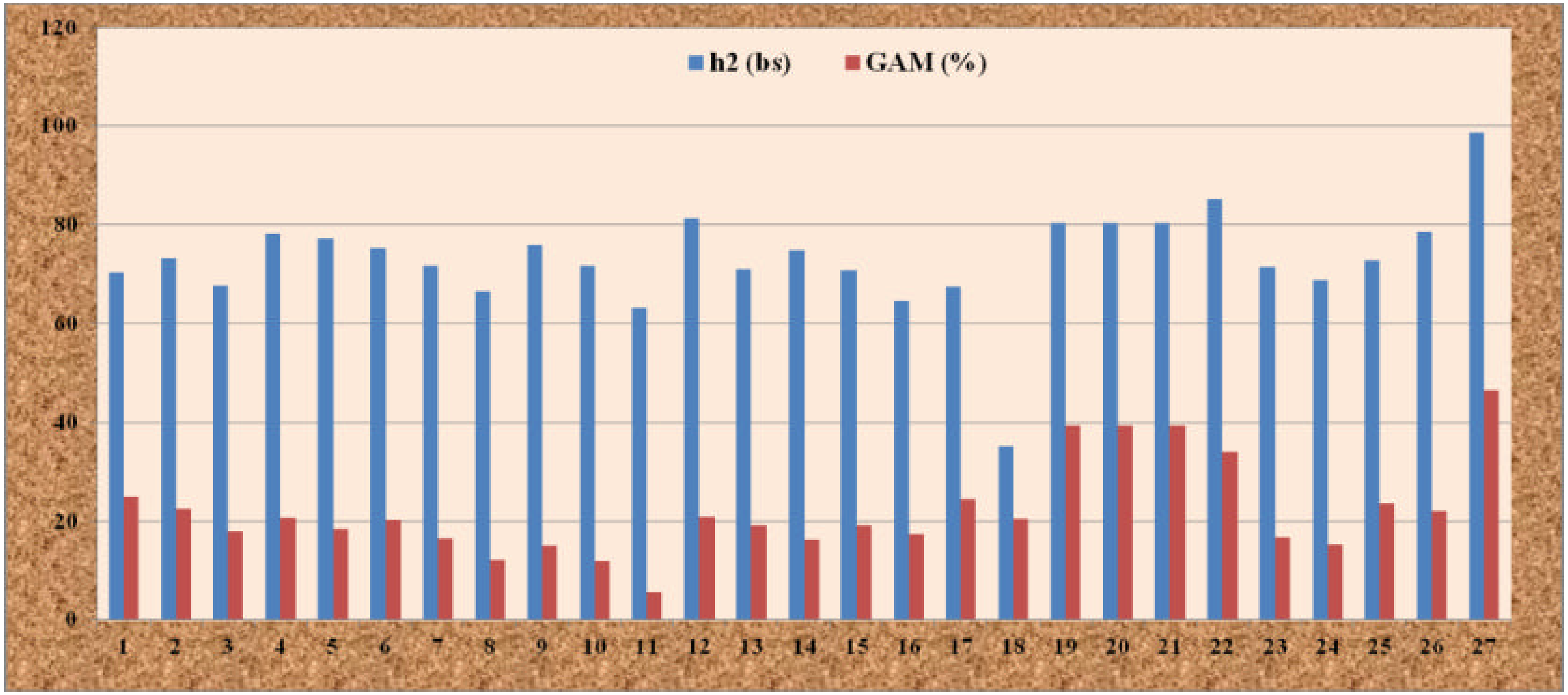

Fig. 2. Heritability and genetic advance over mean for different characters in french bean genotypes

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 per cent 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. Yield per plant
20. Yield per plot
21. Yield per hectare
22. No. of root nodules per plant
23. Dry matter content in leaves
24. Dry matter content in stem
25. Dry matter content in pods
26. Dry matter content in roots
27. Protein content in pods

findings were also reported by several investigators like Rai *et al.* (2006), Rai *et al.* (2010), Kumar *et al.* (2014), Prakash and Ram (2014) and Jayprakash *et al.* (2015) in french bean. Pan *et al.* (2004), Gnanesh *et al.* (2006), Islam *et al.* (2011), Chaudhari *et al.* (2013), Magalingham *et al.* (2013) and Chaitanya *et al.* (2014) in dolicos bean, Sharma and Bora (2013) and Saxesena *et al.* (2014) in pea, Roy *et al.* (2006) in bush bean.

High heritability (>60%) with moderate genetic advance (11-12%) were recorded for the characters like pod length, pod flesh thickness, number of seeds per plant, number of clusters per plant, number of pods per cluster, dry matter content of leaves and stem. This indicated the influence of non additive gene action and considerable influence of environment on the expression of these traits. These traits could be exploited through manifestation of dominance and epistatic components through hybridization followed by selection. These results broadly corroborate with that of results obtained by Kamaluddin and Ahmed (2011) in french bean. Gnanesh *et al.* (2006), Prashanth *et al.* (2014) and Islam *et al.* (2011) in dolicos bean. Rai *et al.* (2012) in cluster bean. Sharma and Bora (2013) and Singh *et al.* (2014a) in pea.

5.1.3 Quality parameters

High PCV and GCV were observed for protein content in pods indicated the existence of broad genetic base, which would be amenable for further selection. Similar result was also obtained by Magalingham *et al.* (2013) in dolicos bean.

High heritability (>60%) accompanied with high genetic advance as percentage over mean (>20%) was recorded for protein content. Therefore, additive component is predominant and hence, direct selection would be more effective in improving these traits. The findings of Kumar *et al.* (2014) and Prakash and Ram (2014) in french bean, Roy *et al.* (2006) in bush bean, Chaudari *et al.* (2013), Magalingham *et al.* (2013) and Verma *et al.* (2013a) in dolicos bean were similar.

5.2 Correlation studies

Variability studies provide information on the extent of improvement could be achieved in different characters, but they do not throw light on the extent and nature of relationship existing between various characters. Therefore, for rational approach towards the improvement of yield, selection has to be made for the components of yield, since there may not be genes for yield *per se*, but only for various yield components (Grafius, 1959). Further, many of these yield contributing characters may interact in desirable and undesirable direction. Hence, a knowledge regarding the association of various characters among themselves and with economic characters is essential. In the present study, the genotypic and phenotypic correlation coefficients were worked for growth, earliness, yield and quality components in french bean. The observed difference between the genotypic and phenotypic correlation coefficients was narrow for various traits in the present findings and this indicates the lesser influence of environment in the expression of these traits and presence of strong inherent association among the traits. Hence, only genotypic correlations are discussed here under.

Total yield per plant was found to be highly significant and positively associated with plant height at 25 DAS (r_g=0.585), plant height at 50 DAS (r_g= 0.552), number of primary branches at 50 DAS (r_g= 0.525), plant spread (N- S) at 50 DAS (r_g= 0.707), plant spread (E-W) at 50 DAS (r_g= 0.857), plant spread (N- S) at 25 DAS (r_g= 0.815), plant spread (E-W) at 25 DAS (r_g= 0.807),pod length (r_g =0.499), pod flesh thickness ($r_{g=}$ 0.594), number of seeds per pod(r_g= 0.614), number of clusters per plant (r_g= 0.648), number of pods per cluster (r_g=0.481), number of pods per plant (r_g = 0.809), weight of ten pods (r_g = 0.717), dry matter content of pods (r_g =0.700) and number of root nodules per plant (r_g= 0.601).Whereas days to first flowering (r_g=-0.499), days to 50 per cent flowering (r_g = -0.573), days to first pod maturity (r_g = -0.51) and pod width (r_g = -0.354) showed negative and significant association at genotypic level. Hence, direct selection for growth and yield components could be made for improving yield. The findings of Singh *et al.* (2005), Rai *et al.* (2006), Rai *et al.* (2010), Kamaluddin and Ahmed (2011), Singh *et al.* (2014b) and Verma *et al.* (2014b) in french bean, Hanchimani (2003), Gnanesh *et al.* (2006), Islam *et al.* (2011), Chaudhari *et al.* (2013) and Magalingham *et al.* (2013) in dolicos bean, Ullah *et al.*(2011) in yard long bean, kumar *et al.* (2015) and Girish *et al.* (2012) in cluster bean, Lenkala *et al.* (2015) in jack bean were similar.

Plant height at 25 DAS (Table 11) had positive and significant correlation at p=0.01 with plant height at 50 DAS (0.957), number of primary branches at 50 DAS

(0.645), plant spread (N-S) at 50 DAS (0.553), plant spread (E-W) at 50 DAS (0.613), plant spread (N-S) at 25DAS (0.622), plant spread (E-W) at 25 DAS (0.685), pod length (0.794), pod flesh thickness (0.661), number of seeds per pod(0.621),number of clusters per plant (0.374), weight of ten pods (0.793), dry matter content of pods (0.576), number of root nodules (0.496) and yield per plant (0.585). While it showed significant and negative correlation with days to first flowering (-0.492), days to 50% flowering (-0.692), days to first pod maturity (-0.575) and pod width (-0.485). Similar results were reported by Verma *et al.* (2014b), and kumar *et al.* (2014) in French bean, Gnanesh *et al.* (2006) and Ravinaik *et al.*(2014) in dolicos bean, Singh *et al.* (2004) in cluster bean.

A significant (at p=0.01) and positive correlation of plant height at 50 DAS (Table 11) was observed with number of primary branches at 50 DAS (0.447), plant spread (N-S) at 50 DAS (0.342) plant spread (E-W) at 50 DAS (0.486), plant spread (N-S) at 25 DAS (0.582) plant spread (E-W) at 25 DAS (0.552), pod length (0.682), pod flesh thickness (0.448), number of seeds per pod(0.537), number of clusters per plant (0.421), number of pods per plant (0.314), weight of ten pods (0.573), dry matter content of pods (0.673), number of root nodules (0.471) and yield per plant (0.552). Whereas it showed significant and negative correlation with days to first flowering (-0.422), days to 50% flowering (-0.684), days to first pod maturity (-0.530) and pod width (-0.304). Angadi *et al.* (2012) and Gangadhara (2012) in french bean also reported similar findings.

Number of primary branches at 50 DAS (Table 11) had positive and significant association at p=0.01 with plant spread (N-S) at 50 DAS (0.661), plant spread (E-W) at 50 DAS (0.641), plant spread (N-S) at 25 DAS (0.584), plant spread (E-W) at 25 DAS (0.642), pod length (0.298), number of seeds per pod (0.462), number of clusters per plant (0.389), weight of ten pods (0.622.), dry matter content of pods (0.465), number of root nodules (0.707) and yield per plant (0.525).It showed significant and negative correlation with days to first flowering (-0.341) and days to first pod maturity (-0.342). This trait had positive and significant (at p=0.05) association with number of pods per plant (0.236). The findings of Govankoppa (2001) and Syed mudasir *et al.* (2012) in French bean, Ravinaik *et al.* (2014) and Chaudhari *et al.* (2013) in dolicos bean, Singh *et al.* (2002) in cluster bean are in conformity with present findings.

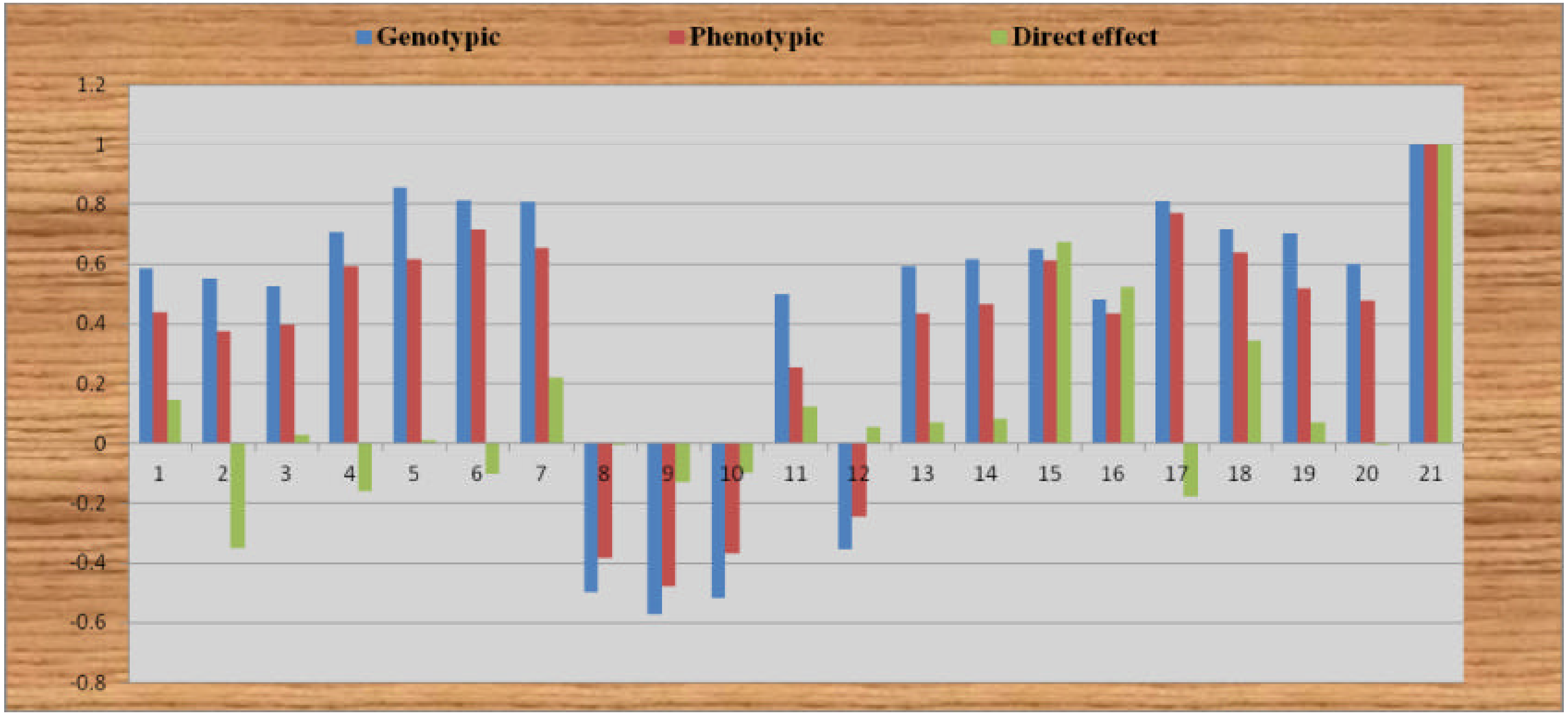

Fig. 3. Genotypic and phenotypic correlation of different characters and direct phenotypic effect with yield per plant in french bean genotypes

8. Plant height at 25 DAS
9. Plant height at 50 DAS
10. No. of primary branches at 50 DAS
11. Plant spread (N-S) at 50 DAS
12. Plant spread (E-W) at 50 DAS
13. Plant spread (N-S) at 25 DAS
14. Plant spread (E-W) at 25 DAS

8. Days to first flowering
9. Days to 50 per cent 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

A highly significant and positive correlation of plant spread (N-S) at 50 DAS (Table 11) was observed with plant spread (E-W) at 50 DAS (0.895), plant spread (N-S) at 25 DAS (0.822), plant spread (E-W) at 25 DAS (0.830), pod length (0.328), pod flesh thickness (0.470), number of seeds per pod (0.429), number of clusters per plant (0.371), number of pods per cluster (0.448), number of pods per plant (0.596), weight of ten pods (0.465), dry matter content of pods (0.617), number of root nodules (0.543) and yield per plant (0.707) and pod width (-0.266) had positive relation at p= 0.05. It showed significant and negative correlation with days to first flowering (-0.370), days to 50% flowering (-0.465), days to first pod maturity (-0.428). This view was supported by Girish *et al.* (2012) in cluster bean.

Plant spread (E-W) at 50 DAS (Table 11) was highly significant and positively associated with plant spread (N-S) at 25 DAS (0.917), plant spread (E-W) at 25 DAS (0.904), pod length (0.376), pod flesh thickness (0.551), number of seeds per pod (0.386), number of clusters per plant (0.639), number of pods per cluster(0.441), number of pods per plant (0.793), weight of ten pods (0.493), dry matter content of pods (0.802), number of root nodules (0.665) and yield per plant (0.857). It showed significant and negative correlation with days to first flowering (-0.431), days to 50% flowering (-0.490), days to first pod maturity (-0.304). Similar results were obtained by Hanchimani (2003) in dolicos bean.

A significant at p=0.01 and positive association of days to first flowering (Table 11) was noticed with days to 50 per cent flowering (0.479), days to first pod maturity (0.476). While it showed significant and negative correlation with pod flesh thickness (-0.407), number of pods per plant (-0.373), weight of ten pods (-0.377), dry matter content of pods (-0.677), number of root nodules (-0.416) and yield per plant (-0.499). Whereas negative and significant (at p=0.05) association was found with number of seeds per pod (-0.292), number of clusters per plant (-0.272). The similar results were observed by Verma *et al.* (2014b) in french bean, Gnanesh *et al.* (2006) and Islam *et al.* (2011) in dolicos bean, Lenkala *et al.* (2015) in jack bean.

Days to 50 per cent flowering (Table 11) was positively and significantly (at p=0.01) correlated with days to first pod maturity (0.452), pod width (0.390). It showed significant and negative correlation with pod length (-0.507), number of seeds per pod (-0.438), number of pods per plant (-0.375), weight of ten pods (-0.510), dry matter content of pods (-0.743), number of root nodules (-0.324) and yield per plant (-0.573). Whereas negative and significant (at p=0.05) association was noticed with pod flesh thickness (-0.277) number of clusters per plant (-0.243) and number of pods per cluster (-0.231). The findings of Syed mudasir *et al.* (2012), Verma *et al.* (2014b) and Jayprakash *et al.* (2015) in French bean, Karnwal *et al.* (2013) in pea, Chaudhari *et al.* (2013) and Ravinaik *et al.* (2014) dolicos bean are in conformity with present findings.

A significant at p=0.01 and negative association of days to first pod maturity (Table 11) was observed with number of pods per cluster (-0.315), number of pods per plant (-0.426), weight of ten pods (-0.363), dry matter content of pods (-0.447), number of root nodules (-0.478) and yield per plant (-0.517). While, number of seeds per pod (-0.268) and number of clusters per plant (-0.291) were found significant (at p=0.05) but negatively correlated with this trait. Several workers like Syed mudasir *et al.* (2012) in french bean, Chaudhari *et al.* (2013), Magalingham *et al.* (2013) and Ravinaik *et al.* (2014) in dolicos bean, Karnwal *et al.* (2013) in pea, Lenkala *et al.* (2015) in jack bean also observed similar results.

Pod length (Table 11) had positive and highly significant association with pod flesh thickness (0.512), number of seeds per pod (0.608), number of clusters per plant (0.631), number of pods per cluster (0.572), number of pods per plant (0.589), weight of ten pods (0.591) and yield per plant (0.553). But it showed significant and negative correlation with pod width (-0.499). These results were obtained by Rai *et al.* (2006), Kamaluddin and Ahmed (2011), Syed mudasir *et al.* (2012), Singh *et al.* (2014b) and Verma *et al.* (2014b) in french bean, Pan *et al.*(2004), Ali *et al.* (2005) and Gnanesh *et al.* (2006) in dolicos bean are in accordance with present findings.

Pod width (Table 11) had negative and highly significant correlation with pod flesh thickness (-0.436), number of seeds per pod (-0.477), weight of ten pods (-0.549) and yield per plant (-0.354). Similar results were also obtained by Rai *et al.* (2004) and Verma *et al.* (2014b) in french bean, Lenkala *et al.* (2015) in jack bean.

Number of seeds per pod (Table 11) had positive and highly significant association with weight of ten pods (0.790), dry matter content of pods (0.493), number of root nodules per plant (0.317) and yield per plant (0.614). These results are in conformity with the readings of Rai *et al.* (2010), Kamaluddin and Ahmed (2011) and Singh *et al.* (2014b) in French bean, Gnanesh *et al.* (2006) and Ravinaik *et al.* (2014) in dolicos bean, Lenkala *et al.* (2015) in jack bean.

The significant at p=0.01 and positive correlation of number of clusters per plant (Table 11) was observed with number of pods per plant (0.760), dry matter content of pods (0.366), number of root nodules per plant (0.410) and yield per plant (0.648). Girish *et al.* (2012) in cluster bean also obtained similar results.

Number of pods per cluster (Table 11) had positive and highly significant association with number of pods per plant (0.667) and yield per plant (0.481). While and dry matter content of pods (0.269) and number of root nodules per plant (0.234) were found significant (at p=0.05) and positively associated with this trait. Similar results were obtained by Chaudhari *et al.* (2013) and Ravinaik *et al.* (2014) in dolicos bean, Venkatesan *et al.* (2003) in cowpea.

The significant at p=0.01 and positive correlation of number of pods per plant (Table 11) was observed with yield per plant (0.809), dry matter content of pods (0.484) and number of root nodules per plant (0.465). These results are in conformity with the observations of Raffi and Nath (2004), Rai *et al.* (2010), Kamaluddin and Ahmed (2011), Syed Mudasir *et al.* (2012), Singh *et al.* (2014b) and Jayprakash *et al.* (2015) in french bean, Gnanesh *et al.* (2006), Islam *et al.* (2011) and Chaudhari *et al.* (2013) dolicos bean.

Weight of ten pods exhibited the positive and highly significant association with pod yield (0.717), dry matter content of pods (0.611) and number of root nodules per plant (0.433). These results obtained by Rai *et al.* (2006), Verma *et al.* (2014b) and Singh *et al.* (2014b) in french bean, Lenkala *et al.* (2015) in jack bean, Pan *et al.* (2004) and Parmar *et al.* in dolicos bean are in accordance with present findings.

Dry matter content of pods had positive and significant (at p=0.01) association with number of root nodules per plant (0.639) and yield per plant (0.717). Similar results were also obtained by Verma *et al.* (2014b) in French bean and Aditya *et al.* (2011) in soyabean.

5.3 Path co-efficient analysis

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 by Wright (1921) and demonstrated by Dewey and Lu (1957) facilitates in partitioning the correlation coefficients into direct and indirect contribution of various characters on yield. It is a standardised 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 utilise 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.

In the present study, path coefficient analysis between the components of french bean was worked out. As the genotypic associations are inherent, the path analysis is discussed only at genotypic level.

Plant height at 25 DAS (Table 13) had low and direct positive effect (0.114) on total yield per plant. It had negligible to low indirect and positive effects through plant height at 50 DAS (0.138), number of primary branches at 50 DAS (0.093), plant spread (N-S) at 50 DAS (0.079), plant spread (E-W) at 50 DAS (0.088), pod length (0.114), pod flesh thickness (0.095), number of seeds per pod (0.089), weight of ten pods (0.114) and dry matter content of pods (0.089). It also had low and indirect negative effects through days to first flowering (-0.071), days to 50% flowering (-0.099), days to first pod maturity (-0.083) and pod width (-0.070). Similar results were obtained by Nath and Korla (2004) in french bean, Roy *et al.* (2006) in bush bean and Gnanesh *et al.* (2006) in dolicos bean.

Plant height at 50 DAS (Table 13) had high and direct negative effect (-0.352) on total yield per plant. It had moderate and indirect negative effects through plant spread (N-S) at 25 DAS (-0.205), pod length (-0.240), weight of ten pods (-0.202) and

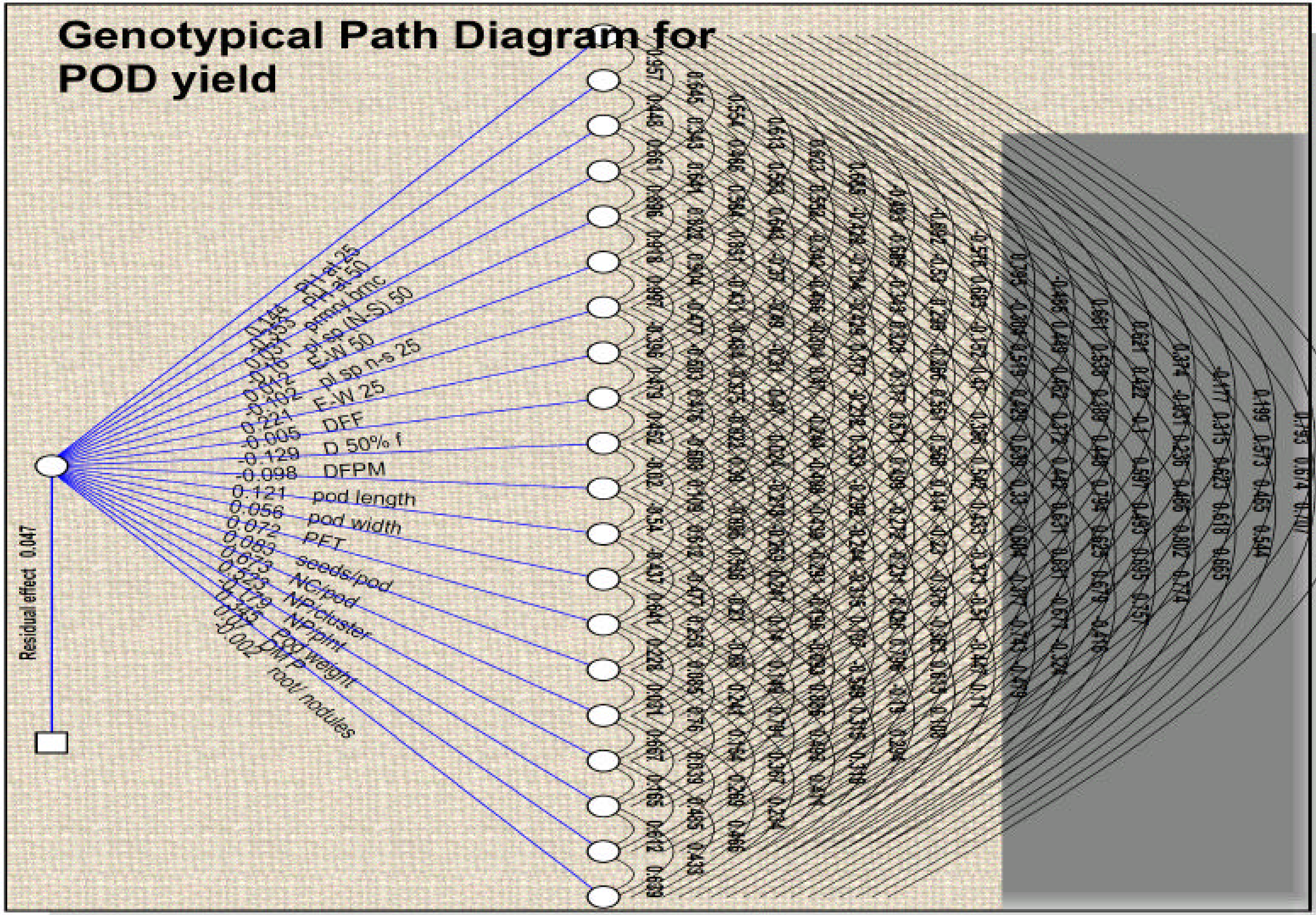

Fig. 4. Genotypic path diagram for yield per plant in 36 genotypes of french bean

dry matter content of pods (-0.237). It also had low and indirect negative effect through number of primary branches at 50 DAS (-0.157), plant spread (E-W) at 50 DAS (-0.171), plant spread (E-W) at 25 DAS (0.194), number of seeds per pod (-0.189) and number of clusters per plant (-0.148) and also showed low to moderate indirect but positive effect through days to first flowering (0.149) and days to first pod maturity (0.187) and days to 50 % flowering (0.241). The findings of Govankoppa (2001), Raffi and Nath (2004), Kamaluddin and Ahmed (2011) in french bean, Chaudhari *et al.* (2013) and Ravinaik *et al.* (2014) in dolicos bean were in conformity with the present readings.

Number of primary branches at 50 DAS (Table 13) had negligible and direct positive effect (0.030) on total yield per plant. It had negligible indirect and positive effects through plant spread (N-S) at 50 DAS (0.020), plant spread (E-W) at 50 DAS (0.019), plant spread (N-S) at 25 DAS (0.018), plant spread (E-W) at 25 DAS (0.019), pod flesh thickness (0.016), number of seeds per pod (0.014), weight of ten pods (0.019) and number of root nodules per plant (0.021). Similar results are reported by Ganghadhara *et al.* (2012) and Mehra and Singh (2012) in french bean, Chaudhari *et al.* (2013) and Ravinaik *et al.* (2014) in dolicos bean and kumar *et al.* (2015) in cluster bean.

Plant spread (N-S) at 50 DAS (Table 13) had low and direct negative effect (-0.160) on total yield per plant. It had low and indirect negative effect through plant spread (E-W) at 50 DAS (-0.143), plant spread (N-S) at 25 DAS (-0.131) and plant spread (E-W) at 25 DAS (-0.133). It also had negligible and negative indirect effects through number of pods per plant (-0.095), pod flesh thickness (-0.075), weight of ten pods (-0.074), dry matter content of pods (-0.099), and number of root nodules per plant (-0.087) and negligible and positive indirect effects through days to 50 % flowering (0.074) and days to first pod maturity (0.068).

Plant spread (E-W) at 50 DAS (Table 13) 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).

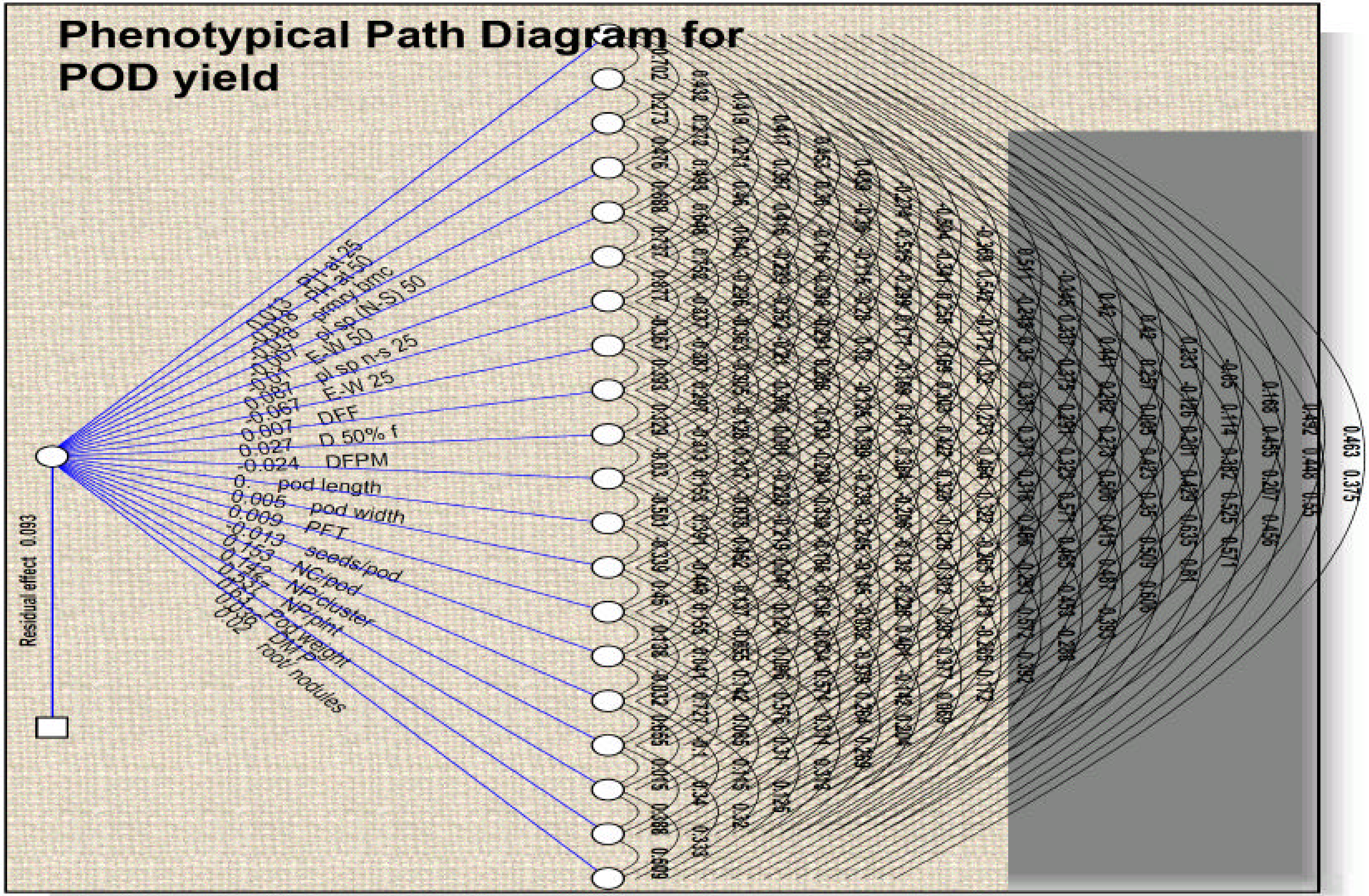

Fig 5. Phenotypic path diagram for yield per plant in 36 genotypes of french bean

Days to first flowering (Table 13) had negligible and direct negative effect (-0.005) on total yield per plant. It had negligible and indirect positive effect through pod flesh thickness (0.002), dry matter content of pods (0.003) and number of root nodules per plant (0.002). These results are in accordance with those of Joshi and Mehra (1984) and Verma *et al.* (2014b) in french bean, Gnanesh *et al.* (2006) and Singh *et al.* (2011) in dolicos bean, and kumar *et al.* (2015) in cluster bean.

Days to 50% per cent flowering (Table 13) 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), 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.* (2013) in dolicos bean.

Days to first pod maturity (Table 13) had negligible and direct negative effect (-0.098) on total yield per plant. It had negligible and indirect positive effect through number of pods per plant (0.041), weight of ten pods (0.035), number of seeds per pod (0.026) and number of clusters per plant (0.028) and number of pods per cluster (0.031). The findings of Raffi and Nath (2004) in french bean and Pal and Singh (2012) in pea were similar.

Pod length (Table 13) 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 Joshi and Mehra (1984), Nath and Korla (2004), Rai *et al.* (2010) and Verma *et al.* (2014b) in french bean, Gnanesh *et al.* (2006), Singh *et al. (*2011) and Ravinaik *et al.* (2014) in dolicos bean and Karnwal *et al.* (2006) in pea were in conformity with present findings.

Pod width (Table 13) 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, Govankoppa (2001) in french bean and Ravinaik *et al.* (2014) in dolicos bean.

Number of seeds per pod (Table 13) 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.* (2014) and Verma *et al.* (2014b) in french bean, Chaudhari *et al.* (2013) and Gnanesh *et al.* (2006) in dolicos bean, Venkatesan *et al.* (2003) in cowpea were similar.

Number of clusters per plant (Table 13) 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 12) 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 dolicos bean are in accordance with present findings.

Number of pods per plant (Table 13) 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.* (2014b) and Singh *et al.* (2014b) in french bean, Kutty *et al.* (2003) in cowpea, Pal and Singh (2012) in pea.

Weight of ten pods (Table 13) 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.* (2014b) in french bean.

5.4 Genetic divergence

The success of a breeding programme depends upon the selection of parents. It has been found that the progenies derived from crossing divergent parents give divergent and useful progenies. The D2 analysis proposed by Mahalanobis (1936) has been reported to be an effective tool to assess the genetic divergence. Such an analysis eventually helps to choose desirable parents for recombination breeding and thus results in the development of superior varieties.

Ecological diversity has been regarded as a reasonable index of genetic diversity (Vavilo, 1926, Moll *et al.*, 1962 and Ram and Panwar, 1970). Assuming this, the cultivars from widely separated localities has been included in hybridization programme by most of the plant breeders for recovering promising segregants. But, Sachan and Sharma (1971) could not find any direct relationship between geographic distribution and genetic diversity in crops belonging to different breeding systems.

The material for present study includes 36 genotypes grouped into five clusters using Tocher's method. Of the five clusters studied, Cluster I was the largest having 24 genotypes followed by cluster II (9) and remaining three clusters had one genotype each. Genotypes usually did not cluster according to geographical distributions. The findings of Mishra *et al.* (2010), Syed mudasir *et al.* (2012) and Gangadhara *et al.* (2014) in french bean, Patel *et al.* (2011) and Salim *et al.* (2013) in dolicos bean, Panigrahi *et al.* (2014) in black gram and kutty *et al.* (2003) in cowpea were similar.

Intra cluster distances revealed cluster I with 24 genotypes showed maximum intra cluster diversity (D^2=69.06) followed by cluster II (D^2 =48.21). The clusters III, IV and V had solitary genotype. Maximum intra-cluster distance was observed in cluster I indicating existence of wide genetic divergence among the constituent genotypes in it as compared to other cluster. High degree of divergence among the genotypes within a cluster would produce more segregating breeding materials and selection within such cluster might be executed based on maximum mean value for the desirable characters.

Based on distance between clusters *i.e.* inter-cluster distance, the maximum divergence was observed between cluster II and cluster V (D^2=395.94) followed by clusters I and V (D2=241.08), cluster II and III (D^2=223.39), cluster II and IV (D^2=171.48) and cluster IV and V (D^2=158.28). Maximum inter-cluster D^2 values was observed between the clusters II and V indicating that the genotypes in these clusters can be used as a parents in hybridization programme to obtain the superior segregants.

The clusters have been formed based on the contribution of different characters to the divergence. The relative contribution of different quantitative characters towards expression of genetic divergence was calculated. Number of pods per plant (27.46%) contributed maximum to the genetic diversity followed by total yield per plant (13.97%), dry matter content of pods (13.65%), pod width (8.57%), number of clusters per plant (5.87%), number of pods per cluster (5.45%), number of seeds per pod (3.65%), plant spread (N-S) at 50 DAS (3.33%), number of root nodules (2.70%), days to first pod maturity (2.54%), pod flesh thickness (2.38%), days to 50 per cent flowering (2.06%), weight of ten pods (1.90%), days to first flowering (1.59%) and pod length (1.43%). The contribution was less than one percent from some of the character *viz.*, plant height at 50 DAS (0.95%), plant spread (N-S) at 25 DAS (0.79%) and plant spread (E-W) at 25 DAS (0.79%). The findings of Syed mudasir *et al.* (2012) and in french bean, Chaitanya *et al.* (2013) and Salim *et al.* (2013) in dolicos bean, Panigrahi *et al.* (2014) in black gram.

Highest cluster mean for plant height at 25 and 50 DAS was observed in the cluster II followed by cluster I, cluster IV and cluster III. The inter-cluster distance between cluster II and I (D^2=146.06), cluster II and IV (D^2=171.48) and II and III (D^2=223.39) were comparatively high. Hence crosses between the genotypes of these respective clusters would be more rewarding to achieve improvement in plant height.

Highest cluster mean for number of primary branches at 50 DAS was observed in the cluster IV followed by cluster II, cluster I and cluster III. The inter-cluster distance between cluster IV and II (D^2=171.48), cluster IV and I (D^2=127.39) and IV and III (D^2=133.13) were comparatively high. Therefore, crosses between the genotypes belonging to these respective clusters would be of much help to isolate genotypes with more number of branches per plant.

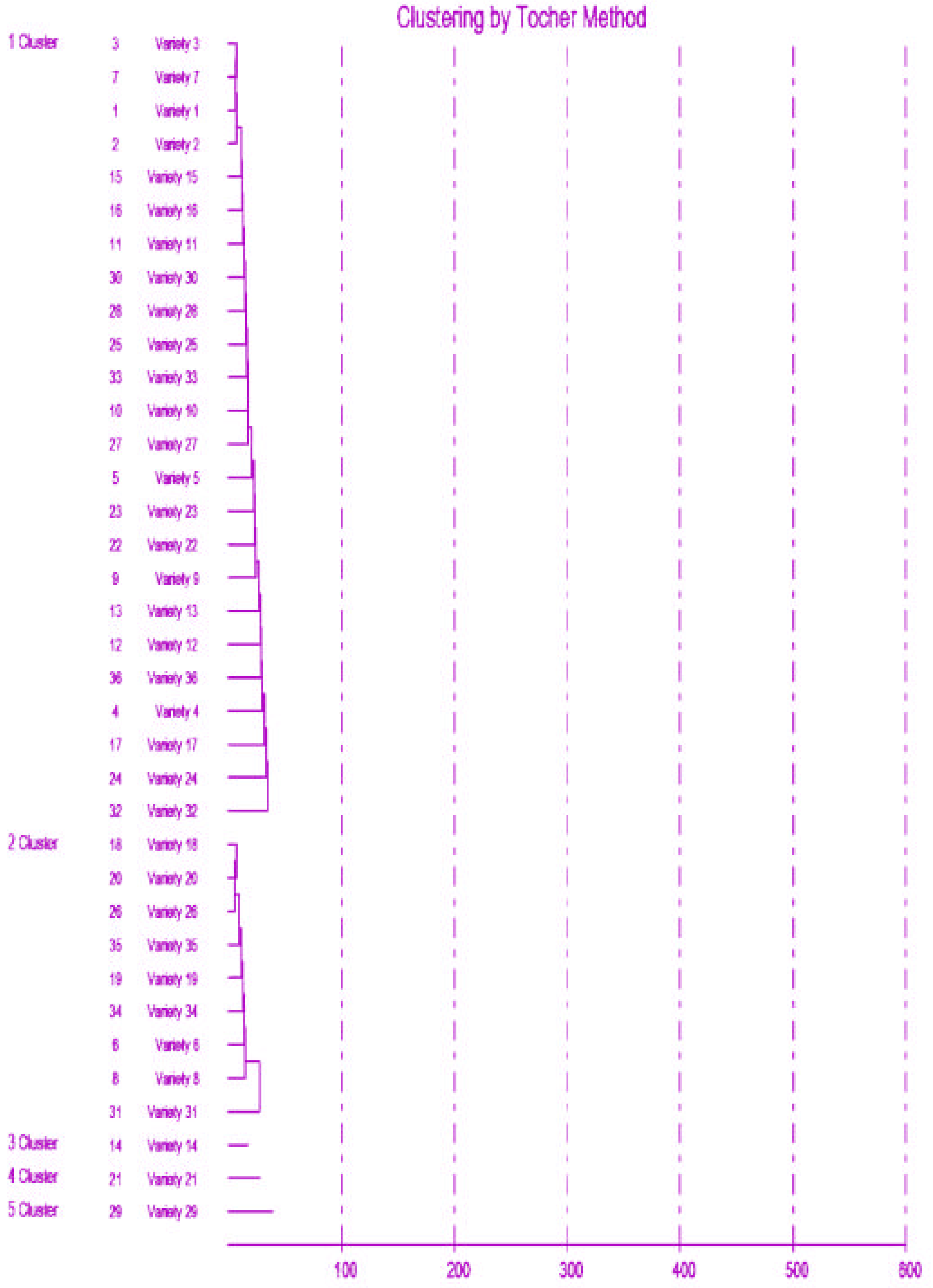

Fig. 6. Dendrogram of clustering pattern of thirty six genotypes of french bean

The mean for plant spread (N-S) at 50 DAS was highest in the cluster II followed by cluster I, cluster III and cluster V. The inter-cluster distance between cluster II and I (D^2=146.06), cluster II and III (D^2=223.39) and II and V (D^2=395.94) were comparatively high. Hence, crosses can be made between the genotypes belonging to the respective clusters to isolate genotypes with better spreading habit, which ultimately help in increasing the branches, flowers, fruit set and finally resulting in higher yields.

Highest cluster mean for plant spread (N-S) at 50 DAS was observed in the cluster II followed by cluster I, cluster III and cluster IV. The inter-cluster distance between cluster II and I (D^2=146.06), cluster II and III (D^2=223.39) and II and IV (D^2=171.48) were comparatively high. Hence, hybridization between genotypes of these respective clusters could be attempted to get better spreading genotypes to obtain higher pod yield.

The mean for plant spread (N-S) at 25 DAS was highest in the cluster II followed by cluster I, cluster IV and cluster III. The inter-cluster distance between cluster II and I (D^2=146.06), cluster II and IV (D^2=171.48) and II and III (D^2=223.39) were comparatively high. Hence, crosses can be made between the genotypes belonging to the respective clusters to isolate genotypes with better spreading habit, which ultimately help in increasing the branches, flowers, fruit set and finally resulting in higher yields.

The highest mean for plant spread (E-W) at 25 DAS was observed in the cluster II followed by cluster I, IV and cluster III. The inter-cluster distance between cluster II and I (D^2=146.06), cluster II and IV (D^2=171.48) and II and III (D^2=223.39) were comparatively high. Hence hybridization between genotypes of respective clusters to improve plant spread is suggested.

The mean for days to first flowering was highest in the cluster III followed by cluster I, cluster IV and cluster V. The inter-cluster distance between cluster III and I (D^2=116.20), cluster III and IV (D^2=133.13) and III and V (D^2=102.98) were comparatively high. Hence, hybridization between genotypes of these respective clusters is expected to be helpful in enhancing the earliness.

For days to 50 per cent flowering highest cluster mean was observed in the cluster V followed by cluster IV, cluster III and cluster I. The inter-cluster distance between cluster V and IV (D^2=158.28), cluster V and III (D^2=102.98) and V and I (D^2=241.08) were comparatively high. Hence, hybridization between genotypes of respective clusters may yield desirable results.

Highest cluster mean for days to first pod maturity was observed in the cluster V followed by cluster I, cluster III and cluster II. The inter cluster distances between V and I (D^2=241.08), V and III (D^2=102.98) and V and II (D^2=395.94) were comparatively high. Hence, hybridization between genotypes of these respective clusters could be attempted to get early pod yield.

Highest cluster mean for pod length and pod flesh thickness were observed in the cluster II followed by cluster I, cluster III and cluster IV. The inter cluster distances between II and I (D^2=146.06), II and III (D^2=223.39) and II and IV (D^2=171.48) were comparatively high. Hence, hybridization between genotypes of respective clusters can be attempted to improve pod length and pod flesh thickness that ultimately contributes towards yield.

The mean for pod width was highest in the cluster V followed by cluster IV, cluster III and cluster I. The inter-cluster distance between cluster V and IV (D^2=158.28), cluster V and III (D^2=102.98) and V and I (D^2=241.08) were comparatively high. Therefore it would be logical to attempt crossing among the genotypes belonging to these cluster so as to evolve desirable high pod width.

For number of seeds per pod highest cluster mean was observed in the cluster II followed by cluster III, cluster I, cluster IV. The inter cluster distances between II and III (D^2=223.39), II and I (D^2=146.06) and II and IV (D^2=171.48) were comparatively high. Hence, hybridization between genotypes of these respective clusters could be attempted to get more number of seeds per pod.

The highest cluster mean for number of clusters per plant was observed in the cluster II followed by cluster I, cluster IV and cluster V. The inter cluster distances between II and I (D^2=146.06), II and IV (D^2=171.48) and II and V (D^2=395.94) were comparatively high. Hence, crosses between the genotypes of these respective clusters may be tried for improvement of the number of clusters per plant.

For number of pos per cluster highest cluster mean was observed in the cluster III followed by cluster V, cluster II, cluster I. The inter cluster distances between III and V (D^2=102.98), III and II (D^2=223.39) and I and IV (D^2=127.39) were comparatively high. Therefore, it would be logical to attempt crossing among the genotypes belonging to these clusters so as to obtain more pods per cluster

The highest cluster mean for number of pods per plant was observed in the cluster II followed by cluster V, cluster I and cluster III. The inter cluster distances between II and V (D^2=395.94), II and I (D^2=146.06) and II and III (D^2=223.39) were comparatively high. Hence, crosses can be made between the genotypes of these pair of clusters for improvement of number of pods per plant.

The highest cluster mean for weight of ten pods was observed in the cluster II followed by cluster I, cluster III and cluster IV. The inter cluster distances between II and I (D^2=146.06), II and III (D^2=223.39) and II and IV (D^2=171.48) were comparatively high. Hence, crosses can be made between the genotypes of these respective clusters for improvement average fruit weight that contributes for yield.

For dry matter content of pods highest cluster mean was observed in the cluster II followed by cluster I, cluster IV, cluster III. The inter cluster distances between II and I (D^2=146.06), II and IV (D^2=171.48) and II and III (D^2=223.39) were comparatively high. Hence, crosses between the genotypes of these respective clusters may be tried for improvement of the dry matter content of pods.

Highest cluster mean for pod yield per plant was observed in the cluster II followed by cluster I, cluster III and cluster IV. The inter cluster distances between II and I (D^2=146.06), II and III (D^2=223.39) and II and IV (D^2=171.48) were comparatively high. Hence, crosses can be made between the genotypes of these respective clusters for improvement of total pod yield per plant.

The mean for number of root nodules per plant was highest in the cluster IV followed by cluster II, cluster V and cluster I. The inter-cluster distance between cluster IV and II (D^2=171.48), cluster IV and V (D^2=158.28) and IV and I (D^2=127.39) were comparatively high. Hence, hybridization between genotypes of these respective clusters is expected to increase the number of root nodules per plant.

6. SUMMARY AND CONCLUSIONS

An investigation on the Variability and genetic diversity studies in french bean (*Phaseolus vulgaris* L.) was carried out during *rabi* season of the year 2015-2016 at Research Block of Vegetable Section in Sector No. 1 under the University of Horticultural Sciences, Bagalkot with 36 genotypes. The main objectives of the present investigation were to study the nature and extent of genetic variability and character association in french bean germplasm for growth, earliness, yield and quality parameters and to study the extent of diversity in french bean germplasm.

Variability studies

The variance due to treatments (genotypes) was significant for all 27 characters *viz.*, plant height (25 and 50 DAS), plant spread (25 and 50 DAS), number of primary branches (at 60 DAS), days to first flowering, days to 50 per cent flowering, days to first pod maturity, 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, average pod weight, pod yield per plant, pod yield per plot, pod yield per hectare, number of root nodules per plant, dry matter content (leaves, stem, pod and roots) and protein content. Means of genotypes varied greatly for several traits indicating the higher magnitude of variability in the germplasm.

High (>20%) GCV and PCV were observed for yield per plant, yield per plot, yield per hectare and protein content. It indicated the existence of sufficient variability in genetic stock studied and the traits are governed by additive genes. Hence, there is ample scope for improving these characters based on direct selection. Moderate GCV and PCV (10-20%) were observed for plant height at 25 and 50 DAS, number of primary branches at 50 DAS, plant spread (N-S) at 25 DAS, plant spread (N-S) at 50 DAS, plant spread (E-W) at 25 DAS, pod length, pod width, pod flesh thickness, number of pods per cluster, number of pods per plant, weight of ten pods, number of root nodules per plant, dry matter content of pods and roots. It implied equal importance of additive and non additive gene action and substantial amount of variability for these traits. Therefore phenotypic variability may be a good measure of genetic variability and hence selection for such traits would be rewarding.

Low GCV (>10%) and moderate PCV (11-12%) were observed for plant spread (E-W) at 50 DAS, number of seeds per pod, dry matter content in leaves and stem. These results indicate that apparent variation is not only due to genotypes but also due to the influence of environment on the expression of character. Selection for such traits may not give desirable results. Low GCV and PCV were observed for days to first flowering, days to 50 % flowering and days to first pod picking. This indicated low variability in the germplasm stock necessitating generation of new variability for these characters.

High heritability (>60%) along with high genetic advance as per cent over mean (>20%) was recorded for the plant height (25 and 50 DAS), pod width, number of pods per plant, average pod weight, yield per plant, yield per plot, yield per hectare, number of root nodules per plant, dry matter content of pods and roots and protein content. These results indicated the presence of additive gene effects. Thus, there is an ample scope for improving these characters with direct selection.

High heritability (>60%) with moderate genetic advance (11-12%) were recorded for the characters like number of primary branches at 50 DAS, plant spread (E-W) at 50 DAS, plant spread (N-S) at 25 DAS, pod length, pod flesh thickness, number of seeds per plant, number of clusters per plant, number of pods per cluster, dry matter content of leaves and stem. This indicated the influence of non additive gene action and considerable influence of environment on the expression of these traits. These traits could be exploited through manifestation of dominance and epistatic components through hybridization followed by selection.

Correlation and path analysis

Total yield per plant was found to be positively and significantly (p=0.01) associated with plant height at 25 and 50 DAS, number of primary branches at 50 DAS, plant spread (N- S) at 50 DAS, plant spread (E-W) at 50 DAS, plant spread (N- S) at 25 DAS, plant spread (E-W) at 25 DAS, pod length, 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 pod and number of root nodules per plant. Whereas days to first flowering, days to 50 per cent flowering, days to first pod maturity and pod width showed negative and significant association at both genotypic level and phenotypic level.

Path analysis 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.

Genetic divergence

Thirty six genotypes were grouped into five clusters. A maximum of 24 genotypes included in cluster I followed by 9 genotypes in cluster II and the clusters III, IV and V had solitary genotype.

Intra cluster distances revealed cluster I with 24 genotypes showed maximum intra cluster diversity (D^2=69.06) followed by cluster II (D^2 =48.21). The clusters III, IV and V had solitary genotype. Maximum intra-cluster distance was observed in cluster I indicating existence of wide genetic divergence among the constituent genotypes in it as compared to other cluster. High degree of divergence among the genotypes within a cluster would produce more segregating breeding materials and selection within such cluster might be executed based on maximum mean value for the desirable characters.

Based on distance between clusters *i.e.* inter-cluster distance, the maximum divergence was observed between cluster II and cluster V (D^2=395.94) followed by clusters I and V (D^2=241.08), cluster II and III (D^2=223.39), cluster II and IV (D^2=171.48) and cluster IV and V (D^2=158.28). This clustering helps the breeders for selection of genotypes for hybridization programmes and can be used as base for patenting or registration.

Among the 21 characters included for D^2 analysis, number of pods per plant (27.46%) contributed maximum to the genetic diversity followed by total yield per plant (13.97%), dry matter content of pods (13.65%), pod width (8.57%), number of clusters per plant (5.87%), number of pods per cluster (5.45%), number of seeds per pod (3.65%), plant spread (N-S) at 50 DAS (3.33%), number of root nodules (2.70%), days to first pod maturity (2.54%), pod flesh thickness (2.38%), days to 50 per cent flowering (2.06%), weight of ten pods (1.90%), days to first flowering (1.59%) and pod length (1.43%). The contribution was less than one percent from some of the character *viz.*, plant height at 50 DAS (0.95%), plant spread (N-S) at 25 DAS (0.79%) and plant spread (E-W) at 25 DAS (0.79%).

The top three characters contributing most towards the genetic divergence were number of pods per plant followed by total yield per plant and dry matter content of pods. These characters may be used in selecting genetically diverse parents for hybridization programme to execute efficient selection in the segregating generation.

Salient findings and future line of work

1. Moderate GCV and PCV (10-20%) were observed for pod length, pod width, pod flesh thickness, number of pods per cluster, number of pods per plant, weight of ten pods, number of root nodules per plant, dry matter content of pods and roots. It implied equal importance of additive and non additive gene action and substantial amount of variability for these traits. Therefore phenotypic variability may be a good measure of genetic variability and hence selection for such traits would be rewarding.

2. Plant spread (E-W) at 25 DAS, number of clusters per plant, number of pods per cluster per plant and weight of ten pods had high direct and indirect effects on total yield per plant at genotypic level. Hence, more emphasis has to be given to these traits for improving the yield.

3. For recovering improved progenies for growth, earliness and yield parameters, crosses can be attempted between the genotypes belonging to clusters II and I, clusters II and III and clusters II and IV, respectively as revealed by divergence studies.

4. The high yielding genotypes IIHR-62, Arka Arjun, IIHR-53, IIHR-232 and Arka Anoop are high yielders having desirable quality characters. Hence there need to be assessed further for their performance in different environments.

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Appendix I. chemical properties of soil from experimental site

Sl. No.	Particulars	Value obtained
A.	**Chemical properties**	
1.	EC	0.31
2.	Organic carbon (%)	0.496
3.	Soil reaction (pH)	7.9
4.	Available nitrogen (kg/ha)	208.56
5.	Available phosphorus (kg/ha)	22.37
6.	Available potassium (kg/ha)	615.24

Appendix II. Meteorological data recorded during experimental period from October 2015 to March 2016in MHREC, Bagalkot

Month	Temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)
	Min	Max	Min	Max	
November	20.00	30.00	64.00	86.53	29
December	18.00	31.00	67.00	76.65	07
January	17.00	30.00	63.12	74.58	00

VARIABILITY AND GENETIC DIVERSITY STUDIES IN FRENCH BEAN (*Phaseolus vulgaris* L.)

JHANAVI D. R. **2016** **Dr. H. B. PATIL**
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ABSTRACT

An investigation on "Variability and genetic diversity studies in French bean (*Phaseolus vulgaris* L.)" was undertaken during *rabi* season of 2015. Thirty six french bean genotypes were evaluated in randomized complete block design with two replication in sector No. 1 under University of Horticultural Sciences, Bagalkot.

Analysis of variance revealed highly significant difference among genotypes for all 27 characters studied. Moderate genotypic and phenotypic coefficient of variations were observed for pod length, pod flesh thickness, number of pods per cluster, number of pods per plant, weight of ten pods and dry matter content of pods and roots. High heritability along with high genetic advance as per cent over mean was recorded for the plant height, pod width, number of pods per plant, average pod weight, yield per plant, number of root nodules per plant, dry matter content of pods, roots and protein content. These results indicated the presence of additive gene effects. Thus, there is an ample scope for improving these characters with direct selection.

Correlation studies revealed that total yield per plant was positively and significantly (p=0.01) associated with all the characters except days to first flowering, days to 50% flowering, days to first pod picking and pod width. Path analysis studies revealed high direct effects of number of clusters per plant, number of pods per cluster and weight of ten pods on total yield per plant.

Mahalonobis D^2 analysis grouped 36 genotypes into 5 clusters. The cluster I showed maximum intracluster distance and maximum intercluster distance was observed between cluster II and cluster V. Number of pods per plant contributed (27.46%) maximum to the total divergence followed by yield per plant and drymatter content of pods. Hybridization studies can be planned by involving genotypes belonging to cluster II and cluster V. The high yielding genotypes IIHR-62, Arka Arjun, IIHR-53, IIHR-232 and Arka Anoop are high yielders having desirable quality characters. Hence there need to be assessed further for stability before exploiting them for commercial cultivation.

wAU¼À CªgÀ¼ÉAiÀÄ (¥ÉÆ¹AiÀÄÆÃ®¸ï ªÀÄj¸ï) v½ÀU¼ÀªÀiÁ¤¸ÀªÀÄvÀÄ C£ÀÄªÀA²ÃPÀ ªÉÊ«zsÀåvÉAiÀÄ CzsÀåAiÀÄ£À

eÁ£À r. Dgï. **2016** **qÁ. ºÉZï. ©. ¥ÁnÃ®**
¥ÁæzsÁå¥ÀPÀgÀÄ

¸ÁgÁA±À

wAU¼À CªgÀAiÀÄ° (¥Ã¹AiÆÃ®¸ï ª®Äj¸ï) v½U¼ ªÀiÁ¤¸ ªÀÄvÀÄ C£ÀÄªÀA²ÃP ªÉÊ«zsÀvÀAiÀÄ CzsÀAiÀÄ£ª£ÀÄß 2015 g »AUÁgÀÄ ¯ÁvÀ«£° ¸Pgï £A. 1 vÆÃ¯UÁjP ªÀÄºÁ«zÁå®AiÀÄ ¨ÁU®PÆÃmAiÀÄ° PÈUÆ¼¯Á¬ÄvÀÄ. wAU¼ CªgÀAiÀÄ 36 v½U¼£ÀÄß JgqÀ ¥æÀPÁwU¼£ÁßV¹ AiiÁzÈaÒP ¥æÀÃ± «£Á¸z° F ¥æÀÆÃUª£ÀÄß £q¸¯Á¬ÄvÀÄ. ªÀiÁ¤¸z «±ÃµuAiÀÄ ¥ÀæÀg CzsÀAiÀÄ£ ªiÁrz 27 UÀt®PtU¼ ¥ÈQ J¯Á UÀt®PtU¼° UªÀÄ£ÁºÕ ªÀiÁ¤¸ PAqÀÄ§A¢z. C£ÀÄªA²ÃP ªÀÄvÀÄ ¥Àæ ®PtU¼ UÀuÁAPz ªÀiÁ¤¸z ªiË®åU¼ ¥ÀæÀg PÁ¬ÄAiÀÄ Gz, PÁ¬ÄAiÀÄ wgÀ½£ ¸Äv¼v, ¥æÀ UÆAZ°£ PÁ¬ÄU¼ ¸ASÉ, ¥æÀ Vqz PÁ¬ÄU¼ ¸ASÉ, 10 PÁ¬ÄU¼ vÆP, ¨ÃgÀ ªÀÄvÀÄ PÁ¬ÄAiÀÄ°gÀª ±Ã. Mt¥zÁxð ªÀÄzÀªÀÄ ªÀÄ¯z° EgÀªÀzjAz C£ÀÄªA²ÃAiÀÄ CzÁg ¸µªÁUÀvz. C£ÀÄªA²ÃAiÀÄ CzsÀAiÀÄ£z° ºa£ C£ÀÄªA²ÃAiÀÄ ¸ÁªÀxÀð ªÀÄvÀÄ ¸gÁ¸j C£ÀÄªA²ÃAiÀÄ ªÀÄÄAzÀªjPAiÀÄÄ PAqÀÄ§A¢z. GzÁºguU Vqz Jvg, PÁ¬ÄAiÀÄ CU®, ¥æÀ Vqz PÁ¬ÄU¼ ¸ASÉ, 10 PÁ¬ÄU¼ vÆP, Vqz M¯Ä E¼ÀÄªj, Vqz ¨Ãj£ UA¯ÄU¼ ¸ASÉ, PÁ¬ÄAiÀÄ°gÀª ±Ã. Mt¥zÁxð ªÀÄvÀÄ ¥ÇæÀ£ï CA±, F J¯Á UÀt®PtU¼ ºa£ G¥AiÆÃU ¥qAiÀÄ®Ä £Ãg DAiÀÄAiÀÄ DzÁgz° GvªÀÄ v½U¼£ÀÄß DAiÀÄ ªiÁq§ºÀzÁVz.

¨¼ªtU ªÀÄvÀÄ E¼ÀÄªj UÀt®PtU¼ £qÀ«£ ¥g¸g ¸A§Azz CzsÀAiÀÄ£z ¥ÀæÀg ¨ÃU ºÆ ©qÀªÀzÀ, ±Ã. 50 gµÀ ºÆ ©qÀªÀzÀ, ªÆz® PÁ¬ÄAiÀÄ PÆÃAiÀÄÄ ºÁUÆ PÁ¬ÄAiÀÄ CU® EªÀU¼£ÀÄß ºÆgvÀ ¥r¹ J® UÀt®PtU¼Ä ¥æÀ Vqz PÁ¬ÄAiÀÄ E¼ÀªjAiÆA¢U ¤¢ðµ z£ÁvP ¸ºAiÆÃUª£ÀÄß ºÆA¢ª. ªiÁUð «±ÃµuAiÀÄ ¥°vÁA±z ¥ÀæÀg ¥æÀ Vqz UÆAZ°£ ¸ASÉ, ¥æÀ UÆAZ°£ PÁ¬ÄU¼ ¸ASÉ ªÀÄvÀÄ 10 PÁ¬ÄU¼ vÆP,Vqz M¯Ä E¼ÀªjAiÀÄ ªÀÄÃ¯ C¥ÃPtÃAiÀÄ z£ÁvP ªÀÄvÀÄ £Ãg ¥juÁªÀÄ ºÆA¢ª JAzÀ zÈq¥nz.

ªÀÄº®£ÆÃ©¸ï r^2 «±ÃµuAiÀÄ£ÀÄß C£À¸j¹ 36 wAU¼ Cªg v½U¼£ÀÄß 5 UÀA¥ÄU¼£ÁßV «AUr¸¯Á¬ÄvÀÄ. Ujµ DAvjP UÀA¥ÄU¼ zÆgªÀ MAz£Ã UÀA¦£° PAqÀÄ§Azg, ¥g¸g UÀA¦£ CAvg CwÃ ºZÁV 2 ªÀÄvÀÄ 5 g £qÀª PAqÀÄ§A¢z. ¥æÀ Vqz PÁ¬ÄU¼ ¸ASÉAiÀÄ PÆqÀÄUAiÀÄÄ (27.46 %) MmÁg C£ÀÄªA²ÃP ªÉÊ«zsÀvÀAiÀÄ UjµªÁVzÀÄ £Avgz ¸ÁÜ£z° Vqz M¯Ä E¼ÀÄªj (10.97 %) ªÀÄvÀÄ PÁ¬ÄAiÀÄ°gÀª ±Ã. Mt¥zÁxð (10.67 %) EgÀªÀzÀ PAqÀÄ§gÁvz. 2 ªÀÄvÀÄ 5 £ÃAiÀÄ UÀA¦£ v½U¼£ÀÄß ¸AQÃtð CzsÀAiÀÄ£PÁV §¼¸§ºÀzÀ.

¥ÇæÀv CzsÀAiÀÄ£z° wAU¼ Cªg v½U¼Áz LLºZgï-62, LLºZgï-53, LLºZgï-232, CPÁð Cd¹ð£ï ªÀÄvÀÄ CPÁð C£Æ¥ï EªÀU¼£ÀÄß ºZÀ E¼ÀÄªj ¤ÃqÀª ªÀÄvÀÄ GvªÀÄ UÀtªÀÄ¯z v½U¼ÁV UÄgÀw¸¯ÁVz. F v½U¼£ÀÄß ªÁtdå PÈ¶UÁV §¼¹PÆ¼ÀÄª ªÆz®Ä v½U¼ "¹gvAiÀÄ CzsÀAiÀÄ£ " PÈUÆ¼ÀÄªÀzÀ Cª±ÀP.