Assessment of genetic variability in Indian bean (*Lablab purpureus* L.)

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Thesis

Master of Science in Agriculture

(Horticulture)

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Department of Horticulture

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Dated / /2011

This is to certify that **Mr. Rajneesh Kumar Sharma** has successfully completed the comprehensive examination held on July 08, 2011 as required by the regulation for degree of **Master of Science in Agriculture (Horticulture).**

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This is to certify that the thesis entitled **"Assessment of genetic variability in Indian bean (*Lablab purpureus* L.)"** submitted for the degree of **Master of Science in Agriculture** in the subject of **Horticulture**, embodies bonafied research work carried out by **Mr. Rajneesh Kumar Sharma** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on / /2011.

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This is to certify that the thesis entitled **"Assessment of genetic variability in Indian bean (*Lablab purpureus* L.)"** submitted by **Mr. Rajneesh kumar Sharma** to the Maharana Pratap University of Agriculture and Technology, Udaipur in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** in the subject of **Horticulture** after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination on his thesis has been found satisfactory; we therefore, recommended that the thesis should be approved.

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This is to certify that **Mr. Rajneeesh Kumar sharma** of the Department of **Horticulture,** Rajasthan College of Agriculture, Udaipur has made all corrections and modifications in the thesis entitled **"Assessment of genetic variability in Indian bean (*Lablab purpureus* L.)"** which were suggested by the external examiner and the advisory committee in the oral examination held on /07/2011. The final copies of the thesis duly bound and corrected were submitted on / /2011 are enclosed here with for approval.

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Assessment of genetic variability in Indian bean (*Lablab purpureus* L.)

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ABSTRACT

The present investigation was carried out to estimate genetic variability, character association and path coefficient analysis among 16 genotypes of Indian beans for pod yield per vine and its contributing characters. These genotypes were planted in Randomized Block Design with six replications during *kharif* season 2010-11 at Instructional Farm, Department of Horticulture, Rajasthan College of Agriculture, Udaipur.

Analysis of variance indicated presence of considerable variability for all the 14 characters. High GCV and PCV were recorded for pod yield per vine, average pod weight and leaf area. High estimates of heritability along with high genetic advance as per cent of mean were observed for pod yield per vine and pod width. Therefore, these characters can aid in selection programme.

The results from character association indicated that pod yield per vine had significant and positive correlation with stem diameter, number of branches per vine, average pod weight and number of pods per vine at both the levels. Path coefficient analysis revealed that characters *viz*., average pod weight, number of pods per vine, days to 50% flowering, number of flowers per cluster, days to maturity, number of pods per clusters, stem diameter and pod length had positive direct effect on pod yield per vine. Number of pods per vine, average pod weight, days to maturity and number of flowers per clusters showed high and positive indirect effect towards pod yield per vine.

On the basis of mean performance the genotypes DL-14, DL-8, DL-2 and DL-12 were found superior in terms of high mean values of pod yield per vine. These genotypes may further be utilized in breeding programme aimed at improving pod yield per vine in Indian bean. All those characters which showed positive direct effect towards yield proved effective in enhancing productivity level in Indian bean.

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1. INTRODUCTION

India is the second largest producer of vegetable in world, next to China with an annual production estimate around 133.73 million tons from 7.98 million hectare and productivity is 16.7 metric tons (Anon., 2010). The per capita availability of vegetable is around 112 g per day in contrast to recommendation of 300 g per day per head by dietician. Even this low level does not fully reflect the consumption pattern of vegetable in rural household where it may be 70-80 g per day. This may be because of insufficient production of vegetable. Since the demand of vegetable in India has been increasing with population, increasing in awareness of importance of vegetable and rise in standard of living. Thus the foremost objective to the agricultural scientist is to bred crop varieties or strains having higher yield potential, both in term of quality and quantity.

Indian bean (*Lablab purpureus* L.) is an important ancient pulse crop among cultivated plants in the western countries, so it is called Bonavest. As most of the species of Indian bean are endemic to Africa and only few are native of India, most probably Africa is the main centre and India is the secondary centre of origin of Indian bean (Dana, 1976). It belongs to the group Dicotyledons, class- Polypetalae, series- Calyciflorae, order-Rosales, Family- Leguminosae of papilionoideae sub family with chromosome number 2n= 22. There are two cultivated types of Indian bean viz., typicus and lignosus (Shivashankar et al. 1977). Typicus is a garden type and cultivated for its soft and edible pods. Lignosus is known as field bean and mainly cultivated for dry seed as a pulse. There are also many common names almost every country (indeed every province in India) uses a different one. Among these are Chink, Egyptian bean, Lablab bean, Dolichos bean, Field bean, Labia bean, and more popularly recognized as hyacinth bean, avasai in South India and sem in North India.

The immature fresh green pods are used for vegetable purpose, whereas ripe and dried seeds are consumed as split pulse. Among fresh legume vegetables it is very nutritive, being a good source of digestible protein (3.8 g $100g^{-1}$ of edible portion). Besides this, it also contains fairly good amount of carbohydrates (6.7 g $100g^{-1}$), vitamins [vitamin-A (312 I.U.) and Riboflavin (0.06 mg $100g^{-1}$)] and minerals (calcium (210 mg $100g^{-1}$) and phosphorus (68 mg $100g^{-1}$). While the mature seeds contains approximate 24.9 per cent protein, 67 per cent carbohydrate, 1.4 per cent fiber, 0.8 percent fat, 0.06 per cent calcium having 340 calories per 100 g of edible portion (Key, 1975). Being a rich source of proteins and other nutrients, it is also known as ‘poor man’s meat. Dried seeds can be processed to make bean cake and protein concentrates. The amino acid composition of dried seeds is moderately well balanced with high lysine content (6.1 per cent).

In addition to high nutritional value, pulses are endowed with unique property of maintaining and restoring soil fertility through biological nitrogen fixation as well as conserving and improving physical property of soil by addition of organic matter by the leaf drop towards maturity and their deep root system. Indian bean fodder is palatable and the cattle are nourished well. Incorporating this crop in to pastures improves the quality, palatability and digestibility of pastures. This crop can be used as an excellent green manure, as a nitrogen fixing crop, as a cover crop for effective control of soil erosion and soil protection.

Indian bean is found growing throughout the tropics and subtropics as minor pulse crop. Although it has been grown since, ancient times in many countries viz., Africa, India, Australia, Egypt, Uganda, Switzerland, Burma, Argentina, Mexico, Brazil, Colombia, Venezuela, Zambia and Sudan. Within India Lablab as a field crop mostly confined to the peninsular region and cultivated to a large extent in Karnataka and adjoining districts of Tamil Nadu, Andhra Pradesh and Maharashtra. Karnataka contributes a major share, accounting for nearly ninety per cent in terms of both area and production in the country.

In Rajasthan there is not a single known variety/cultivar which has occupied large area. Only local types, traditional farmer collections and cultivars are being cultivated. The crop prefers relatively cool seasons with sowing done in July-August. It starts fruiting in winter and continues indeterminately in spring. This crop can be grown on a wide variety of soil ranging from acid to alkaline soil (pH 4.4-7.8). It does particularly well on sandy loams. It is a hardy, quite drought tolerant and suitable for growing as rainfed crop. It requires adequate moisture during the early stage of growth.

Pulses are indispensable sources of proteins for predominantly vegetarian population of our country and they constitute a major part in our daily diet. Since the domestication and cultivation of crop plants, the staple food crops have received more attention than other food crops like pulses. Although pulses are being ceaselessly grown under marginal lands of low fertility level and moisture stress conditions, the natural selection process that has been occurring through ages made these genotypes more adaptable to poor management which registers limitations on their yield as compared to that of cereals. This however, does not reflect low genetic potential of pulses because there is an evidence to indicate that pulses may have even higher genetic potential for yield than cereals (Jain, 1975). Poor yield potentiality of Indian bean may be due to the genotypes adapted to poor management practices as it was constantly grown under marginal lands, residual moisture or stress condition by the farmers.

Average yield of Indian bean is very low and year to year variation in yield is also remarkably high. Therefore, the major objectives of present breeding programme should be to enhance the productivity and stabilize the yield performance. This is possible only, when there is high genetic potential for yield and greater degree of adaptability. Although, research the outstanding qualities of this crop has drawn the attention of pulse breeder recently. Therefore, there is an ample scope for improvement in this crop. In spite of its high nutritional and high agronomical values for poor man and poor farmers, Indian bean was not given due place in pulses, rather, it was neglected in worlds scenario and data. As this crop is under exploited, there is an immense need to start a planned genetic research/breeding work to have varieties for sole cropping, inter cropping, relay cropping systems and adopted to high and low management practices.

It has also been implicated that lack of variability is one of the main factors responsible for the poor progress made in breeding programmes of pulse crops. At the same time, among the pulses lablab bean has received less attention. Only few reports of genetic studies on some quantitative characters are available (Singh, 1984). Assessment of variations made on truly diverse germplasm provides an idea about the extent of genetic variation. Greater the genetic variability better the chances of improvement. If heritability is high and genetic advance is more, possibility of improvement is higher. But for yield and quality which are complex polygenic characters, direct selection would not be a reliable approach on account of being highly influenced by environmental factors. As such efforts may be concentrated on the selection of some characters which ultimately contribute towards yield. Therefore, it becomes very essential to find out yield contributing traits, their variability parameters and multiple regressions. Unfortunately, negligible work has been done on variability study of Indian bean in this agro climatic conditions in spite of the fact that lot of variability exist in this region which can be utilized for improving pod yield coupled with high nutritive value.

Keeping all these in view the present investigation “Assessment of genetic variability in Indian bean (*Lablab purpureus* L.)” among 16 genotypes were carried out with following objectives:

- To determine the variability for yield and yield traits.
- To find out the various component of pod yield and their degree of association in terms of genotypic and phenotypic correlation coefficient.
- To determine the direct and indirect effect of characters related to yield.

3. MATERIALS AND METHODS

The present investigation entitled "Assessment of genetic variability in Indian bean (*Lablab purpureus* L.)" was carried out at Horticulture Farm, Department of Horticulture, Rajasthan College of Agriculture, Udaipur from July 2010 to January 2011. The details of the techniques followed and materials used during the course of investigation are described in this chapter under suitable heads.

3.1 Experimental Site:

The experiment was laid out at Horticulture Farm, Department of Horticulture, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur which is situated at South Eastern part of Rajasthan. This region falls under agro-climatic zone IVa "Sub-humid Southern Plain and Aravalli Hills of Rajasthan'' at an altitude of 582.17 meter above mean sea level, at 24º35' N latitude and 74°42' E longitude.

3.2 Climatic Condition:

This region has a typical sub-tropical climate, characterized by mild winters and summers. The average rainfall of this tract ranges from 592.5 mm to 620 mm per year. More than 90 per cent of rainfall is received during mid-June to September with scanty showers during winter season. Data recorded for mean weekly weather parameters during the period of field experimentation have been presented in Table 3.1 and Fig.3.1.

3.3 Experimental material:

The experimental material for the present investigation consisted of sixteen genotypes of Indian bean *viz.*, DL-1, DL-2, DL-3, DL-4, DL-5, DL-6, DL-7, DL-8, DL-9, DL-10, DL-11, DL-12, DL-13, DL-14, DL-15 and Konkan Bhusan. All DL (Dungarpur Local) strains were provided by KVK Dungarpur (Raj.) which were collected from local farmers of different places and Konkan Bhusan cultivar released from Konkan Krishi Vidhyapeeth, Dharwad during 1993.

Table 3.1: Meteorological observations during experiment (July 2010 to January 2011)

Date	Week No	Temperature (^{0}C)		R.H. (%)		Rain	Evap.
		Max.	Min.	I	II	(mm)	(mm)
2 July - 8 July	27	33.3	24.1	84	65	120.0	4.9
9 July - 15 July	28	32.1	25.4	80	62	0.0	5.4
16 July - 22July	29	33.0	24.9	88	71	87.2	4.5
23 July - 29 July	30	28.7	23.5	93	84	113.9	2.4
30 July - 5Aug	31	30.3	23.4	91.4	74.7	154.8	3.4
6 Aug.- 12 Aug.	32	29.5	23.9	92.3	83.0	69.2	2.5
13 Aug.- 19 Aug.	33	30.8	24.0	92.7	75.9	16.5	2.7
20 Aug.- 26 Aug.	34	30.8	23.6	86.0	66.1	27.2	3.2
27 Aug.- 2 Sept.	35	31.0	23.3	92.6	79.3	55.7	2.3
3 Sept. - 9 Sept.	36	30.4	23.2	93.4	81.7	100.3	2.6
10 Sept.- 16 Sept.	37	28.8	22.8	91.6	77.6	13.2	2.4
17 Sept. - 23 Sept.	38	32.1	18.5	81.9	39.4	0.0	4.7
24 Sept.- 30 Sept.	39	32.8	18.4	77.6	32.4	0.0	4.4
1 Oct. - 7 Oct.	40	34.5	18.3	76.1	29.3	0.0	4.9
8 Oct.- 14 Oct.	41	33.9	17.7	77.1	31.0	0.0	4.2
15 Oct.- 21 Oct.	42	33.7	19.6	74.9	38.2	0.0	4.6
22 Oct.- 28 Oct.	43	33.7	17.1	69.7	39.0	0.0	3.9
29 Oct.- 4 Nov.	44	31.1	14.8	73.7	50.9	0.0	3.7
5 Nov.- 11 Nov.	45	29.9	16.6	77.7	68.6	2.8	3.2
12 Nov.- 18 Nov.	46	29.2	19.1	90.9	75.9	37.4	2.0
19 Nov.- 25 Nov.	47	23.6	13.6	88.4	72.3	37.4	1.2
26 Nov.- 2 Dec.	48	26.0	13.2	90.6	59.3	0.0	1.7
3 Dec.- 9 Dec.	49	24.1	8.4	89.9	66.9	0.0	2.1
10 Dec.- 16 Dec.	50	24.0	5.7	88.1	78.0	0.0	1.8
17 Dec.- 23 Dec.	51	25.9	5.0	87.9	33.6	0.0	2.1
24 Dec.- 30 Dec.	52	24.9	9.2	86.9	41.8	2.4	1.9
31 Dec. - 6 Jan.	1	23.3	3.1	87.7	`30.6	0.0	2.2
7 Jan. - 13 Jan.	2	25.8	4.8	82.6	21.4	0.0	2.5
14 Jan.- 20 Jan.	3	26.2	5.2	77.3	23.6	0.0	2.5
21 Jan.- 27 Jan.	4	26.8	7.7	84.0	36.0	0.0	2.6

Source: Agromet observatory, Instructional Farm, Department of Agronomy, RCA, Udaipur.

3.4 Experimental Design:

The experiment was laid out in Randomized Block Design with six replications. Randomization of lines was done with the help of random number table as advocated by Fisher (1954). Each entry was planted at a spacing of 2.5 m row to row and 1.5 m plant to plant respectively. Seeds were sown on 25 July 2010. For healthy crop appropriate standard and uniform agronomical /cultural practices and timely plant protection measures were followed.

3.5 Observations:

The observations for following characters were recorded on all the plants and detailed procedures adopted for recording the observations are given as under

A. Vegetative parameters/Morphological traits:-

(i) **Vine length (cm) :** Length of main shoot was measured in centimeter from the base of the vine to tip of main shoot at the time of maturity.

(ii) **Leaf area (cm^2):** Ten leaves were randomly selected from each vine and area was measured with the help of leaf area meter and the average leaf area in sq cm was calculated.

(iii) **Stem diameter (cm):** Stem diameter was measured with the help of "Vernier caliper" at the height of five centimeter above ground level in centimeter.

(iv) **Number of branches per vine:** Total number of branches emerged from the axis of the main stem of individual vine were counted at the last picking.

(v) **Number of flowers per cluster:** Randomly five clusters were selected for each vine and recorded average number of flowers per cluster.

(vi) **Days to 50% flowering:** The number of days from the date of sowing to the date of appearance of 50 per cent flowers in the vine was recorded.

(vii) **Fruit set (%):** Per cent fruit set was calculated by dividing total number of flowers borne on a vine by number of actual fruits harvested on that vine and finally multiplied by 100.

(viii) **Days to maturity:** The number of days from the date of sowing to the date on which edible pods were ready for harvest (Horticulture maturity) was taken as days to maturity.

B. Yield and yield contributing parameters:

(i) **Pod length (cm):** Pod length was recorded in five randomly selected green pods in each vine at edible stage. It was measured in centimeter from the base to the tip of the pod with the help of measuring scale.

(ii) **Pod width (cm):** Five green pods selected randomly in each vine and the width measured using measuring scale and recorded the average width in centimeter.

(iii) **Average pod weight (g)** The pods were weighed by physical balance and average pod weight was measured by taking an average of five randomly selected pods for each vine.

(iv) **Number of pods per vine:** The cumulative number of green pods of all the pickings were counted and recorded as number of pods per vine.

(v) **Number of pods per cluster:** Randomly five clusters were selected for each vine and recorded average number of pods per cluster**.**

(vi) **Pod yield per vine (kg):** This observation was recorded by weighing green marketable pods of individual vine of each picking and then sum of all pickings were considered as yield per vine.

3.6 Statistical Methodology:

Mean value of the data were subjected to statistical analysis as per detail given below:

3.6.1 Analysis of variance:

To test the variation among the genotypes, analysis of the variance was carried out as per the method suggested by Panse and Sukhatme (1978).

Skeleton of ANOVA

Source	**d.f.**	**S.S**	**M.S.**	**Expected M.S.**
Replication	r-1	a	a’	
Genotype	g-1	b	b’	$\sigma^2 + r\,\sigma^2 g$
Error	(r-1)(g-1)	c	c’	σ^2
Total	(rg-1)			

Standard error of difference between genotype means was calculated as:

$$SE_d = \sqrt{\frac{2EMS}{r}} = \sqrt{\frac{2c'}{r}}$$

Where,

g = number of genotypes

r = number of replication

Coefficient of variation was calculated as

$$CV = \frac{\sqrt{EMS}}{\overline{X}} \times 100$$

Where,

CV = Coefficient of variation $\overline{X}$ = Population mean

3.6.2 Estimation of variability parameters:

3.6.2.1 Genetic variance: It is the variance contributed by genetic causes or the genetic occurrence of difference among the individuals due to their genetic makeup. It was calculated by using the formula.

$$Vg = \frac{MSV - V_E}{r} = \frac{b' - c'}{r}$$

Where,

Vg = Genotypic variance,

MSV = mean square for varieties,

V_E = Error mean square and

r = Number of replication

3.6.2.2 Phenotypic variance: It is the sum of variance contributed by genetic causes and environmental factors and was computed as:

Vp = Vg + Ve = Vg + C’

Where,

Vp = Phenotypic variance,

Vg = Genotypic variance and

Ve = Error variance.

3.6.2.3 Genotypic coefficient of variation (GCV): The magnitude of genetic variation existing in a character was estimated by the formula given by Burton (1952).

$$GCV = \frac{\sqrt{V_g}}{\overline{X}} \times 100$$

Where,

Vg = Genotypic variance and

$\overline{X}$ = General mean of the character under study.

3.6.2.4 Phenotypic coefficient of variation (PCV): The magnitude of phenotypic variation existing in a character was estimated by the formula given by Burton (1952).

$$PCV = \frac{\sqrt{V_p}}{\overline{X}} \times 100$$

Where,

Vp = Phenotypic variance and

$\overline{X}$ = General mean of the character under study.

3.6.2.5 Heritability: Heritability in the broad sense was calculated by the formula given by Burton and Devane (1953).

$$H = \frac{V_g}{V_p} \times 100$$

Where,

H = Heritability (Broad sense)

Vg = Genotypic variance and

Vp = Phenotypic variance.

3.6.2.6 Expected genetic advance: It was measured by formula proposed by Lush (1949).

$$GA = \frac{V_g}{V_p} x \sqrt{V_p}\, x K$$

$$= \frac{V_g}{\sqrt{V_P}} \times K$$

Where,

GA = Genetic advance,

Vg = Genotypic variance,

Vp = Phenotypic variance and

K = Selection differential (constant) i.e. 2.06 at 5% selection intensity (Allard, 1960).

3.6.2.7 Genetic gain: It was calculated by using the following formula suggested by Johnson *et al* (1955).

$$\text{Genetic gain} = \frac{GA}{\overline{X}} \times 100$$

Where,

GA = Genetic advance and

$\overline{X}$ = General mean of the character under study.

3.6.3 Association analysis:

Simple correlation coefficient value (r) was calculated by using the following formula suggested by Singh and Choudhary (1977).

$$r = \frac{Cov(xy)\sqrt{V_g}}{\sqrt{V(x)V(y)}}$$

Where, x and y are two characters under consideration.

Genotypic and phenotypic correlation coefficients were calculated using the genotypic and phenotypic variance (Vg and Vp) and covariance (CoVg and CoVp) in the formula suggested by Fisher (1954) and Al-Jibouri *et al* (1958).

3.6.3.1 Genotypic correlation coefficient :

$$r(xy)_{(g)} = \frac{Cov(xy)_{(g)}}{\sqrt{Vx_{(g)}Vy_{(g)}}}$$

3.6.3.2 Phenotypic correlation coefficient :

$$r(xy)_{(p)} = \frac{Cov(xy)_{(p)}}{\sqrt{Vx_{(g)}Vy_{(p)}}}$$

Where,

$r(xy)_{(g)}$ = Genotypic correlation coefficient between a pair of characters *viz*. x and y.

$r(xy)_{(p)}$ = Phenotypic correlation coefficient between a pair of characters *viz*. x and y.

$Cov.(xy)_{(g)}$ = Genotypic covariance for a pair of character viz. x and y.

$Cov.(xy)_{(p)}$ = Phenotypic covariance for a pair of character viz. x and y.

$V_{x(g)}$ = Genotypic variance for character x.

$V_{y(g)}$ = Genotypic variance for character y.

$V_{x(p)}$ = Phenotypic variance for character x.

$V_{y(p)}$ = Phenotypic variance for character y.

The significance of correlation was tested using the formula

$$t = \frac{r}{\sqrt{1-r^2}} X \sqrt{n-2}$$

Where,

r = Correlation coefficient and

n = Total number of observations.

The calculated values of ‘t’ were tested against the table values of ‘t’ with (n-2) d.f. at 5 and 1% levels of significance.

3.6.4 Path coefficient analysis:

Path coefficient can be defined as the ratio of the standard deviation of the effect due to given cause to the total standard deviation of the effect. The direct and indirect effects were estimated through path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959). The following equations were solved for estimating the various direct and indirect effects.

$$r_{1y} = P_{1y} + r_{12}P_{2y} + \ldots\ldots\ldots\ldots + r_{1p}P_{py}$$

$$r_{2y} = r_{21}P_{1y} + P_{2y} + \ldots\ldots\ldots\ldots + r_{2p}P_{py}$$

………………………………………….

………………………………………….

$$R_{py} = r_{p1}P_{1y} + r_{p2}P_{2y} + \ldots\ldots\ldots\ldots + P_{py}$$

Where,

P_{1y}, P_{2y}……………P_{py} are direct effect of character 1,2, ………..p on y and r_{1y}, r_{2y}…………r_{py} denotes correlation coefficient between independent characters 1,2……..p and dependent character 'Y'.

Residual effect was calculated using the following formula:

$$1 = P2Rg + \Sigma P_{iy}R_{iy}$$

$$P_{Ry} = \sqrt{1- (P_{1y}r_{1y}) - (P_{2y}r_{2y})\ldots\ldots\ldots\ldots\ldots(P_{iy}r_{iy})}$$

Where, P_{Ry} is the residual effect

Y is the yield

4. EXPERIMENTAL RESULTS

The present investigation, "Assessment of genetic variability in Indian bean (*Lablab purpureus* L.)" was carried out on 16 genotypes of Indian bean. These genotypes were evaluated in a Randomized Block Design (RBD) with six replications during *Kharif* season, 2010-11 at Horticulture Farm, Department of Horticulture, Rajasthan College of Agriculture, Udaipur. The results obtained on various aspects are presented under the following sub heads:

4.1 Analysis of variance

4.2 Range and mean

4.3 Variability

4.4 Heritability and genetic advance

4.5 Correlation coefficient

4.6 Path coefficient analysis

4.1 ANALYSIS OF VARIANCE

The analysis of variance was carried out for each of the observed characters separately to know the extent of variation of genotypes. Analysis of variance has been presented in Table 4.1. Analysis of variance indicated significant differences among genotypes for all the characters indicating a good deal of variability in the material used. The coefficient of variation which expresses experimental error as a percentage of mean varied from 2.59 for days to maturity to 10.89 percent for pod yield per vine (Table 4.2)

4.2 RANGE AND MEAN

Mean performance of all the genotypes has been presented in Table 4.2. Mean performance and range of different characters exhibited by the genotypes has been presented in Table 4.3. Performance with respect to individual character has been presented as below:

4.2.1 Vine length (cm)

On the basis of mean performance the DL-9 exhibited minimum vine length (257.50 cm) and DL-13 gave maximum vine length (340.00 cm) followed by DL-8 (336.67 cm) and

DL-10 (321.67 cm). The mean value for vine length was 296.04 cm. It ranged from 257.50 to 340.00 cm.

4.2.2 Leaf area (cm2)

On the basis of mean performance, the minimum leaf area was exhibited in genotypes DL-10 (54.00 cm2) and maximum leaf area was observed in DL-1 (115.17 cm2) followed by DL-3 (109.83 cm2) and DL-7 (97.50 cm2). The mean value for leaf area was 78.00 cm2 with the range of 54.00 to 115.17 cm2.

4.2.3 Stem diameter (cm)

The mean values for stem diameter was 11.46 cm and ranged from 10.37 cm (DL-9) to 12.52 cm (DL-13). The maximum diameter of stem was observed for DL-13 (12.52 cm) followed by DL-3 (12.47cm) and DL-5 (12.32 cm).

4.2.4 Number of branches per vine

On the basis of mean performance, the minimum branches was exhibited in genotypes DL-9 (19.17) and maximum branching was observed in DL-3 (27.17) followed by DL-14 (25.67) and DL-11 (24.83). The mean value for number of branches per plant was 22.65 with the range of 19.17 to 27.17.

4.2.5 Number of flowers per cluster

The mean values for number of flowers per cluster was 8.43 and it ranged from 6.50 (DL-9) to 10.67 (DL-12). The maximum number of pods per cluster were observed in DL-12 (10.67) followed by DL-1 (10.17) and Konkan Bhusan (9.83).

4.2.6 Days to 50 per cent flowering

On the basis of mean performance the DL-4 was earliest in flowering (42.33 days) followed by DL-5 (44.00 days) and DL-12 (45.67 days), while DL-9 took maximum number of days to 50 per cent flowering (64.83 days). The mean value for days to 50 per cent flowering was 53.43 days. It ranged from 42.33 to 64.83 days.

4.2.7 Fruit set (%)

Fruit set (%) varied from 48.39 to 61.98 per cent. The highest fruit set was recorded in DL-9 (61.98%) followed by DL-3 (56.61%) and DL-14 (55.82%). The lowest fruit set was recorded in DL-10 (48.39%). The mean value for fruit set was recorded per cent.

4.2.8 Days to maturity

It was observed that, on the basis of mean performance, the genotype DL-4 was earliest in maturity (77.17 days), while the genotype DL-8 matured in the last (107.33 days). The mean value for days to maturity was 92.03 days. It ranged from 77.17 to 107.33 days.

4.2.9 Pod length (cm)

Length of pod ranged from 5.04 to 6.11 cm on the basis of mean performance. The mean was 5.53 cm. The high mean performance was observed for DL-5 (6.11 cm) followed by DL-8 (6.03 cm), the lowest being observed for DL-13 (5.04 cm).

4.2.10 Pod width (cm)

The mean value for pod width was 1.70 cm. It ranged from 1.03 to 1.96 cm. On the basis of mean performance, the DL-8 genotype was found to be maximum pod width (1.96 cm) followed by DL-15 (1.95 cm) DL-7 (1.92 cm) and Konkan Bhusan (1.91 cm). DL-1 was found to be lowest width of pod (1.03 cm) among all the 16 genotypes.

4.2.11 Average pod weight (g)

Pod weight ranged from 5.23 g to 14.35 g and mean was 10.34 g for this character. Pod weight was highest for DL-14 (14.35 g) followed by DL-3 (14.21 g) and DL-2 (13.57 g), the lowest being for DL-8 (5.23 g).

4.2.12 Number of pods per vine

The range for number of pods per vine was 53.37 to 94.15. The mean for this character was 76.71. The maximum number of pods per vine was observed for genotype DL-9 (94.15) followed by DL-10 (93.69) and DL-11 (89.52). The minimum number of pods per vine was observed for DL-5 (53.37).

4.2.13 Number of pods per cluster

The mean values for number of pods per cluster was 9.55 and it ranged from 7.1 (DL-1) to 12.15 (DL-8). The maximum number of pods per cluster were observed in DL-8 (12.15) followed by DL-9 (11.17) and DL-6 (10.97). The minimum number of pods per cluster was observed for DL-1 (7.1).

4.2.14 Pod yield per vine (Kg)

The range for pod yield per vine was 0.40 to 1.07 Kg. The mean was 0.80 Kg. Maximum yield per plant were observed from the genotype DL-14 (1.07 kg) followed by DL-2 (0.96 kg), DL-8 (0.96 kg) and DL-12 (0.92 kg), while minimum in DL-1 (0.40 kg)

4.3 GENETIC PARAMETERS OF VARIATION

4.3.1 Phenotypic and genotypic coefficients of variance

Phenotypic and genotypic coefficients of variation were estimated for all the characters and have been presented in Table 4.3. The phenotypic coefficient of variance was higher in magnitude than the respective genotypic coefficient of variance for all the characters. The phenotypic coefficients of variance estimates were generally higher than genotypic coefficient of variance estimates indicating positive effect of environment on character expression. The differences between genotypic coefficient of variance and phenotypic coefficient of variance estimates were negligible for leaf area, days to 50% flowering, number of flowers per cluster, days to maturity and average pod weight while the difference was high for rest of the characters.

The highest (27.13) genotypic coefficient of variation was recorded for yield per vine. The other characters which showed high genotypic coefficient of variation (>20 %) were average pod weight (27.08%) and leaf area (23.16%). The estimates of genotypic coefficient of variance were moderate (10-20%) for width of pod (18.97%), number of pods per vine (14.65%), number of pods per cluster (14.60%), number of flowers per cluster (14.03%) and days to 50% flowering (13.64%). The low genotypic coefficient of variance was recorded for number of branches per vine (9.65%), days to maturity (9.26%), vine length (8.15%), fruit set (5.70%), stem diameter (5.19%) and pod length (4.99%). The highest phenotypic coefficient of variance was recorded for pod yield per vine (29.23%). High estimates of phenotypic coefficient of variation (> 20 %) were recorded for average pod weight (28.41%), leaf area (24.66%) and pod width (20.95%). The estimates were moderate (10-20%) for number of pods per cluster (16.26%), number of pods per vine (16.21%), number of flowers per cluster (15.88%), days to 50% flowering (13.99%), vine length (11.91% and number of branches per vine (11.18%). The characters stem diameter (9.88%), pod length (9.89%), fruit set (9.63%) and days to maturity (9.62%) recorded the low phenotypic coefficients of variation.

4.3.2 Heritability

Wide range (25.51 to 95.04%) heritability was observed for all the characters (Table 4.3). High heritability (>80%) estimates were recorded for days to 50% flowering (95.04%), days to maturity (92.75%), average pod weight (90.85%), leaf area (88.21%), pod yield per vine (86.12%), pod width (82.05%), number of pods per vine (81.71%) and number of pods per cluster (80.60%). Moderate heritability (50-80 %) was recorded for number of flowers per cluster (78.01%) and number of branches per vine (74.43%). Whereas, low estimates were recorded in case of vine length (46.88 %), fruit set (35.03%), stem diameter (27.61%) and pod length (25.51%).

4.3.3 Genetic advance and genetic advance as percent of mean

Genetic advance was estimated for all the characters (Table 4.3). The comparison of genetic advance for various characters is not meaningful, as it is not free of unit of measurement. Therefore, genetic advance as percent of mean was estimated for all the characters so that comparison of the response to selection can be made among the various characters. The highest genetic advance (%) was recorded for pod yield per vine (83.16%). The estimates were also high (>25%) for pod width (45.65%). The estimates were moderate (10-25%) for number of flowers per cluster (17.40%), average pod weight (22.68%) and number of pods per cluster (16.82%). The numerical value of this parameter were low (<10 %) for pod length (9.69%), number of branches per vine (8.70%), leaf area (7.58%), days to 50% flowering (7.16%), stem diameter (7.00%), number of pods per vine (5.96%), days to maturity (4.47%), fruit set (3.61%) and vine length (1.97%). The lowest (1.97%) genetic advance was recorded in case of vine length

4.4 CHARACTER ASSOCIATION ANALYSIS

The correlations between all possible combinations among the characters were calculated at phenotypic and genotypic level and are presented in Table 4.4. Perusal of the table indicated that the magnitude of genotypic correlation coefficient was higher for most of the character pairs than their respective values of phenotypic correlation coefficient, which may be ascribed to the low effect of environment on the character expression. The differences in the magnitude and direction of correlation coefficient between phenotypic and genotypic level was negligible for most of the characters but some correlation coefficient association value was not in same direction at phenotypic and genotypic level. These values were vine length associated with number of flower per cluster (-0.097 and 0.094), stem diameter with pod length (0.11 and -0.252*), number of flowers per cluster (-0.06 and 0.041) with fruit set (%), days to 50% flowering with pod yield per vine (0.169 and -0.178), pod length (-0.024 and 0.097) with pod width, and pod width (0.03 and -0.001) with number of pods per cluster at phenotypic and genotypic level, respectively. The degree of association was quantified on the basis of phenotypic and genotypic correlation coefficient.

4.4.1 Pod yield per vine

Pod yield per vine which was the most important characters under present investigation, was found to have significant positive correlation with number of branches per vine (rp=0.292** and rg=0.407**), average pod weight (rp=0.798** and rg=0.875**) and number of pods per vine (rp=0.313** and rg=0.319**) at phenotypic level and genotypic level, respectively. Pod yield per vine was positively correlated with pod width but did not reach the level of significance. Pod yield per vine exhibited significant positive correlation with stem diameter (rg=0.299**) at genotypic level. Vine length (rp=-0.11 and rg=-0.158), leaf area (rp=-0.032 and rg=-0.015), number of flowers per cluster (rp=-0.131 and rg=-0.168), fruit set (rp=-0.024 and rg=-0.056), days to maturity (rp=-0.305** and rg=-0.348**), pod length (rp=-0.230 and rg=-0.583**) and number of pods per cluster (rp=-0.042 and rg=-0.074) were negatively correlated with yield per vine but only days to maturity reached the level of significance at both phenotypic level and genotypic level while pod length reached the level of significance at genotypic level.

4.4.2 Vine length

Vine length showed positive and highly significant correlation with width of pod (rp=0.396** and rg=0.565**) at both phenotypic level and genotypic level, respectively while stem diameter (rp=0.167 and rg=0.342**), days to 50% flowering (rp=0.191 and rg=0.318**), days to maturity (rp=0.114 and rg=0.244*) and number of pods per cluster (rp=0.184 and rg=0.323**) showed positive and significant correlation with vine length at genotypic level only. The correlation of this character with leaf area (rp=-0.268** and rg=-0.397**), fruit set (rp=-0.250* and rg=-0.469**) possessed negative and highly significant correlation at both phenotypic level and genotypic level, respectively. Average pod weight, number of pods per vine and pod yield per vine also showed negative and non-significant correlation with vine length at both the levels.

4.4.3 Leaf area

Leaf area showed positive and highly significant correlation with stem diameter (rp=0.118 and rg=0.2648**) and average pod weight (rp=0.183 and rg=0.208*) at genotypic level only. Number of branches per vine and number of flowers per cluster possessed non-significant positive correlation with leaf area at both levels. The associations of this trait with days to maturity (rp=-0.252* and rg=-0.280**), pod width (rp=-0.232* and rg=-0.256*), number of pods per vine (rp=-0.380** and rg=-0.450**) and number of pods per cluster (rp=-0.373** and rg=-0.455**) were negative and highly significant at both the levels. Days to 50% flowering, fruit set and pod length exhibited weak negative correlation with leaf area at both the levels.

4.4.4 Stem diameter

This character exhibited positive and highly significant correlations with number of branches per vine (rp=0.536** and rg=0.950**), pod width (rp=0.305** and rg=0.488**) and average pod weight (rp=0.309** and rg=0.585**) at phenotypic and genotypic levels. The number of flowers per cluster and fruit set had weak correlations with stem diameter in positive direction at both the levels. Days to 50% flowering (rp=-0.219* and rg=-0.309**), days to maturity (rp=-0.314* and rg=-0.544**) and number of pods per vine (rp=-0.352* and rg=-0.492**) showed negative and highly significant correlation with stem diameter at both the levels. Pod length (rp=0.110 and rg=-0.252*) and number of pods per cluster (rp=-0.162 and rg=-0.256**) negative and significant correlation with stem diameter at genotypic level only.

4.4.5 Number of branches per vine

This trait exhibited positive and highly significant association with width of pod (rp=0.433** and rg=0.559**) and average pod weight (rp=0.457** and rg=0.558**) at both phenotypic and genotypic levels. The number of flowers per cluster and fruit set exhibited weak and positive correlations with number of branches per vine. This trait showed negative and highly significant correlation with days to 50% flowering (rp=-0.230* and rg=-0.275**) and days to maturity (rp=-0.345* and rg=-0.371**) at both the levels. Number of branches per vine was also negatively correlated with pod length (rp=-0.146 and rg=-0.400**), number of pods per vine (rp=-0.200 and rg=-0.217*) and number of pods per cluster (rp=-0.152 and rg=-0.194) at both the levels but only pod length and number of pods per vine reached the level of significance at genotypic level.

4.4.6 Number of flowers per cluster

This trait exhibited weak and positive correlation with pod width at both the levels. Number of flowers per cluster had negative and highly significant correlations with days to 50% flowering (rp=-0.326** and rg=-0.369**), days to maturity (rp=-0.201* and rg=-0.243*) and number of pods per vine (rp=-0.231* and rg=-0.270**) at phenotypic and genotypic level, respectively. Pod length also had negative and highly significant correlations with number of flowers per cluster (rp=-0.132 and rg=-0.333**) at genotypic level only. Average pod weight and pods per cluster also showed weak and negative correlation with number of flowers per cluster at both of phenotypic and genotypic levels.

4.4.7 Days to 50% flowering

Days to 50% flowering had significant and positive correlation with days to maturity (rp=0.893* and rg=0.941**), number of pods per vine (rp=0.478** and rg=0.533**) and number of pods per cluster (rp=0.419** and rg=0.483**) at phenotypic and genotypic level, respectively while fruit set had positive and significant association with days to 50% flowering (rg=0.255*) at genotypic level only. Negative and significant association was also observed with average pod weight (rp=-0.444** and rg=-0.475**) at genotypic and phenotypic level while pod width (rg=-0.228*) at genotypic level only.

4.4.8 Fruit set (%)

Fruit set per cent exhibited positive and significant association with days to maturity (rg=0.342*) and pod length (rg=0.229*) at genotypic level only. This character also showed weak and positive correlation with average pod weight and number of pods per cluster. Fruit ser also showed weak and negative association with pod width and number of pods per vine.

4.4.9 Days to maturity

Days to maturity had positive and significant correlation with number of pods per vine (rp=0.435** and rg=0.504**) and number of pods per cluster (rp=0.402** and rg=0.458**) at phenotypic and genotypic level, respectively. Days to maturity had negative and significant correlation with pod width (rp=-0.204* and rg=-0.210*) and average pod weight (rp=-0.560** and rg=-0.629**) at both the levels. Pod length showed weak and negative association with days to maturity.

4.4.10 Pod length

Pod length had positive and significant correlation with number of pods per cluster (rp=0.254* and rg=0.561**) at phenotypic and genotypic level, respectively and it also had negative and significant correlation with average pod weight (rg=-0.314**) and number of pods per vine (rg=-0.468**) at genotypic level.

4.4.11 Pod width

Pod width had positive and significant correlation with average pod weight (rp=0.221* and rg=0.277**) at phenotypic and genotypic level, respectively while number of pods per vine showed negative and significant correlation with pod width (rp=-0.286** and rg=-0.326**) at both the levels.

4.4.12 Average pod weight

Average pod weight showed negative and significant correlation with number of pods per clusters (rp=-0.284* and rg=-0.305**) at phenotypic and genotypic level while number of pods per vine showed negative and significant correlation with average pod weight (rg=-0.204*) at genotypic level only.

4.4.13 Number of pods per vine

Number of pods per vine showed positive and significant correlation with number of pods per clusters (rp=0.384** and rg=0.430**) at both phenotypic and genotypic level.

4.5 PATH COEFFICIENT ANALYSIS

Path coefficient analysis measures the direct and indirect effects of one variable on the other, and allows partitioning the total correlation coefficients between two variables into direct and indirect components. Since correlation studies alone are not adequate to establish a clear relationship among the characters, so the assessment of real contribution of individual character towards the yield per vine becomes essential. Path coefficient provides a clear and more realistic picture of complex situation that exists at correlation levels. It measures the direct as well as indirect effect of independent variables (characters) on one variable through other characters. The direct and indirect effects of various characters along with their phenotypic correlation coefficients with pod yield per vine are presented in Table 4.5.

At phenotypic level highest positive direct effect on pod yield per vine was observed for average pod weight (0.924) followed by number of pods per vine (0.459), days to 50% flowering (0.093), number of flowers per cluster (0.078), number of pods per clusters (0.038), vine length (0.0259), stem diameter (0.0239) and pod length (0.0076) while highest negative direct effect was recorded for days to maturity (-0.088) followed by pod width (-0.059), fruit set (-0.041), leaf area (-0.033) and number of branches per vine (-0.031).

At genotypic level highest positive direct effect on pod yield per vine was observed for average pod weight (1.0792), number of pods per vine (0.4128), days to 50% flowering (0.0897), number of flowers per cluster (0.0835), days to maturity (0.0701), number of pods per clusters (0.0338), stem diameter (0.0028) and pod length (0.0012) while highest negative direct effect was recorded for fruit set (-0.1106) followed by vine length (-0.0557), pod width (-0.0531), leaf area (-0.0450) and number of branches per vine (-0.0047).

4.5.1 Vine length

Path analysis revealed that its direct effect was negative (-0.0557). The correlation with pod yield per vine was also negative (-0.1582) and non-significant due to its negative indirect effects via number of branches per vine (-0.0008), number of flowers per cluster (-0.0078), pod width (-0.0300), average pod weight (-0.1775) and number of pods per vine (-0.0138).

4.5.2 Leaf area

Path analysis revealed that its direct effect was negative (-0.0450). The correlation with pod yield per vine was also negative (-0.0152) and non-significant due to its negative indirect effects via number of branches per vine (-0.0006), days to 50% flowering (-0.0141), days to maturity (-0.0196), pod length (-0.0002), number of pods per vine (-0.1859) and number of pods per cluster (-0.0154).

4.5.3 Stem diameter

Path analysis for stem diameter revealed that its direct effect was positive (0.0028). Stem diameter exhibited positive and significant correlation (0.298**) with pod yield per vine due to its positive indirect effect via number of flowers per cluster (0.0044) and average pod weight (0.6315).

4.5.4 Number of branches per vine

Number of branches per vine had significant positive correlation with pod yield per vine (0.407) due to positive indirect effect positive indirect effect via stem diameter (0.0027), number of flowers per cluster (0.0095) and average pod weight (0.6016) but its had negative direct effect (-0.0047).

4.5.5 Number of flowers per cluster

Number of flowers per cluster had negative and non-significant correlation with pod yield per vine (-0.168) due to its negative indirect effect via leaf area (-0.0004), number of branches per vine (-0.0005), days to 50% flowering (-0.0331), fruit set (-0.0045), days to maturity (-0.0170), pod length (-0.0004), width of pod (-0.0044), average pod weight (-0.0789), number of pods per vine (-0.1116) and number of pods per cluster (-0.0061).

4.5.6 Days to 50% flowering

Days to 50% flowering exhibited negative and non-significant correlation with pod yield per vine (-0.1777) had direct effect of (0.0897). The negative correlation was due to its negative indirect effect via vine length (-0.0177), stem diameter (-0.0009), number of flowers per cluster (-0.0308), fruit set (-0.0283), pod length (-0.0002) and average pod weight (-0.5124).

4.5.7 Fruit set (%)

Fruit set (%) had negative and non-significant correlation with pod yield per vine (-0.056) due to its negative direct effect (-0.1106) and had negative indirect effect via number of branches per vine (-0.0004) and number of pods per vine (-0.0462).

4.5.8 Days to maturity

Days to maturity exhibited negative and significant correlation with pod yield per vine (-0.348**) had direct effect of (0.0701). The negative correlation was due to its negative indirect effect via vine length (-0.0136), stem diameter (-0.0015), number of flowers per cluster (-0.0203), fruit set (%) (-0.0379) and average pod weight (-0.6786).

4.5.9 Pod length

Pod length exhibited negative and significant correlation with pod yield per vine (-0.583**) had direct effect of (0.0012). The negative correlation was due to its negative indirect effect via vine length (-0.0063), stem diameter (-0.0007), number of flowers per cluster (-0.0278), days to 50% flowering (-0.0136), fruit set (%) (-0.0253), days to maturity (-0.0013), pod width (-0.0051), average pod weight (-0.3388) and number of pods per vine (-0.1933).

4.5.10 Pod width

Path analysis revealed that its direct effect was negative (-0.0531). The correlation with pod yield per vine was positive and non-significant (0.0765) due to its positive indirect effect via leaf area (0.0115), stem diameter (0.0014), number of flowers per cluster (0.0069), fruit set (%) (0.0150), pod length (0.0001) and average pod weight (0.2986).

4.5.11 Average pod weight

Average pod weight had positive and significant correlation with pod yield per vine (0.8748) due to its positive direct effect (1.0792) and indirect effect via vine length (0.0092) and stem diameter (0.0016).

4.5.12 Number of pods per vine

Number of pods per vine exhibited positive and significant correlation with pod yield per vine (0.319**). The positive correlation was due to its positive direct effect (0.4128) and positive indirect effect via vine length (0.0019), leaf area (0.0203), number of branches per vine (0.0010), days to 50% flowering (0.0478), fruit set (%) (0.0124), days to maturity (0.0354), pod width (0.0173) and number of pods per cluster (0.0145).

4.5.13 Number of pods per cluster

Number of pods per cluster exhibited negative and non-significant correlation with yield per vine (-0.0735) had direct effect of (0.0338). The negative correlation was due to its negative indirect effect via vine length (-0.0180), stem diameter (-0.0007), number of flowers per cluster (-0.0151), fruit set (%) (-0.0196) and average pod weight (-0.3290).

Residual effect

The low residual effect at phenotypic (0.3612) and genotypic (0.0288) level used in the study indicated that all the characters had good contribution towards pod yield per vine.

Table : 4.1 Analysis of variance for 14 characters studied in different genotypes of Indian bean (mean sum of squares)

S.No.	Characters (d.f.)	Replication (5)	Varieties (15)	Error (75)
1.	**Vine length (cm)**	572.29	4156.94**	660.40
2.	**Leaf area (cm^2)**	13.20	2001.09**	43.60
3.	**Stem diameter (cm)**	0.30	3.06**	0.93
4.	**No. of branches per vine**	0.62	30.26**	1.64
5.	**No. of flowers per cluster**	0.46	8.78**	0.39
6.	**Days to 50% flowering**	1.89	321.22**	2.77
7.	**Fruit set (%)**	10.41	72.51**	17.12
8.	**Days to maturity**	4.87	441.63**	5.68
9.	**Pod length (cm)**	0.34	0.68**	0.22
10.	**Pod width (cm)**	0.03	0.65**	0.02
11.	**Average pod weight (g)**	0.12	47.78**	0.79
12.	**No. of pods per vine**	28.76	786.26**	28.28
13.	**No. of pods per cluster**	0.43	12.12**	0.47
14.	**Pod yield per vine (Kg)**	0.01	0.26**	0.01

** Significant at 1% level of significance

Table 4.2: Mean performance for different characters studied in Indian bean genotypes

S. No.	Genotypes	Vine length (cm)	Leaf area (cm^2)	Stem diameter (cm)	No. of branches per vine	No. of flowers per cluster	Days to 50% flowering	Fruit set (%)	Days to maturity	Pod length (cm)	Pod width (cm)	Average pod weight (g)	No. of pods per vine	No. of pods per cluster	Pod yield per vine (Kg)
1.	DL-1	265.00	115.17	10.62	19.33	10.17	54.17	52.76	94.17	5.22	1.03	6.37	66.47	7.10	0.40
2.	DL-2	306.67	84.50	11.55	23.17	7.83	46.50	51.16	84.83	5.40	1.80	13.57	73.72	7.57	0.96
3.	DL-3	261.67	109.83	12.47	27.17	7.67	48.17	56.61	86.33	5.39	1.78	14.21	66.82	7.49	0.90
4.	DL-4	293.33	77.83	11.32	22.17	8.00	42.33	50.30	77.17	5.80	1.87	13.25	69.70	9.88	0.88
5.	DL-5	311.67	60.50	12.32	23.83	8.67	44.00	55.60	83.33	6.11	1.88	9.77	53.37	8.92	0.49
6.	DL-6	290.00	85.17	11.62	21.17	7.83	53.33	48.84	88.33	5.66	1.04	10.46	88.40	10.97	0.88
7.	DL-7	315.00	97.50	11.50	20.83	7.00	55.83	50.30	92.33	6.02	1.92	9.59	65.08	10.01	0.59
8.	DL-8	336.67	65.83	11.05	21.67	9.33	62.00	55.37	107.33	6.03	1.96	5.23	73.18	12.15	0.96
9.	DL-9	257.50	61.50	10.37	19.17	6.50	64.83	61.98	106.67	5.83	1.08	8.46	94.15	11.17	0.76
10.	DL-10	321.67	54.00	10.43	20.50	6.67	62.83	48.39	104.33	5.24	1.83	8.25	93.69	9.19	0.75
11.	DL-11	288.33	73.00	11.38	24.83	8.33	54.67	51.82	93.83	5.41	1.78	6.76	89.52	10.47	0.59
12.	DL-12	268.33	58.00	10.67	22.17	10.67	45.67	53.05	88.83	5.33	1.72	12.29	79.23	9.33	0.92
13.	DL-13	340.00	60.33	12.52	24.83	9.17	57.00	51.32	93.00	5.04	1.82	10.14	84.28	8.97	0.82
14.	DL-14	318.33	86.67	12.05	25.67	8.33	62.67	55.82	96.83	5.17	1.82	14.35	77.97	10.93	1.07
15.	DL-15	281.67	82.00	12.23	23.17	8.83	54.83	55.42	91.33	5.31	1.95	11.67	70.80	8.73	0.78
16.	Konkan Bhusan	280.83	76.17	11.35	22.67	9.83	46.00	54.49	83.83	5.52	1.91	10.97	81.05	9.87	0.85
	Range	257.5-340	54-115.17	10.37-12.52	19.17-27.17	6.5-10.67	42.33-64.83	48.39-61.98	77.17-107.33	5.04-6.11	1.03-1.96	5.23-14.35	53.37-94.15	7.1-12.15	0.40-1.07
	Mean	296.04	78.00	11.46	22.65	8.43	53.43	53.33	92.03	5.53	1.70	10.34	76.71	9.55	0.80
	SE ±	10.49	2.70	0.39	0.52	0.26	0.68	1.69	0.97	0.19	0.06	0.36	2.17	0.28	0.03
	CD (5%)	29.56	7.59	1.11	1.47	0.72	1.91	4.76	2.74	0.54	0.17	1.02	6.12	0.79	0.09
	CD (1%)	39.21	10.08	1.47	1.95	0.96	2.54	6.31	3.64	0.72	0.23	1.36	8.11	1.04	0.12
	CV (%)	8.68	8.46	8.41	5.65	7.45	3.12	7.76	2.59	8.54	8.87	8.59	6.93	7.16	10.89

Table 4.3: Estimates of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2) and genetic advance (GA) for different characters studied in Indian bean

S. No.	Characters	GCV (%)	PCV (%)	h^2 (%)	GA	GA as % of mean
1.	**Vine length (cm)**	8.15	11.91	46.88	34.05	1.97
2.	**Leaf area (cm^2)**	23.16	24.66	88.21	34.95	7.58
3.	**Stem diameter (cm)**	5.19	9.88	27.61	0.64	7.00
4.	**No. of branches per vine**	9.65	11.18	74.43	3.88	8.70
5.	**No. of flowers per cluster**	14.03	15.88	78.01	2.15	17.40
6.	**Days to 50% flowering**	13.64	13.99	95.04	14.63	7.16
7.	**Fruit set (%)**	5.70	9.63	35.03	3.70	3.61
8.	**Days to maturity**	9.26	9.62	92.75	16.91	4.47
9.	**Pod length (cm)**	4.99	9.89	25.51	0.29	9.69
10.	**Pod width (cm)**	18.97	20.95	82.05	0.60	45.65
11.	**Average pod weight (g)**	27.08	28.41	90.85	5.49	22.68
12.	**No. of pods per vine**	14.65	16.21	81.71	20.93	5.96
13.	**No. of pods per cluster**	14.60	16.26	80.60	2.58	16.82
14.	**Pod yield per vine (Kg)**	27.13	29.23	86.12	0.39	83.16

Table 4.4: Genotypic and phenotypic correlation coefficients between yield attributes and yield per vine

Characters		Vine length (cm)	Leaf area (cm^2)	Stem diameter (cm)	No. of branches per vine	No. of flowers per cluster	Days to 50% flowering	Fruit set (%)	Days to maturity	Pod length (cm)	Pod width (cm)	Average pod weight (g)	No. of pods per vine	No. of pods per cluster
Pod yield per vine (Kg)	**P**	-0.11	-0.032	0.114	0.292**	-0.131	0.169	-0.024	-0.305**	-0.23	0.036	0.798**	0.313**	-0.042
	G	-0.158	-0.015	0.299**	0.407**	-0.168	-0.178	-0.056	-0.348**	-0.583**	0.077	0.875**	0.319**	-0.074
Vine length (m)	**P**	1	-0.268**	0.167	0.128	-0.097	0.191	-0.25*	0.114	0.042	0.396**	-0.121	-0.061	0.184
	G	1	-0.397**	0.342**	0.167	0.094	0.318**	-0.469**	0.244*	0.113	0.565**	-0.165	-0.033	0.323**
Leaf area (cm^2)	**P**		1	0.118	0.057	0.025	-0.13	-0.036	-0.252*	-0.059	-0.232*	0.183	-0.38**	-0.373**
	G		1	0.264**	0.121	0.01	-0.157	-0.037	-0.28**	-0.156	-0.256*	0.208*	-0.45**	-0.455**
Stem diameter (cm)	**P**			1	0.536**	0.006	-0.219*	0.062	-0.314**	0.11	0.305**	0.309**	-0.352**	-0.162
	G			1	0.95**	0.053	-0.309**	0.009	-0.544**	-0.252*	0.488**	0.585**	-0.492**	-0.256*
No. of branches per vine	**P**				1	0.08	-0.23*	0.109	-0.345**	-0.146	0.433**	0.457**	-0.2	-0.152
	G				1	0.113	-0.275**	0.095	-0.371**	-0.4**	0.559**	0.558**	-0.217*	-0.194
No. of flowers per cluster	**P**					1	-0.326**	-0.06	-0.201*	-0.132	0.054	-0.084	-0.231*	-0.143
	G					1	-0.369**	0.041	-0.243*	-0.333**	0.083	-0.073	-0.27**	-0.181
Days to 50% flowering	**P**						1	0.128	0.893**	-0.1	-0.194	-0.444**	0.478**	0.419**
	G						1	0.255*	0.941**	-0.151	-0.228*	-0.475**	0.533**	0.483**
Fruit set (%)	**P**							1	0.178	0.14	-0.111	0.025	-0.006	0.119
	G							1	0.342**	0.229*	-0.135	0.009	-0.112	0.177
Days to maturity	**P**								1	-0.075	-0.204*	-0.56**	0.435**	0.402**
	G								1	-0.019	-0.21*	-0.629**	0.504**	0.458**
Pod length (cm)	**P**									1	-0.024	-0.172	-0.177	0.254*
	G									1	0.097	-0.314**	-0.468**	0.561**
Pod width (cm)	**P**										1	0.221*	-0.286**	0.03
	G										1	0.277**	-0.326**	-0.001
Average pod weight (g)	**P**											1	-0.187	-0.284**
	G											1	-0.204*	-0.305**
No. of pods per vine	**P**												1	0.384**
	G												1	0.43**
No. of pods per cluster	**P**													1
	G													1

*, ** - Significant at 5% and 1% levels, respectively

Table 4.5: Direct (diagonal) and indirect effect of different correlated characters towards pod yield per vine on the basis of phenotypic correlation

characters	Vine length (cm)	Leaf area (cm^2)	Stem diameter (cm)	No. of branches per vine	No. of flowers per cluster	Days to 50% flowering	Fruit set (%)	Days to maturity	Pod length (cm)	Pod width (cm)	Average pod weight (g)	No. of pods per vine	No. of pods per cluster	Correlation with pod yield per vine (Kg)
Vine length (cm)	**0.0259**	0.0089	0.0040	-0.0040	-0.0075	0.0176	0.0103	-0.0100	0.0003	-0.0235	-0.1116	-0.0278	0.0070	-0.1104
Leaf area (cm^2)	-0.0069	**-0.0332**	0.0028	-0.0017	0.0019	-0.0120	0.0015	0.0222	-0.0005	0.0138	0.1687	-0.1744	-0.0142	-0.0321
Stem diameter (cm)	0.0043	-0.0039	**0.0239**	-0.0165	0.0004	-0.0202	-0.0025	0.0277	0.0008	-0.0180	0.2852	-0.1615	-0.0062	0.1135
No. of branches per vine	0.0033	-0.0019	0.0128	**-0.0309**	0.0062	-0.0213	-0.0045	0.0304	-0.0011	-0.0257	0.4222	-0.0917	-0.0058	0.2922
No. of flowers per cluster	-0.0025	-0.0008	0.0001	-0.0025	**0.0781**	-0.0301	0.0025	0.0177	-0.0010	-0.0032	-0.0772	-0.1062	-0.0055	-0.1307
Days to 50% flowering	0.0049	0.0043	-0.0052	0.0071	-0.0254	**0.0925**	-0.0053	-0.0786	-0.0008	0.0115	-0.4102	0.2197	0.0160	0.1694
Fruit set (%)	-0.0065	0.0012	0.0015	-0.0034	-0.0047	0.0118	**-0.0411**	-0.0157	0.0011	0.0065	0.0233	-0.0026	0.0045	-0.0241
Days to maturity	0.0030	0.0084	-0.0075	0.0106	-0.0157	0.0826	-0.0073	**-0.0881**	-0.0006	0.0123	-0.5173	0.1997	0.0154	-0.3046
Pod length (cm)	0.0011	0.0020	0.0026	0.0045	-0.0103	-0.0093	-0.0057	0.0066	**0.0076**	0.0014	-0.1590	-0.0815	0.0097	-0.2303
Pod width (cm)	0.0103	0.0077	0.0073	-0.0134	0.0042	-0.0180	0.0045	0.0183	-0.0002	**-0.0593**	0.2043	-0.1315	0.0012	0.0355
Average pod weight (g)	-0.0031	-0.0061	0.0074	-0.0141	-0.0065	-0.0411	-0.0010	0.0493	-0.0013	-0.0131	**0.9242**	-0.0861	-0.0109	0.7976
No. of pods per vine	-0.0016	0.0126	-0.0084	0.0062	-0.0181	0.0443	0.0002	-0.0383	-0.0013	0.0170	-0.1732	**0.4594**	0.0147	0.3133
No. of pods per cluster	0.0048	0.0124	-0.0039	0.0047	-0.0112	0.0388	-0.0049	-0.0354	0.0019	-0.0018	-0.2625	0.1765	**0.0382**	-0.0424

*, ** - Significant at 5% and 1% levels, respectively   Residual = 0.3612

Table 4.6: Direct (diagonal) and indirect effect of different correlated characters towards pod yield per vine on the basis of genotypic correlation

characters	Vine length (cm)	Leaf area (cm^2)	Stem diameter (cm)	No. of branches per vine	No. of flowers per cluster	Days to 50% flowering	Fruit set (%)	Days to maturity	Pod length (cm)	Pod width (cm)	Average pod weight (g)	No. of pods per vine	No. of pods per cluster	Correlation with pod yield per vine (Kg)
Vine length (m)	**-0.0557**	0.0179	0.0010	-0.0008	-0.0078	0.0285	0.0519	0.0171	0.0001	-0.0300	-0.1775	-0.0138	0.0109	-0.1582
Leaf area (cm^2)	0.0221	**-0.0450**	0.0007	-0.0006	0.0008	-0.0141	0.0041	-0.0196	-0.0002	0.0136	0.2242	-0.1859	-0.0154	-0.0152
Stem diameter (cm)	-0.0190	-0.0119	**0.0028**	-0.0045	0.0044	-0.0278	-0.0009	-0.0381	-0.0003	-0.0259	0.6315	-0.2032	-0.0086	0.2985
No. of branches per vine	-0.0093	-0.0055	0.0027	**-0.0047**	0.0095	-0.0246	-0.0105	-0.0260	-0.0005	-0.0297	0.6016	-0.0897	-0.0066	0.4066
No. of flowers per cluster	0.0052	-0.0004	0.0001	-0.0005	**0.0835**	-0.0331	-0.0045	-0.0170	-0.0004	-0.0044	-0.0789	-0.1116	-0.0061	-0.1681
Days to 50% flowering	-0.0177	0.0071	-0.0009	0.0013	-0.0308	**0.0897**	-0.0283	0.0660	-0.0002	0.0121	-0.5124	0.2201	0.0163	-0.1777
Fruit set (%)	0.0261	0.0017	0.0000	-0.0004	0.0034	0.0229	**-0.1106**	0.0240	0.0003	0.0072	0.0096	-0.0462	0.0060	-0.0561
Days to maturity	-0.0136	0.0126	-0.0015	0.0017	-0.0203	0.0844	-0.0379	**0.0701**	0.0000	0.0111	-0.6786	0.2082	0.0155	-0.3482
Pod length (cm)	-0.0063	0.0070	-0.0007	0.0019	-0.0278	-0.0136	-0.0253	-0.0013	**0.0012**	-0.0051	-0.3388	-0.1933	0.0189	-0.5831
Pod width (cm)	-0.0315	0.0115	0.0014	-0.0026	0.0069	-0.0204	0.0150	-0.0147	0.0001	**-0.0531**	0.2986	-0.1346	0.0000	0.0765
Average pod weight (g)	0.0092	-0.0094	0.0016	-0.0026	-0.0061	-0.0426	-0.0010	-0.0441	-0.0004	-0.0147	**1.0792**	-0.0840	-0.0103	0.8748
No. of pods per vine	0.0019	0.0203	-0.0014	0.0010	-0.0226	0.0478	0.0124	0.0354	-0.0006	0.0173	-0.2197	**0.4128**	0.0145	0.3192
No. of pods per cluster	-0.0180	0.0205	-0.0007	0.0009	-0.0151	0.0433	-0.0196	0.0321	0.0007	0.0001	-0.3290	0.1776	**0.0338**	-0.0735

*, ** - Significant at 5% and 1% levels, respectively Residual = 0.0288

6. SUMMARY

The present investigation entitled "Assessment of genetic variability in Indian bean (*Lablab purpureus* L.)" was carried out to study the variability and to find out the correlation and path coefficient analysis for pod yield and component traits. The experiment material comprised of 16 genotypes of Indian bean laid out in randomized block design with six replications during *kharif* season 2010-11 at Horticulture Farm, Department of Horticulture, Rajasthan College of Agriculture, Udaipur. The data were subjected to statistical analysis *viz.* mean, GCV, heritability, genetic advance, correlation and path coefficient analysis.

The major findings of this study are as follows:

1. Analysis of variance revealed highly significant differences among the genotypes for all the characters showing thereby considerably amount of variability for all the characters and were amendable to improvement.

2. Based on the mean values with respect to characters, the genotype DL-14 was the highest yielder followed DL-8, DL-2 and DL-12. The genotype DL-14 was also among the top genotypes for other economic traits also such as average pod weight, number of pods per vine, fruit set, number of branches per vine, leaf area and vine length. These genotypes might be used as potent parents in appropriate breeding programme for improving pod yield per vine and their components.

3. The magnitude of the phenotypic coefficient of variation was higher than corresponding genetic coefficient of variation for all the characters which indicated effect of environment on the character expression. The GCV and PCV were higher for pod yield per vine, average pod weight and leaf area. Moderate GCV and PCV were observed for number of flowers per cluster, days to 50% flowering, number of pods per vine and number of pods per cluster. Stem diameter, fruit set, days to maturity and pod length showed low GCV and PCV.

4. Most of the characters under study exhibited high estimates of heritability *viz.*, days to 50% flowering, days to maturity, average pod weight, leaf area, yield per vine, pod width, number of pods per vine and number of pods per cluster. These characters would be effective in selection for Indian bean improvement.

5. A wide range of expected genetic advance as per cent mean was observed for different characters. High estimates of expected genetic advance were reported for the characters

viz., pod yield per vine and pod width. High heritability along with high genetic advance was observed for pod width and pod yield per vine. In this condition selection will be more effective as these characters might be under the control of additive gene effects. On the other hand high heritability with low genetic advance was observed for leaf area, days to 50% flowering, days to maturity and number of pods per vine. Selection for these characters might be effective in later generations.

6. In general, the estimates of genotypic correlation were higher than the corresponding phenotypic correlation coefficient. It may result from the modifying effect of environment on the association of characters at genotypic level. The character pod yield per vine had highly significant positive correlation with characters like stem diameter, number of branches per vine, average pod weight and number of pods per vine. These associations indicated that improvement in pod yield per vine can be achieved by improving above characters.

7. Path coefficient analysis revealed that the characters like average pod weight, number of pods per vine, days to 50% flowering, number of flowers per cluster, days to maturity, number of pods per clusters, stem diameter and pod length had high direct effect on pod yield per vine. These above characters also had positive indirect effect with each other.

8. Number of pods per vine, average pod weight, days to maturity and number of flowers per cluster showed high and positive indirect effect towards pod yield per vine.

9. The magnitude of residual effect was moderate which indicated that major portion of contribution towards yield per vine may be explained on the basis of character included in the study.

CONCLUSION

On the basis of mean performance the genotypes DL-14, DL-8, DL-2 and DL-12 were found superior in terms of high mean values of pod yield per vine. These genotypes may further be utilized in breeding programme aimed at improving pod yield per vine in Indian bean. All those characters which showed positive direct effect towards yield proved effective in enhancing productivity level in Indian bean.

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2. REVIEW OF LITERATURE

The improvement in any crop depends upon the extent, nature and magnitude of genetic variability in the material and the extent to which it is heritable. Yield is complex and polygenic character and highly influenced by environment, therefore it is necessary to know the role of environment for expression of traits. To exploit the variability for improving yield, knowledge of inter-relationship between yield and its component characters and among the component characters are essential. Further, path coefficient analysis provides precise information about the cause and effect situation and helps in determining the selection criteria in crop improvement.

The literature available on Indian bean pertaining to present investigation is scanty. Hence available literature on Indian bean and related other pulse crops has been reviewed and presented in the following sub headings:

2.1 Variability parameters

2.2 Correlation studies

2.3 Path coefficient analysis

2.1 Variability Parameters:

Assessment of genetic variability in the base population is the first step in crop improvement because the progress of any breeding programme depends largely on the extent of variability present in the population.

Genetic variability is determined with the help of certain genetic parameters such as coefficient of variation, heritability and genetic advance. The observed variability could be partitioned into heritable and non-heritable components. Heritability is the heritable portion of phenotypic variance and it is a good index of the transmission of characters from parents to their offspring (Falconer, 1981). The knowledge of heritability helps the plant breeder in pre-assessment of the results of selection for a particular character. Heritability is the ratio of genotypic variance to phenotypic variance. Its estimate is quite important from the breeder’s point of view because it is due to additive effects of genes. If the heritability of the character is high, the phenotypic value provides a fairly close measure of the genotypic value and thus the breeder can base his selection on the phenotypic performance. For predicting the effect of selection, heritability estimates along with genetic advance are more useful than the heritability estimates alone (Johnson *et al.* 1955).

Gupta and Samanta (1991) evaluated thirty six genotypes of Indian bean and observed highest genotypic coefficient of variation (46.38%) and phenotypic coefficient of variation (51.07%) for number of pods per plant followed by number of inflorescence per plant. High heritability was observed for pod length, days to flower, number of inflorescence, number of pods per plant, number of pods per cluster. High genetic advance was found for number of pods per plant, number of inflorescence per plant, days to flower and pod length. High heritability was coupled with high genetic advance for pod length, number of inflorescence per plant and number of pods per plant indicating predominance of additive gene effects.

Borah and Shadeque (1992) evaluated twelve genotypes of field bean collected from different parts of Assam. They noted high GCV, heritability and high genetic advance for inflorescence length, pod weight, pod breadth and Vitamin C content indicating the additive gene effects in their expression and direct selections can be made based on these traits for improvement.

Ushakumari and Chandrasekharan (1992) studied thirty genotypes of field bean for thirteen characters. The maximum GCV was obtained for dry matter production followed by total leaf area. Heritability was higher for number of leaves followed by plant height and dry matter production. Genetic advance as per cent mean was the maximum for dry matter production.

Topare (1994) studied genetic variability in Indian bean and observed that the genotypic coefficient of variation ranged from 8.35 per cent for number of seeds per pod to 68.32 per cent for leaf area. It was also high for number of branches per plant, number of pods per plant, yield per plant. The heritability was ranged 41.90 per cent for number of seeds per pod to 90.70 per cent for leaf area. High heritability was observed for all characters except number of seeds per pod and pod length. Genetic advance as percentage of mean was ranged from 11.03 per cent for number of seeds per pod to 141.26 per cent for leaf area. High genetic advance was found for plant height, number of inflorescence per plant, number of branches per plant, number of pods per plant and seed yield per plant.

Uddin and Newaz (1997) estimated the genetic variability among fifteen genotypes (including two exotic and thirteen local genotypes) collected from different regions of Bangladesh. Highly significant variation was observed among the genotypes for all the eight characters studied. Highest genetic variability was found in green pod yield and green pods per plant whereas rate of flower abortion exhibited the lowest genotypic coefficient of variability. High heritability as well as genetic advances was found in pod yield, number of pods per plant, inflorescence per plant, pod weight and flowers per inflorescence.

Bendale *et al.* (2004) conducted an experiment in Dapoli, Maharashtra, to quantify the genetic variability and identify the superior genotype among thirty two lablab bean genotypes. Analysis of variance indicated the presence of highly significant genotypic variation for all morphological characters. Genotypic coefficient of variation (GCV) showed that harvest index had the highest GCV followed by dry weight and number of pods per plant. The phenotypic coefficient of variation (PCV) had a higher magnitude than GCV. Leaf area, dry weight of pods per plant, number of pods per plant, seed yield and number of branches showed high estimates of heritability associated with higher magnitude of genetic advance as percentage of mean. The number of seeds per pod, overall maturity, first pod maturity, first flower bud appearance and pod length showed higher level of heritability associated with lower magnitude of genetic advance as percentage of mean.

Basavarajappa and Gowda (2004) conducted a field experiment in Karnataka, to assess genetic variability in 144 field bean (*Lablab purpureus*) genotypes. Greater variability associated with high heritability and genetic advance was observed for pods per plant, pod yield per plant and grain yield per plant indicating that the additive gene effects were operating for these characters

Ali *et al.* (2005) collected twenty genotypes of lablab bean from different regions of Bangladesh for six agronomic characters and estimated that heritability values were higher for number of flower per inflorescence (96.21%) followed by pod weight (92.03%) and number of pods per inflorescence (91.08%). Maximum genetic advance expressed as percentage of mean was recorded for number of pod per inflorescence (115.72).

Nahar and Newaz (2005) conducted an experiment in Bangladesh Agricultural University Mymensingh with a view to observe genetic variability in twenty lablab bean genotypes. All the characters studied, showed significant variation among the genotypes. The highest genetic variability was observed in days to first flowering, days to first pod setting and number of inflorescences per plant. High heritability coupled with high genetic advance in percentage of mean was recorded in days to first flowering, days to first pod setting, number of flowers per inflorescence, pod length, pod width and 20-seed weight.

Lal *et al*. (2005) studied genetic variability for seven characters in forty two genotypes of dolichos bean (*Lablab purpureus*) in Varanasi, Uttar Pradesh. Analysis of variance showed significant differences among genotypes for all characters studied. Phenotypic coefficients of variation (PCV) were slightly higher than the corresponding genetic coefficients of variation (GCV) due to environmental influence. Estimates of PCV and GCV indicated the existence of fairly high degree of variability for pod weight, pods per plant and yield per plant. High heritability coupled with high genetic advance was observed for days to flowering and yield per plant, indicating the preponderance of additive effects for these characters. In contrast, high heritability coupled with low genetic advance was observed for pod length and pod weight, indicating the preponderance of non-additive effects for these characters.

Singh and Vikas (2005) evaluated twenty-five diverse genotypes of mung bean to study the variability of eight quantitative characters. The estimates of high heritability with high genetic advance were observed for the characters biological yield, days to 50% flowering, number of pods per plant, plant height indicated the presence of additive gene action for these characters. The phenotypic and genotypic coefficients of variation were high for biological yield, number of pods per plant, harvest index, seed yield per plant.

Saini *et al.* (2005) assessed forty genotypes of cluster bean (Cyamopsis tetragonoloba) for twelve traits at Durgapura, Navgoan and Tabiji in Rajasthan. The significant mean squares due to genotypes for all traits in all environments indicated the presence of enormous variability in the material studied. The maximum range of variation was noted for branches per plant, biological yield, pods per plant, seed yield, clusters per plant and plant height. Phenotypic and genotypic coefficients of variation were high for branches per plant, days to flowering, clusters per plant and pods per plant and moderate for plant height and seed yield. High heritability coupled with high genetic gain was observed for days to flowering, branches per plant, clusters per plant, pods per plant and plant height.

Kathiria and Modha (2006) studied the genetic variability in Indian bean (*Lablab purpureus var. typicus*). There was moderate heritability for pod length (58.01%) and days to flowering (52.64%), while it was low for pod width (36.91%), seeds per pod (28.13%) and green pod yield per plant (16.82%). The regression coefficient significantly deviated from unity for plant height, primary branches per plant, pod weight, 100 dry seed weight and moisture content. The results showed that both additive and non-additive components of genetic variance are important for most of the yield and yield contributing characters study.

Rao *et al*. (2006) studied genetic variability in sixty mung bean genotypes grown in Guntur, Andhra Pradesh. High estimates of genetic and phenotypic coefficients of variation, heritability and genetic advance were recorded for seed yield per plant, biological yield per plant, number of clusters per plant and number of pods per plant.

Eswari and Rao (2006) evaluated thirteen Mung bean (green gram) cultivars, selected from different locations in Andhra Pradesh for grain yield and its components (days to 50% flowering, days to maturity, plant height, pods per plant, clusters per plant, seeds per pod and 100-seed weight). A wide range of variability was observed for all characters studied. Considerable amount of phenotypic and genotypic variability was observed for grain yield, pods per plant and clusters per plant. High heritability coupled with low genetic advance were recorded for days to 50% flowering, days to maturity and plant height, suggesting that selection based on these characters could be effective.

Rai *et al*. (2006) evaluated fifty-two genotypes of pole type French bean during in Meghalaya and observed that there was wide range of phenotypic variation along with high heritability in pole type French bean. The characters namely, pod yield per plant, number of pods per plant, seed weight and pod weight showed high GCV and high heritability along with high genetic advance revealing that these characters are controlled by additive gene.

Golani *et al*. (2007) evaluated eighteen diverse and promising genotypes of hyacinth bean (*Lablab purpureus*) and observed that the analysis of variance revealed significant differences among the genotypes for all the traits. Moderate value of GCV along with high heritability and genetic advance were recorded for pod width, 10-pod weight, plant spread and pod length.

Makeen *et al.* (2007) evaluated twenty diverse mung bean genotypes in Uttar Pradesh for ten quantitative characters. The genotypes differed significantly for all characters studied. Higher genotypic and phenotypic coefficients of variation were observed for seed yield and number of pods per plant. Maximum heritability values were recorded in seed protein content, plant height and test weight. High heritability coupled with high genetic advance were observed for pods per plant, plant height and test weight, indicating the importance of additive gene effect for the expression of these characters.

Pandey *et al.* (2007) evaluated twenty mung bean genotypes to study the genetic variability and observed that the genetic parameters exhibited high to moderate values for genotypic coefficient of variation, broad-sense heritability and genetic advance for plant height, pod number, cluster number and harvest index. The highest heritability was observed for cluster number per branch (85%) followed by plant height (79%) and number of pods per cluster (78%), while it was lowest for biological yield per plant (35.5%).

Marappa *et al.* (2008) studied genetic variability in 169 lines of 4 mung bean wild relatives (*Vigna aconitifolia, V. glabrescens, V. sublobata and V. umbellata*) grown in Bangalore, Karnataka. The analysis of variance showed the presence of significant variability among the genotypes. The estimates of phenotypic and genetic coefficients of variation were relatively high for plant height, number of primary branches per plant, number of clusters per plant, pod yield per plant and seed yield. High heritability estimates coupled with high genetic advance as percent of mean were recorded for the eleven characters evaluated, suggesting that these traits can be improved through simple selection.

Patel *et al.* (2008) conducted an experiment in Gujarat to assess genetic variability among thirty genotypes of moth bean for twelve characters. The genotypic coefficient of variation was highest for branches per plant, followed by grain yield per plant, clusters per plant and pods per plant. High heritability estimates were observed for grain yield per plant, days to 50% flowering, days to maturity, plant height, branches per plant, clusters per plant, pods per plant and harvest index. The expected genetic advance as per cent of mean was high for grain yield per plant, branches per plant, clusters per plant and pods per plant.

Chattopadhyay and Dutta (2010) evaluated twelve genotypes of pole type dolichos bean (*Lablab purpureus* var. *typicus*) for their genetic variability under the Gangetic plains of eastern India. The study revealed significant variation in days to 50% flowering (57-115), length of pod (7.15-15.05 cm), breadth of pod (1.44-3.11 cm), weight of pod (2.92-8.92 g), 100 seed weight (22.2-45.50 g), number of pods per plant (768.3-1897), protein content of pod (0.70-5.45%) and pod yield per plant (5.07-12.21 kg). Characters like protein content of pod, number of pods per plant, breadth of pod, weight of pod and pod yield per plant exhibited high GCV, PCV, heritability and genetic advance as per cent of mean indicating that such situation may arise due to the action of additive genes controlling the characters.

Kumar *et al.* (2010) studied genetic variability in twenty three genotypes of mung bean. The analysis of variance revealed highly significant difference for all characters, under study among the genotypes, indicating the presence of sufficient amount of variability in the varieties. The highest GCV and PCV were observed for harvest index and pods per plant respectively. High estimates of genetic advance as per cent of mean were observed for 100 seed weight and harvest index.

. Rai *et al.* (2010) observed wide range of variation along with high heritability values in sixty six pole type French bean genotypes. Number of pods per plant, 100-seed weight, green pods yield per plant showed high heritability along with high genetic advance.

Makhdoomi and Dar (2011) evaluated thirty five genotypes of common bean. The analysis of variability parameters revealed presence of substantial variability for all traits in all the genotypes used in the experiment. Highest genotypic and phenotypic variations were observed for, days to maturity and pod length respectively. All the characters showed high heritability with high genetic advance.

Ahmed (2011) conducted an experiment on ten common bean genotypes to study the genetic variability. Significant variations were observed for all the characters in all the genotypes used in the experiment. Highest genotypic and phenotypic variations were observed for plant height followed by number of pods per plant and pod length. Plant height, 100-seed weight and days to 50% flowering showed high heritability with high genetic advance.

2.2 Correlation studies

The concept of correlation was first put forward by Galton (1889) and later elaborated by Fisher (1918) and Wright (1921). In plant breeding correlation coefficient analysis measures the mutual relationship between yield and its components and among the components. Selection is mostly done on phenotypic basis by a plant breeder. However, in quantitative characters the genotype is influenced by the environment and affecting the phenotypic expressions of traits. Hence, it is essential to measure the correlations at phenotypic and genotypic levels.

Dahiya *et al.* (1991) evaluated thirty six genotypes of Indian bean and observed that all the characters except pod length exhibited high degree of correlation at both genotypic and phenotypic levels. Further, they reported that magnitude of genotypic correlations was higher than the phenotypic relations. Number of branches per plant was negatively correlated with almost all characters. Yield was positively and significantly correlated with plant height, number of pods per plant and weight per pod.

Altinbas and Sepetoglu (1993) evaluated seventy five accessions of cowpea and observed that seed yield per plant was correlated significantly and positively with pods per plant, seeds per pod and branches per plant. Both days to flowering and maturity had no influence on seed yield. 1000-seed weight was negatively and significantly associated with pods per plant and seeds per pod.

Topare (1994) studied on correlation among different traits in Indian bean and found positive and significant correlation of yield with days to first flowering, days to first pod maturity, number of inflorescence per plant and number of pods per plant at both phenotypic and genotypic levels. Pod length and number of seeds per pod was negatively correlated with seed yield. In general, correlations involving pod length, number of seeds per pod, 100-seed weight and harvest index was negative.

Uddin and Newaz (1997) studied the association among flower and pod characteristics of hyacinth bean. For this, fifteen hyacinth bean genotypes were evaluated for eight flower and pod characters at different locations. Correlation studies showed significant positive associations of number of flowers per inflorescence with rate of flower abortion, number of pods per inflorescence, number of green pods and inflorescences per plant. Green pod yield had strong significant positive association with pod number, inflorescences per plant and pod weight.

Tikka *et al.* (2003) studied character interrelationship in grain type Indian bean. They observed that the correlation between grain yield with pods per plant (0.967), grain yield with plant height (0.314), grain yield with branches per plant (0.354), days to flowering and days to maturity (0.513) and pod length and 100-seed weight (0.547) was significant and positive.

Basavarajappa and Gowda (2004) studied character association in field bean and observed positive significant association with days to 50% flowering, days to maturity, plant height, pods per plant, pod yield per plant and 100-seed weight with grain yield favoured effective selection.

Nahar and Newaz (2005) studied on character association in twenty lablab bean genotypes and observed that pod yield per plant was positively and significantly correlated with days to first pod setting, number of pods per inflorescence, number of inflorescence per plant, pod length, 10-green pod weight and 20-seed weight.

Ali *et al.* (2005) evaluated twenty genotypes of lablab bean and observed that pod weight shows significant positive correlation with pod diameter and yield per plant but showed negative significant correlation with flowers per inflorescence and number of pods per inflorescence. Pod length showed positive significant correlation with yield per plant.

Lal *et al.* (2005) studied correlation in Indian bean and found that genotypic correlations were higher than phenotypic correlations for most of the character pairs, indicating the inherent association between these characters. Correlations showed that pod weight and pods per plant had the highest positive correlation on yield per plant. Therefore, these characters may be exploited in genetic improvement programmes.

Singh and Vikas. (2005) studied correlation in twenty-five diverse genotypes of mung bean and observed the maximum positive and significant phenotypic correlation coefficient (0.825) between the number of pods per plant and seed yield per plant, followed by seed yield per plant with harvest index (0.822), days to 50% flowering and plant height (0.752), number of pods per plant and harvest index (0.670), days to 50% flowering and biological yield (0.663), plant height and biological yield (0.599).

Saini *et al.* (2005) studied correlation in forty genotypes of cluster bean and reported the significant correlation of seed yield with pods per plant, harvest index, biological yield and clusters per plant. Seed yield had negative but desirable correlation with days to flowering, days to maturity and plant height.

Rao *et al.* (2006) studied correlations in 60 mung bean genotypes and estimated that genotypic correlation for seed yield had a positive and highly significant association with number of pods per plant, biological yield per plant, and harvest index.

Rai *et al.* (2006) studied character association in fifty-two genotypes of pole type french bean and observed that pod yield per plant exhibited significant positive correlation with pod length, pod weight and seed weight at both genotypic and phenotypic levels.

Golani *et al.* (2007) subjected eighteen diverse and promising genotypes of hyacinth bean (*Lablab purpureus*) and observed that pod width had positive and strong correlation with yield, while days to first picking had negative and strong association with yield.

Malik *et al.* (2007) studied correlation coefficient in twenty seven genotypes of soybean and reported that correlation coefficient for yield was positive with leaf area, first pod height, days to flowering, days to maturity, plant height and number of branches per plant. Therefore, increase in these traits will ultimately increase the grain yield.

Makeen *et al.* (2007) evaluated twenty diverse mung bean genotypes and indicated that pods per plant and plant height had significant positive correlation with seed yield.

Pandey *et al.* (2007) studied on twenty mung bean genotypes and reported significant and positive correlation of harvest index, pod number, 100-seed weight and pod length with seed yield.

Patel *et al.* (2008) studied correlation in thirty genotypes of moth bean and recorded high correlation of seed yield with pods per plant, clusters per plant, harvest index, branches per plant, days to 50% flowering, days to maturity and plant height. Significant inter-correlations also existed among themselves.

Kumar *et al.* (2010) studied character association in twenty three genotypes of mung bean and recorded high significant correlation for pods per plant and harvest index at both genotypic and phenotypic levels with seed yield per plant.

. Rai *et al.* (2010) studied correlation in sixty six pole type French bean genotypes and reported that pod yield per plant exhibited significant positive correlation with number of pods per plant, % fruit set per cluster and 100 seed weight at both genotypic and phenotypic level.

Makhdoomi and Dar (2011) studied correlation in thirty five genotypes of common bean and noticed that grain yield was found to be positively correlated with number of pods per plant, pod length, number of seeds per pod, and 100 seed weight.

Ahmed (2011) used ten common bean genotypes to correlation study and found that Seed yield was positively correlated with days to 50% flowering, plant height and number of seeds per pod.

2.3 Path coefficient analysis:

Path coefficient analysis is simply a standard partial regression coefficient which splits the genotypic correlation coefficient into direct and indirect effects. It reveals whether the association of the characters with yield is due to their direct effects on yield or is a consequence of their indirect effects via other component characters. Path analysis was initially suggested by Wright (1921) and it was applied for the first time in plant breeding by Dewey and Lu (1959). Path analysis technique helps in indirect selection through component characters for genetic improvement of yield. The indirect selection would be more efficient than direct selected for yield when the character has a high heritability and high correlation with yield (Searle, 1965).

Dahiya *et al.* (1991) suggested that selection based on number of pods per plant, plant height and pod weight will be more effective for the improvement of yield in Indian bean. Number of pods per plant exhibited highest direct effect (0.8918) followed by weight of pod, while number of branches and days to flowering had low contribution towards yield.

Topare (1994) studied path analysis in 32 strains of lablab bean and found that days to overall maturity, number of seeds per pod, number of pods per plant, number of branches per plant, days to first flowering, harvest index and 100-seed weight have positive direct effects on yield. While, days to first pod maturity, pod length, plant height, number of inflorescence per plant had direct negative effects on yield. Generally indirect effects involving pod length and 100-seed weight were negative.

Sawant (1994) studied Path analysis in 10 varieties and 45 crosses of cowpea and reported that pods per plant had highest positive direct effect on seed yield followed by 100-seed weight, seeds per pod, days to 50 per cent flowering, inflorescence per plant, harvest index, plant height and pod length.

Tikka *et al.* (2003) studied path coefficient analysis in Indian bean and showed that pods per plant (0.926), pod length (0.481), branches per plant (0.076), plant height (0.056) and harvest index were the main yield contributing traits in Indian bean.

Basavarajappa and Gowda (2004) studied path analysis in field bean and reported that pod yield per plant exhibited highest direct effect (0.8368) followed by branches per plant (0.1058) on grain yield. Pods per plant followed by inflorescence number showed higher indirect effects on grain yield. Days to 50 per cent flowering had negative direct effect.

Nahar and Newaz (2005) evaluated twenty lablab bean genotypes for path coefficients analysis and suggested that days to first flowering, number of flowers per inflorescence, number of pods per inflorescence, 10-green pod weight, 20-seed weight and number of inflorescence per plant were the most important yield contributing characters in lablab bean. Therefore, selection based on these characters would bring good response on pod yield in lablab bean

Lal *et al.* (2005) studied path analyses in forty two genotypes of dolichos bean (*Lablab purpureus*) and found that pod weight and pods per plant had the direct effect on yield per plant. Therefore, these characters may be exploited in genetic improvement programmes.

Singh and Vikas (2005) studied path coefficient analysis in twenty-five diverse genotypes of mung bean and observed that number of pods per plant (0.561), harvest index (0.425), 1000 seed weight (0.216), had positive and direct effect towards seed yield, whereas at phenotypic level biological yield (0.195) number of seeds per pod (0.087), days to 50% flowering (0.011) had relatively low direct effect, therefore, these characters may be selected directly to improve seed yield.

Saini *et al.* (*2005*) evaluated forty genotypes of cluster bean (Cyamopsis tetragonoloba) for twelve traits. Path analysis revealed that biological yield, pod length, clusters per plant and branches per plant had positive desirable direct as well as indirect effects on seed yield. Selection based on branches per plant, clusters per plant, pods per plant, biological yield and pod length may result in simultaneous improvement of cluster bean yield.

Rao *et al.* (2006) Studied path coefficient analysis in sixty mung bean genotypes and reported that the number of pods per plant, biological yield, and harvest index had maximum direct contribution on seed yield

Rai *et al.* (2006) evaluated fifty-two genotypes of pole type French bean and observed maximum direct effect in pod weight followed by seed length, seed thickness and number of pods per plant towards yield indicated that these characters are very important while making selection for high yielding genotypes.

Golani *et al.* (2007) subjected eighteen diverse and promising genotypes of hyacinth bean (*Lablab purpureus*) and recorded that number of branches per plant had maximum direct effect towards yield, followed by pod width. Hence, these characters should be given more emphasis while making selection for high yielding genotypes in hyacinth bean.

Malik *et al.* (2007) studied path analysis in twenty seven genotypes of soybean reported that days to flowering completion had maximum direct contribution to yield, followed by days to pod initiation, chlorophyll content, number of pods per plant and plant height. It was suggested that these characters can be considered as selection criteria in improving the yield of soybean genotypes.

Makeen *et al.* (2007) studied path coefficient analysis in twenty diverse mung bean genotypes for ten quantitative characters. The maximum direct effect on seed yield was observed in pods per plant, test weight and plant height.

Pandey *et al.*(2007) studied path coefficient analysis in twenty mung bean genotypes and found a high positive direct effect of harvest index and biological yield on seed yield with considerable positive effect of maturity duration and plant height. Hence, selection for genotypes with higher harvest index and biological yield, taller height and longer duration could facilitate augmentation of seed yield in mung bean.

Chattopadhyay and Dutta (2010) studied path coefficient analysis in twelve genotypes of pole type dolichos bean (*Lablab purpureus* var. *typicus*) and suggested that the top priority should be given to selection based on the weight of pod, 100 dry seed weight and number of pods per plant for green pod yield improvement and could be considered while formulating selection indices in the improvement of pole type dolichos bean.

Kumar *et al*. (2010) evaluated twenty three genotypes of mung bean and observed that plant height, primary branch per plant, clusters per branch and days to maturity had direct positive effect on seed yield.

. Rai *et al.* (2010) evaluated sixty six pole type French bean genotypes. Maximum direct effect was observed in number of pods per plant followed by % fruit set per cluster, number of seeds per pod towards yield. Hence, these characters have significant effect on yield, while making selection for high yielding genotypes.

Makhdoomi and Dar (2011) evaluated thirty five genotypes of common bean in field trials. Path coefficient analysis revealed the importance of plant height, pods per plant, pod length, seeds per pod and 100-seed weight as the major yield components in this crop

Ahmed (2011) studied path coefficient analysis in ten common bean genotypes and observed that, days to 50% flowering, number of pods per plant, pod length and 100-seed weight showed positive direct effects on seed yield. Hence, selection for these traits for improving seed yield in French bean is suggested.

On the basis of above literature carried out in different pulses by different workers, it seem to appear that information on the variability present in the materials, extent of heritability and genetic gain for a particular trait and contributing effect of one character on to other is prerequisite for formulating a suitable breeding technique to bring out a high jump in yield of any crop. Since Indian bean is a under exploited leguminous vegetable, very little attempts have been made to gather the genetic information in this crops. Owing to the favorable condition, Indian bean finds a good home in Rajasthan. There are greater variability exists in different characters. Due to non ability of the improved line farmer are growing still the existing land races which give poor yield and also low in quality. Seeing the importance of Indian bean in the culture of people of Rajasthan and their wide existing variability, present investigation was envisaged to gather the basic information on the genetic parameters needed for crop improvement in the Indian bean.