Variability studies in pole type of Dolichos bean (*Lablab purpureus* L.)

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(Vegetable Science)

By
MONALISA MISHRA
Adm. No. 10 VSC /15

DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF AGRICULTURE
ODISHA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR- 751003, ODISHA

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ODISHA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF AGRICULTURE
BHUBANESWAR-751003, ODISHA

Dr. Gouri Shankar Sahu **Bhubaneswar**
Professor and Head **Date:**

CERTIFICATE - I

This is to certify that the thesis entitled **"Variability studies in pole type of Dolichos bean (*Lablab purpureus* L.)"** submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (VEGETABLE SCIENCE)** to the Odisha University of Agriculture and Technology is a faithful record of *bona fide* and original research work carried out by **Monalisa Mishra** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by her from various sources during the course of investigation has been duly acknowledged.

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DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF AGRICULTURE
BHUBANESWAR-751003, ODISHA

CERTIFICATE –II

This is to certify that the thesis entitled **"Variability studies in pole type of Dolichos bean (*Lablab purpureus* L.)"** submitted by **Monalisa Mishra** to the Odisha University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (VEGETABLE SCIENCE)** has been approved by the student's advisory committee and external examiner.

Advisory committee

CHAIRMAN: **Dr. Gouri Shankar Sahu**
Professor and Head
Dept. of Vegetable Science
College of Agriculture, OUAT _____

MEMBERS:

1. **Dr. Pradyumna Tripathy**
Professor
Dept. of Vegetable Science
College of Agriculture,
OUAT, Bhubaneswar _____

2. **Dr. Bansidhar Pradhan**
Professor and Head
Dept. of Plant Breeding and Genetics
College of Agriculture,
OUAT, Bhubaneswar _____

3. **Dr. Anita Mohanty**
Senior Scientist
AICRP on Vegetable Crops, _____
OUAT, Bhubaneswar

EXTERNAL EXAMINER: _____
(NAME AND DESIGNATION)

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whose blessings helped me in this entire journey.

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Place: Bhubaneswar (**Monalisa Mishra**)
Date: Adm No. 10 VSC/15

ABSTRACT

A field experiment was conducted at All India Co-ordinated Research Project on Vegetable Crops, Odisha University of Agriculture and Technology, Bhubaneswar with fourteen genotypes of dolichos bean (*Lablab purpureus* L.) in Randomized Block Design with three replications during Rabi 2018-19. The variability, correlation of pod yield with its component characters and among the components and the magnitude of influence of the characters on pod yield was worked out through path analysis. . The analysis of variance revealed highly significant differences among the mean sum of squares due to genotypes for different quantitative characters studied except number of primary branches, stem thickness, average leaf weight, pod width and number of seeds per pod indicating the presence of variability among the genotypes. The high GCV and PCV were observed for pod yield per plant (42.58 and 43.70), pod yield per hectare (42.55 and 43.69), number of pods per plant (35.32 and 36.32), inflorescence length (30.43 and 30.66), pod weight (24.73 and 25.34), pod length (23.40 and 23.72), fresh weight of roots (23.35 and 23.81) and plant height (22.73 and 23.34) indicating high variability available in the germplasm for these characters for further improvement. High heritability coupled with high genetic advance as per cent of mean was observed for characters *viz.*, pod yield per plant, number of pods per plant, inflorescence length, pod weight, pod length, fresh weight of root, plant height, number of primary branches, pod width, days to first flowering, days to 50% flowering and number of seeds per pod indicating that these characters were least influenced by the environmental effects and governed by additive genes. The result on phenotypic and genotypic correlation coefficient revealed that pod yield per plant was significantly and positively correlated with pod yield per hectare (0.966 and 0.968), plant height (0.791 and 0.832), Number of pods per plant (0.739 and 0.766), Number of primary branches (0.521 and 0.552), Pod weight (0.486 and 0.529), Pod width (0.460 and 0.476), Stem thickness (0.426 and 0.494). However, days for 50% flowering (-0.579 and -0.626) and Days to first flowering (-0.517 and -0.559) showed significantly and negatively correlated with pod yield per plant at both phenotypic and genotypic level. Further, path coefficient analysis partitioned the correlation into direct and indirect effects. Path analysis revealed that maximum positive direct effect on pod yield per plant was exhibited through days to first flowering, plant height, number of primary branches, pod length, internodal length, pod width, fresh weight of root, inflorescence length, number of pods per plant and pod weight these characters play a major role in recombination breeding and suggested that direct selection based on these traits will be rewarded for crop improvement of dolichos bean. The genotypes *viz.*, 2016/DOLPVAR-9 (1185.58 g), 2016/DOLPVAR-4 (1009 g) and 2016/DOLPVAR-12 (905.67 g) were found promising for pod yield per plant than other genotypes. There is a need to evaluate these high yielding genotypes in large plots and over multi locations in Odisha for their commercial utilization.

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ABBREVIATIONS USED

%	:	Per cent
/	:	Per
CV	:	Coefficient of variation
C.D.	:	Critical Difference
SE m	:	Standard error mean
cm	:	Centimetre
cm^2	:	square centimetre
ml	:	Millilitre
ESS	:	Error sum of square
et al.	:	And others
g	:	Gram
q	:	Quintal
ha	:	Hectare
i.e.	:	(*Id est.*) that is
kg	:	Kilogram
N	:	Nitrogen
P	:	Phosphorus
K	:	Potash
Fig.	:	Figure
V	:	Variety/Genotype
Max.	:	Maximum
Min.	:	Minimum
No.	:	Number
m	:	Metre
RSS	:	Replication sum of square
PCV	:	Phenotypic coefficient of variation
GCV	:	Genotypic coefficient of variation
AICRP	:	All India Coordinated Research Project
ANOVA	:	Analysis of variance
GSS	:	Genotype sum of square
t	:	Tonnes
Viz.	:	(*Videlicet*) Namely
°C	:	Degree Celsius

INTRODUCTION

Dolichos bean (*Lablab purpureus* L.) belongs to family leguminosae (2n=2x=22) is one of the important vegetable crop of Indian origin (Deka and Sarkar, 1990). Dolichos bean is popularly known as Field Bean, Hyacinth Bean, Bonavist Bean, Indian Bean, Country Bean, Egyptian Bean, Lablab bean, Sem. It is widely grown throughout the country and distributed in Maharashtra, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, Odisha and North Eastern states. It is also known as 'Poor Man's Bean' (Ismunandji and Arsyad, 1990) or 'Meat of the Poor' as it contributes essential protein to undernourished people living in hills.

Dolichos bean is a multipurpose crop grown for pulse, vegetable and forage crop for livestock. This crop is grown for its green pods for vegetable purpose as well as dried seeds in vegetable food preparation. It is sensitive to photoperiods and both short day and long day types are available. Dolichos bean is rich in proteins (20-25%), amino acid like lysine, vitamins (A, C and Riboflavin), and minerals (Gopalan *et al*., 1982). Its green pods (100 g) contains 6.7 g carbohydrates, 3.8 g protein, 210 mg calcium, 1.7 mg iron, 312 IU vitamin A and 0.1 mg thiamine (Gopalan *et al*., 2004). Immature pods and seeds are rich in dietary fibre and low carbohydrates and lipids. Thus, Dolichos bean is very important from nutritional point of view due to changing pattern of lifestyle and food habit of people.

Dolichos Bean has immense health benefits. The bean constitutes an important source of therapeutic agents used in the modern as well as traditional systems of medicine (Morris 2003, Morris 2009). The seeds of dolichos bean are used as a laxative, diuretic, anthelmintic, anti-spasmodic, aphrodisiac, anaphrodisiac, digestive, carminative, febrifuge and stomachic (Chopra *et al*.,1986; Kirtikar & Basu 1995). Dolichos Bean contains the potential breast cancer fighting flavonoid known as 'Kievitone' (Hoffman, 1995). The flavonoid 'Genistein' found in dolichos bean play a role in the prevention of cancer (Kobayashi *et al.*, 2002) and acts as a chemotherapeutic agent for head and neck cancer (Alhasan *et al*., 2001). The bean contains 'Tyrosinase' which has potential for the treatment of hypertension in humans (Morris 2009) and is present in the plant tissues important in fruit and vegetable processing as well as storage of processed foods.

This crop also helps in soil improvement, soil protection and weed control (Shivashankar and Kulkarni, 1989) and also used as green manure (Morris, 1997). It is a drought tolerant crop which can be grown in dry lands with limited rainfall and can be intercropped in newly established orchard.

Although dolichos bean has been originated and cultivated in India since long time, the crop remained underexploited due to low productivity, photosensitivity, flowering irregularity, growth habit and the preference of consumers with respect to pod shape, pod size, pod color, pod aroma. Though wide genetic base exists for breeding programme, very little efforts or work have been made for its genetic improvement of yield and quality attributing characters. The evaluation of potentialities of the existing varieties is essential because it is the genetic diversity of the initial parent material which helps in further crop improvement.

A great range of variability with plant and pod characters of pole type of dolichos bean is found all over the country (Peter & Kumar, 2008) and thus variability can be exploited for evolving a high yielding type. The success of any breeding programme and improvement of specific trait through selection in particular totally depends upon the genetic variability present in the available germplasm of the crop (Parmar *et al*., 2013). It is very difficult to judge whether observed variability is heritable or due to environment alone. Moreover, knowledge of heritability is essential for selection based improvement as it indicates extent of transmissibility of character in future generations. Heritable variation can be determined with greater accuracy, when heritability is studied along with genetic advance.

Among the quantitative characters, yield is a complex character, which is dependent on a number of yield contributing characters (Savitha, 2008). The knowledge of association between yield and its contributing characters will be important for breeding programme for an effective ‘Plant Selection’ of high yielding genotypes. Partitioning of total correlation into direct and indirect effects of various characters by path analysis helps in making the selection more effective (Biju *et al*., 2001) and helps in identifying the most promising components and minimizes undesired characters in the selection process.

Dolichos bean is very popularly grown in Odisha as a rainfed crop in *kharif* and there exists less genetic variability among the varieties available in Odisha. So, keeping in view of the above facts, the field experiment has been designed for further crop improvement for the selection of superior genotypes in dolichos bean with the following objectives:

1. To evaluate the yield and yield attributing characters in pole type of dolichos bean.

2. To estimate the variability, character association and path analysis in pole type of dolichos bean.

REVIEW OF LITERATURE

In the present investigation, a sincere effort has been made to review the genetic variability, heritability, character association, path coefficient analysis and genetic divergence in pole type of dolichos bean. The literature available related to present study entitled "Variability studies in pole type of Dolichos bean (*Lablab purpureus* L.)" have been reviewed in this chapter under the following broad outline.

2.1 Yield and yield attributing characters, variability and heritability

2.2 Character association and Path analysis

2.1 Yield and yield attributing characters, variability and heritability

Bendale *et al*. (2004) conducted studies on dolichos bean genotypes and found higher heritability percentage as well as higher genetic advance for leaf area, number of branches per plant, number of pods per plant as well as yield per plant.

Rai *et al*. (2008) evaluated 46 genotypes of Indian bean and observed that the PCV values were slightly greater than GCV. High heritability was expressed for days to flowering, number of pods per plant, pod length and pod yield per plant along with high genetic advance was observed for number of pods per plant followed by days to first flowering and days to first picking. Genetic advance as per cent of mean was observed maximum for number of pods per plant and pod yield per plant.

Mohan *et al*. (2009) conducted a replicated experiment for pod yield and pod related traits at IIHR, Bangalore by taking fifty seven pole type vegetable dolichos bean (*Lablab purpureus* var. *typicus*) germplasm lines. IIHR 177 was the earliest to flower in 43 days and pods matured in 65 days. IIHR 6 recorded maximum pod length (16.5 cm), ten-pod weight was maximum in IIHR 7 (122 g), pod width was highest in IIHR 11 (4.05 cm). Number of pods per plant ranged from 10 to 91 which was maximum in IIHR 159. Maximum pod yield was recorded in IIHR 150 and IIHR 159 (576.0 g/plant).

Chattopadhyay and Dutta (2010) evaluated twelve genotypes of pole type dolichos bean (*Lablab purpureus* var. *typicus*) for their genetic variability and character association among nine quantitative traits and revealed that 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/plant (768.3-1897), protein content of pod (0.70-5.45%) and pod yield/plant (5.07-12.21 kg). Characters like protein content of pod, number of pods/plant, breadth of pod, weight of pod and pod yield/plant exhibited high GCV, PCV, heritability and genetic advance as per-cent of mean due to the action of additive genes controlling the characters.

Upadhyay and Mehta (2010) reported a wide range of variability for most of the characters in dolichos bean. The highest genotypic coefficient of variation was recorded for pod width followed by pod length and lowest in number of seeds per pod. The highest heritability estimate was observed for marketable pod weight, pod width, hundred seed weight and number of pods per inflorescence.

Islam *et al*. (2011) studied forty four hyacinth bean genotypes and found large variation among the genotypes for all the characters. Green pod yield per plant varied from 0.46 kg to 3.45 kg indicating the presence of high yielding genotypes. High GCV was obtained for 100-green seed weight, pod yield per plant, number of pods per plant and harvesting duration. The highest heritability was observed for days to first flower (98.39%) followed by days to first harvest (96.1 %).The pod yield per plant also exhibited high heritability of 77.9% with highest genetic advance (68.28) indicating the possibility of selection to improve this traits.

Magalingam *et al*. (2013) evaluated 23 genotypes of dolichos bean and reported that the difference between PCV and GCV was narrow for all characters except percentage of pod set. Hence, these characters were less influenced by environment. High GCV and heritability estimates were associated with greater genetic advance for the nine traits viz., percentage of pod set, number pods per cluster, number pods per plant, green pod length, green pod width, individual green pod weight, pod yield, crude protein and crude fibre indicating that these characters had additive gene effect and were more reliable for effective selection in crop improvement.

Parmar *et al*. (2013) evaluated thirty genotypes of Dolichos bean (*Lablab purpureus*) to study the genetic variability on yield, yield contributing and related

characters and reported that highest and lowest coefficient of variation was observed for single podded clusters per plant and protein content respectively. PCV was high for the single podded clusters per plant and the lowest phenotypic coefficient of variation was observed in protein content. Days to 50% flowering, pod length, width of pod, weight of 10 green pods accounted for higher heritability and higher genetic advance which suggests the role of additive gene action in the expression of these characters and could be improved through selection.

Pawar and Prajapati (2013) by taking 58 genotypes of Indian bean concluded that highest GCV was recorded for grain yield per plant followed by number of inflorescences per plant and number of pods per plant. Heritability estimates were high for days to 50% flowering, protein content, days to maturity, pod length and plant height. The expected genetic advance as a percentage of mean was high for grain yield per plant, number of inflorescences per plant, number of pods per plant, pod length and plant height. High heritability coupled with high genetic advance was exhibited by plant height and pod length indicating the presence of additive gene action.

Chaitanya *et al*. (2014) evaluated forty eight vegetable pole type dolichos bean (*Dolichos lablab* var. *typicus)* germplasm lines in a replicated experiment for pod yield, yield attributing characters and qualitative characters, analysis of variance, range, mean, genotypic and phenotypic coefficients of variability, heritability and genetic advance were estimated for 19 quantitative characters. High genetic variability was noticed for marketable pod yield per plant, number of pods per plant, number of pods per inflorescence, number of inflorescences per plant, length of inflorescence, number of flowers per inflorescence, plant height, pod weight, pod length, 100 seed weight. High values of heritability as well as high genetic advance were recorded for all the characters except for days to first pod harvest, pod width and number of seeds per pod indicating additive action of genes controlling them.

Chaitanya *et al*. (2014) evaluated thirty four genotypes of dolichos bean for genetic variability among characters. Genetic and phenotypic coefficient of variation, heritability and genetic advance as per cent of mean were estimated for fifteen yield and yield contributing characters. The differences between PCV and GCV were low for days to first flowering, days to 50% flowering, inter node length (cm), days to first

pod harvest, pod length (cm), pod width (cm), pod weight (g), plant height (cm) and number of seeds per pod indicating that these traits are less influenced by environment and the effect of heritable components was high. High heritability coupled with high genetic advance as per cent of mean was recorded by all the characters except for leaf width (cm), leaf length (cm) and number of pods per plant indicating additive action of genes controlling them.

Kulkarni and Musmade (2014) studied genetic variability, heritability and genetic advance studies in French bean and reported high heritability for thickness of pods, green pod yield per plant, number of seeds per pod, weight of 100 seeds and plant height. Highest heritability coupled with high genetic advance was obtained for plant height, total leaf area and green pod yield per plant.

Kumar *et al*. (2014) evaluated forty four genotypes of French bean for eighteen quantitative characters and found wide variability for all the characters studied. Maximum variation was showed by marketable pod yield per plant followed by plant height, number of pods per plant, number of inflorescences per plant and 100 seed weight. GCV values were high for length of inflorescence, number of pods per plant, marketable yield per plant and 100 seed weight. High heritability coupled with high expected genetic advance as percentage was observed for all the traits indicating the additive gene effects.

Mohan *et al*. (2014) studied fifty seven pole type vegetable dolichos bean (*Lablab purpureus* L.) germplasm lines and reported that GCV was comparatively high in days to 50% flowering, days to pod maturity, pod length, pod weight, number of pods per cluster, number of pods per plant, pod yield per plant and pod width. High heritability estimates were observed for number of pods per plant, pod yield per plant, pod weight, days to 50% flowering, pod length, days to pod maturity, pod width and number of pods per cluster. High genetic advance, along with relatively high heritability per cent, was observed for number of pods per cluster and pod width. Existence of wide variation along with high heritability and genetic advance for number of pods per cluster, pod length, pod width and pod yield per plant indicate that selection would be effective for these traits.

Sharma *et al*. (2014) conducted an experiment with 23 genotypes and 2 commercial varieties of dolichos bean and reported that genotype 10/DOLPVAR-6 exhibited maximum spikes/plant, number of pods/cluster, number of seeds/pod, 25 pods weight, pod length, pod width, 1000 seed weight, pod yield/plant, pod yield/plot and pod yield/ha. High level of phenotypic coefficient of variation, genotypic coefficient of variation, heritability with genetic advance for number of flowers/cluster, pod yield/plant, pod yield per plot and pod yield per ha could be improved through direct selection.

Asaduzzaman *et al*. (2015) studied on genetic variability, heritability and genetic advance with 14 genotypes of Lablab bean (*Lablab purpureus* L.) and found that highest genetic and phenotypic variation were observed for green pod yield per plant. Heritability values were higher for days to maturity (81.37) , number of raceme per plant (80.62), pod length (99.43), pod width (99.27), green pod yield per plant (89.29), dry shelling percentage (91.58), seed yield per plant (84.93) and protein content (98.11) indicating the better potentials of improving these characters for improvement of yield. Maximum genetic advance expressed as percentage of mean was recorded for green pod yield per plant (95.22).

Das *et al*. (2015) evaluated thirteen pole and seven bush type advanced lines/varieties of dolichos bean to study the genetic variability and character association among different quantitative characters with pod yield. Higher estimates of PCV and GCV were observed for number of pods per plant and pod weight in pole and bush types, and pod length in bush type, indicating much scope for their improvement through selection. The characters pod weight, number of pods per plant, pod length and pod width were characterised by high heritability coupled with high genetic advance in both types.

Devi *et al*. (2015) evaluated thirty three genotypes of French bean and reported high phenotypic and genotypic coefficient of variations for pod yield/plant and pods/plant in both the years and also pooled over years, indicating high potentiality of these traits for effective selection. These traits also showed high heritability coupled with high genetic advance in the respective years and in pooled years which indicated the role of additive gene action for the inheritance of these traits and are likely to respond better to selection.

Dhillon and Kumar (2015) studied variability, heritability, and correlation in 30 strains of dolichos bean (*Lablab purpureus* L.) for various growth and yield attributing parameters. High phenotypic and genotypic coefficient of variation was found in number of flowers per cluster, fresh green pod yield per plant, green pod yield per hectare, and mineral content. High heritability and expected genetic advance was found in number of flowers per cluster, vine length, weight of 10 green pods, fresh green pod yield per plant, and green pod yield per hectare.

Jyoti *et al*. (2015) studied genetic variability in thirty three genotypes of French bean and found sufficient variability for all the characters *viz.* days to flowering, days to first picking, average pod weight, pod length, pods per plant, plant height, and pod yield per plant. High PCV and GCV were recorded for pod yield per plant and pods per plant. High heritability coupled with high genetic advance were also seen in these traits.

Kumar and Ram (2015) evaluated 30 genotypes of Cluster bean and found highest range of variation for pod yield (q/ha) followed by pod yield/plant (g). The coefficient of variation was minimum for number of branches/plant at maturity followed by days to maturity. Coefficient of variation was maximum for pod width (cm) followed by pod breath (cm). In the first year, heritability estimates were high for all the characters except pod width (cm), pod breath (cm) and days taken for first flowering, whereas in the second year pod breath (cm), days taken for 50 % flowering, pod width (cm), pod length (cm) and number of pods/plant attain lower heritability values. High heritability with high genetic advance were found with number of clusters/plant, number of pods/plant, pod yield/plant (g), plant height (cm), days to maturity, pod yield/plant (g), number of pods/plant, number of clusters/plant and pod yield (q/ha), indicating that selections based on phenotypic performance could be effective for improvement of these characters.

Lenkala *et al*. (2015) studied fifteen genotypes of Jack bean for variability, correlation and path analysis. The characters like plant height at first harvest, number of primaries per plant at first harvest, plant height at last harvest, number of primaries per plant at last harvest, pod weight, number of pods per plant, number of seeds per pod, 100 seed weight and pod yield per plant were observed with high genetic variability, high heritability in conjunction with higher genetic advance as per cent

mean indicating the predominance of additive gene action on the expression of these traits and hence direct selection will be rewarding for improvement of these traits in Jack bean.

Singh *et al*. (2015) evaluated twenty four dolichos bean genotypes from different parts of India for ten quantitative traits. Moderate to low genotypic and phenotypic coefficients of variation were recorded for all the traits. High heritability (70.97%) and high genetic advance (74.96%) were observed for plant height, while high heritability (64.24%) but low genetic advance (2.58%) were recorded for pod length.

Choudhary *et al*. (2016) evaluated sixty four genotypes of Indian bean (*Lablab purpureus* L.) for genetic variability and correlation coefficient analysis for green pod yield and its contributing characters and found that Plant height, seed yield per plant, seed yield q/ha, green pod yield per plant, green pod yield q/ha, pod width, weight of 10 pod, number of green pod per plant, pericarp thickness and days to first flowering exhibited high GCV and PCV values indicating large amount of variation. The highest heritability estimate was observed for days to last picking (99.60 %).

Kambale *et al*. (2016) evaluated ninety one progenies from F_4 generation along with one check of Lablab bean to study the genetic variability for yield and yield attributing traits. The highest and lowest coefficient of variation was observed for hundred seed weight and days to maturity respectively. A wide range of variation exhibited for yield and yield attributing traits among the progenies under study. The traits *viz*. hundred seed weight, number of pods per plant, seed yield per plant, plant height and number of peduncles per plant recorded high magnitude of GCV and PCV along with high to moderate estimates of heritability. The high estimates of heritability coupled with high genetic advance as per cent of mean was noticed for hundred seed weight and plant height which indicate additive gene action and more reliable for effective selection in improvement of lablab bean.

Dewangan *et al*. (2017) carried out a study on genetic variability, heritability and genetic advance for 17 traits in 38 genotypes of dolichos bean (*Lablab purpureus* L.).The highest value of genotypic coefficient of variation (GCV) was recorded for inflorescence length (28.10%). The highest value of phenotypic coefficient of

variation (PCV) was recorded for inflorescence length (28.16%). The highest heritability estimate was observed for days to 50% flowering (99.95%). The highest genetic advance as percent of mean observed for inflorescence length (57.76). Hence selection will be effective for these traits.

Hadavani *et al*. (2018) evaluated fifty diverse genotypes of Indian bean in a RBD with three replications to study the genetic variability parameters. The analysis of variance revealed that mean square due to genotypes was highly significant for all seventeen characters studied. A wide range of variation was observed for green pod yield per plant, 10-green pod weight, seed yield per plant, plant height and number of pods per plant. High phenotypic and genotypic coefficient of variations, high heritability coupled with high genetic advance as per cent of mean was observed for 10-green pod weight, green pod yield per plant, number of pods per plant, seed yield per plant, pod width, 100-seed weight, pod length and plant height.

2.2 Character association and path analysis

Basavarajappa and Byre Gowda (2004) reported significant and positive association of seed yield with pod yield per plant, pods per plant, branches per plant, days to 50 per cent flowering, days to maturity, plant height, inflorescence per plant and 100 seed weight also showed positive direct effect on pod yield per plant in field bean.

Ali *et al*. (2005) reported 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 in lablab bean. Pod length showed positive significant correlation with yield per plant.

Lal *et al*. (2005) stated that yield per plant is the most important economic trait in dolichos bean and it exhibited positive character association with pod weight (0.31) and number of pods per plant (0.41). The high and positive correlation was observed for pod length with pod weight (0.58) and seeds per pod (0.56).

Lovely and Radhadevi (2006) conducted association studies in fifty genotypes of yardlong bean and observed that pod yield per plant had strong positive correlation with pods per cluster, pods per plant, pod weight, pod length, pod breadth and seeds per pod.

From the correlation and path coefficient analysis, it revealed that 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 (Chattopadhyay and Dutta, 2010)

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

Angadi *et al*. (2012) studied path coefficient analysis in twelve genotypes of French bean and reported that leaf area, pod weight, number of seeds per pod, number of pods per plant, pod length and pod width exerted maximum direct effect on pod yield per hectare at genotypic and phenotypic level. Leaf area index exerted highest indirect effect on pod yield per hectare through leaf area at genotypic level and pod length showed highest indirect effect on pod yield per hectare through weight of 10 pods at phenotypic level.

Anburani and Shalini (2013) evaluated 27 genotypes of dolichos bean from various sources in a randomized block design with three replications for two seasons. Path analysis revealed the existence of high magnitude of positive direct effect of pod weight, number of pods per inflorescence, number of branches per plant on yield of pods per plant in season I. In season II, the traits like pod weight, number of branches per plant, number of days taken for fruit setting and number of pods per plant had highly significant and positive direct effect on yield of pods.

Bahadur *et al*. (2013) studied genotypic and phenotypic correlation among different traits like plant height, number of primary branches per plant, number of inflorescence per plant, number of flowers per inflorescence, number of pods per inflorescence, number of pods per plant, number of seeds per pod, pod length, pod width and pod weight showed positive significant correlation with pod yield per plant at genotypic level. Plant height, number of primary branches per plant, number of

inflorescence per plant, number of flowers per inflorescence, number of pods per inflorescence, number of pods per plant, number of seeds per pod, pod length, pod width and pod weight showed positive significant correlation with pod yield per plant at phenotypic level.

Chaudhari *et al*. (2013) investigated forty vegetable Indian bean genotypes for variability, correlation and path analysis. Green pod yield was highly significantly and positively correlated with number of branches per plant, number of pods per cluster, number of pods per plant at both the genotypic and phenotypic levels. Path coefficient analysis indicated the high positive direct effect for number of pods per plant followed by number of seeds per pod and number of days to last picking. The character pod length exhibited high negative direct effect on green pod yield per plant followed by days to 50% flowering, plant height and days to first picking.

Pawar and Prajapati (2013) observed that grain yield per plant was positively and significantly correlated with days to 50% flowering, days to maturity, plant height, number of inflorescences per plant and number of pods per plant indicating their usefulness in selection for yield. The traits number of seeds per pod and pod length were negatively and significantly correlated with grain yield. Path analysis revealed highest positive direct effect of number of pods per plant while days to maturity and pod length exhibited high negative direct effects on grain yield per plant.

Salim *et al*. (2013) observed that seed yield/plant was positively and significantly correlated with days to first flowering, days to 50% flowering, days to first pod setting, number of pods/plant, pod yield/plant and seeds/pod, number of seeds/plant, and seed yield. Path coefficient analysis showed that days to first flowering, days to 50% flowering, number of pods/plant, 20 pod weight (g), pod yield/plant, pod length, number of seeds/pod, number of seeds/plant, 100 seed weight influenced seed yield/plant directly in positive direction. Among the characters, number of seeds/plant had high positive correlation with seed yield/plant. Days to first pod setting exhibited negative direct effects on seed yield. From this result, it can be concluded that days to first flowering, days to 50% flowering, number of pods/plant, pod yield/plant, number of seeds/pod, number of seeds/plant, 100-seed weight are the most important yield contributing characters as they influenced pod yield and seed yield directly in positive direction.

Asaduzzaman *et al*. (2014) studied fourteen genotypes of Lablab bean for sixteen yield and yield contributing characters. Seed yield per plant showed positive and significant correlation with days to maturity, number of raceme per plant, raceme length, pod length, green pod yield per plant, green test weight and shelling percentage and significant negative correlation with days to maturity, number of seeds per pod and protein content at both phenotypic and genotypic levels. Path analysis revealed that green pod length exhibited high positive direct effect on number of raceme per plant, raceme length, green pod width, dry test weight and shelling percentage. The direct negative effects on seed yield were observed by days to maturity, number of flower buds per raceme, green pod yield per plant, green test weight and protein content and revealed the importance of these traits for simultaneous selection of plant for yield improvement.

Kiran *et al*. (2014) stated that number of pods per plant, pod width, pod weight and pod length had positive correlation with pod yield per plant in dolichos bean. The traits like number of branches and leaf length showed positive relation with yield at the same time days to 50% flowering and days to first picking showed negative effect on yield.

Rai and Dharmatti (2014) evaluated thirty one genotypes of cluster bean and correlation studies indicated positive associations of vegetable pod yield per hectare (t) with plant height (0.315, 0.309), pods per cluster (0.322, 0.298), pods per plant (0.443, 0.389) and pod yield per plant (0.905, 0.787) at genotypic and phenotypic levels respectively. Genotypic path analysis shows that yield per plant exhibited positive direct effect (1.138) and had strong positive association with yield per hectare (r_g=0.905). The positive indirect effects were through days to 50% flowering (0.015), pods per cluster (0.035) and pod breadth (0.046). Phenotypic path coefficient shows that yield per plant had high positive direct effect (0.879) and strong degree of association (0.787) for pod yield per hectare. This direct effect is mainly due to the indirect effect of trait positively through plant height (0.043), pods per plant (0.023), pod length (0.025) and pod width (0.002) suggesting that these parameters may be considered as prime traits during the course of selection to have the higher potential of yield.

Ravinaik *et al*. (2014) assessed nine genotypes of dolichos bean where pod yield per plant was significant and positively correlated with plant height, number of branches per plant, number of flowers per cluster, number of pods per cluster, average weight of pod, pod length, pod width, number of seeds per pod and number of pods per plant at both phenotypic and genotypic levels, but days to 50 per cent flowering had kept significant and negative correlation with pod yield per plant at both genotypic and genotypic levels. Path co–efficient analysis revealed that pod yield per plant had highest positive direct effect on number of flowers per cluster followed by number of pods per cluster, pod width, days to 50 per cent flowering, number of branches per plant, pod length but number of pods per plant, plant height, average weight of pod and number of seeds per pod had negative effect on pod yield per plant at genotypic levels whereas at phenotypic level, number of pods per plant had direct effect on pod yield per plant followed by number of branches per plant, pod width, average weight of pod, days to 50 per cent flowering on the other hand, number of pods per plant, number of flowers per cluster.

Das *et al*. (2015) revealed that interrelationships among component characters and pod yield had a significant and positive correlation with number of pods per plant at genotypic level in pole type and none of the traits in bush type. However, positive correlation with pod yield was depicted by pod length, pod width and number of seeds per pod in pole type and by number of pods per plant in bush type.

Devi *et al*. (2015) reported positive and significant correlation of pod yield with days to flowering, average pod weight, branches/plant, pods/plant and plant height was observed, thereby emphasizing special focus on these traits for the improvement of yield.

Dhillon and Kumar (2015) found that genotypic correlation was higher than phenotypic correlation. Yield per plant was positively and significantly correlated with number of branches per plant, number of pods per cluster, number of pods per plant, weight of 10 green pods, number of clusters per plant, and number of flowers per cluster.

Haralayya *et al*. (2015) studied path coefficient analysis in thirty six french bean genotypes. Pod length was found to have highest direct positive contribution

(0.314) towards green pod yield per plant followed by plant height (0.194), days to 50% flowering (0.148) and flower to pod setting ratio (0.107).

Verma *et al*. (2015) studied 12 genotypes of dolichos bean (*Lablab purpureus* L.) and correlation coefficient analysis revealed that number of secondary branches per plant, number of inflorescences per plant, number of pods per inflorescence, number of pods per plant, number of seeds per pod, pod width, days to last harvest and 100 seed weight had the significant positive correlation with marketable green pod yield per plant. Path analysis revealed true relationship between yield and number of secondary branches per plant, number of pods per inflorescence and number of pods per plant and direct selection for these traits will be rewarding for yield improvement as correlation was due to direct effect of the characters. Hence, selection based on these characters could be effective in developing high yielding varieties of dolichos bean.

Choudhary *et al*. (2016) reported that green pod yield per plant showed positive and significant correlation with green pod yield q/ha, seed yield q/ha, plant height at 60 days, days to first flowering, days to first picking, days to last picking, weight of 10 pod, weight of 100 seed, number of green pod per plant, pod length, pericarp thickness, moisture percentage and seed yield per plant at both genotypic and phenotypic levels.

Kanwar *et al*. (2017) studied path coefficient analysis in 28 genotypes of French bean and reported that pod length had the highest positive direct effect on seed yield per plant followed by number of seeds per pod, number of pods per plant, days to 50% flowering, number of branches per plant, leaflet width, harvest duration, plant height at final harvest and 100 seed weight.

Patil *et al*. (2017) studied thirty seven pole type of dolichos bean (*Lablab purpureus* L.) genotypes for character association between yields and its component characters as well as path analysis. The genotypic correlation coefficient was higher than phenotypic coefficient of variation for all most all characters under study. Number of pods per vine, pod length, pod width and average weight of 10 pods showed highly significant positive correlation with green pod yield per plot. Path analysis indicated that number of pods per in florescence, number of pods per vine,

days to 50 per cent flowering and weight of 10 pods had positive direct effects on green pod yield. These traits could therefore be useful for yield improvement programme of pole type dolichos bean.

Lyngdoh *et al*. (2018) conducted correlation studies in eighteen genotypes of french bean and reported that pod yield per plant was significantly and positively correlated with number of pods per plant, pod set per inflorescence, plant height and number of leaves per plant. Number of pods per plant (0.917), pod girth (0.791), plant height (0.765), flowers per inflorescence (0.529), pod length (0.284) and days to first flowering (0.134) had high and positive direct effect on pod yield as concluded from path analysis.

Radhelal *et al*. (2018) reported that green pod yield per plant was significantly positive correlated with 100 seed weight, pod length, pod width, pod per inflorescence, seeds per pod, pod weight, vine length, number of green pod picking and days to last green pod harvest, at genotypic as well as phenotypic level. Hence direct selection for these traits may lead to the development of high yielding genotypes of dolichos bean. The data revealed that 100 seed weight showed highest direct positive effect on green pod yield per plant followed by number of pods per inflorescence, days to last green pod harvest, pod length, days to first flowering, vine length, pod width and seed per pod.

Noorjahan *et al*. (2019) studied path analysis in dolichos bean and revealed that green pod yield per plant was significantly and positively direct effect with 50 per cent flowering, length of inflorescence, number of grains per pod, pod yield per hectare and negative direct effect with days to first flowering, number of flowers per inflorescence, number of pods per inflorescence, first pod harvest, pod length, pod width, mean pod weight.

MATERIALS AND METHODS

The present investigation entitled "Variability studies in pole type of Dolichos bean (*Lablab purpureus* L.)" was conducted at All India Co-ordinated Research Project on Vegetable Crops, Odisha University of Agriculture and Technology, Bhubaneswar during Rabi, 2018-19 to study the yield and yield attributing characters, variability, character association and path analysis with fourteen genotypes of pole type of Dolichos bean.

The details of the materials used and methods adopted during the course of investigation are described in this chapter.

3.1 Geographical location of the experimental site

The experiment was carried out at Research plot of AICRP on Vegetable crops under Odisha University of Agriculture and Technology, Bhubaneswar, 751003. The location of the farm is situated at about 5 km away from the university campus. Bhubaneswar is located at latitude of 20°15' N and longitude of 85°52'E. It is about 60 km away from Bay of Bengal with an altitude of 25.5 m above mean sea level (MSL).

3.2 Cropping history of the plot

In the experimental plot, dolichos bean was grown in the previous season. The plot was properly ploughed, levelled and brought to proper tilth before planting the seeds of dolichos bean.

3.3 Soil and climate

The soil type of the experimental plot was loamy sand with a pH of 5.5.

The experimental site comes under the fourth agro-climatic zone of Odisha *i.e.* Eastern Coastal Plain and is characterized by hot and humid climate with mild winter. The average temperature varies from 14ºC in winter, 40ºC in summer and 30ºC in rainy season and relative humidity varies from 49 to 90% from June to December.

The average annual rainfall of Bhubaneswar was 1552 mm during 2018 *Kharif*. Most of the rainfall of about 85% is received from July to September.

During the experimental cropping season, the monthly average meteorological data was recorded at meteorological observatory of Odisha University of Agriculture and Technology, Bhubaneswar and is presented in (Table 3.1).

Table 3.1 Meteorological data (September 2018 to February 2019) during the experimental period

MONTH	Temperature (ºC)		Rainfall	Relative Humidity (%)		Wind Velocity (Km/hr)	Bright Sunshine hour
	Max	Min	Daily (mm)	7 hr	14 hr		
September, 2018	32.6	25.2	390.4	94	74	0.5	4.7
October, 2018	32.5	22.8	236.8	94	60	0.5	6.5
November, 2018	31.5	18.7	0.0	93	48	0.3	7.7
December, 2018	27.2	14.1	11.1	89	45	0.5	5.8
January, 2019	28.5	13.0	0.0	95	38	0.3	6.5
February, 2019	32.9	17.0	24.6	94	35	0.5	7.9
March, 2019	35.2	23.2	7.1	92	46	0.8	7.2

3.4 Experimental details

(i) Design of Layout : Randomized Block Design (RBD)

(ii) Number of Genotypes : 14

(iii) Number of Replications : 3

(iv) Total no. of plots: 42

(v) Each Plot size in experiment:

a) Length: 3.0 m

b) Width: 2.7 m

c) Area: 8.1 m^2

d) Plant population/plot: In each plot, four basins were prepared and in each basin three plants were maintained i.e.12 plants/plot.

3.5 Experimental material

The experimental material consisted of fourteen genotypes collected from different regions are presented in table 3.2.

Table 3.2 Sources of dolichos bean genotypes (*Lablab purpureus* L.)

Genotypes	Name	Sources (V_1-V_{11},V_{13} seeds received from IIVR)
V1	2016/DOLPVAR-1	AVT-2, AICRP on Vegetable crops, OUAT
V2	2016/DOLPVAR-2	AVT-2, AICRP on Vegetable crops, OUAT
V3	2016/DOLPVAR-4	AVT-2, AICRP on Vegetable crops, OUAT
V4	2016/DOLPVAR-5	AVT-2 , AICRP on Vegetable crops, OUAT
V5	2016/DOLPVAR-6	AVT-2, AICRP on Vegetable crops, OUAT
V6	2016/DOLPVAR-8	AVT-2, AICRP on Vegetable crops, OUAT
V7	2016/DOLPVAR-9	AVT-2, AICRP on Vegetable crops, OUAT
V8	2016/DOLPVAR-10	AVT-2, AICRP on Vegetable crops, OUAT
V9	2016/DOLPVAR-11	AVT-2, AICRP on Vegetable crops, OUAT
V10	2016/DOLPVAR-12	AVT-2, AICRP on Vegetable crops, OUAT
V11	2017/DOLPVAR-1	AVT-1, AICRP on Vegetable crops, OUAT
V12	Pipili Local	Local collection from Pipili
V13	2017/BDB-2	AICRP on Vegetable crops, OUAT
V14	Athgarh Local	Local collection from Athgarh

LAYOUT OF EXPERIMENT

R_1	R_2	R_3
R_1T_1	R_2T_{13}	R_3T_{11}
R_1T_2	R_2T_5	R_3T_6
R_1T_3	R_2T_1	R_3T_{13}
R_1T_4	R_2T_7	R_3T_8
R_1T_5	R_2T_2	R_3T_{14}
R_1T_6	R_2T_8	R_3T_2
R_1T_7	R_2T_{12}	R_3T_{10}
R_1T_8	R_2T_4	R_3T_3
R_1T_9	R_2T_{14}	R_3T_{12}
R_1T_{10}	R_2T_{11}	R_3T_9
R_1T_{11}	R_2T_3	R_3T_5
R_1T_{12}	R_2T_6	R_3T_1
R_1T_{13}	R_2T_{10}	R_3T_7
R_1T_{14}	R_2T_9	R_3T_4

Design- RBD, Plot size- 3m x 2.7m, Treatments- 14

Fig. 3.1 Layout plan of experimental field

Land Preparation

Sowing of seeds

Tagging of plants

Field view before staking

50% flowering

Overall view of experiment

Harvesting

Harvested pods

Fig.3.2 Field activities

3.6 Cultural practices

3.6.1 Land preparation

The experimental field was brought to a fine tilth with thorough ploughing and levelling after the incorporation of 25 tons of FYM/ha during the final land preparation and then plots were prepared as per the plan of layout (Fig-3.1). The experiment was laid out in Randomized Block Design (RBD) with three replications. The fourteen genotypes of the experiment were distributed randomly in each replication.

3.6.2 Sowing

Bold and healthy seeds of all fourteen genotypes were sown in different plots of each replication randomly on 25th September, 2018.

3.6.3 Fertilizer application

Recommended dose of fertiliser (20:60:60 NPK kg/ha) was applied for raising the crop. 50% of nitrogen, full phosphorous and 50% of potash was applied as basal and the rest nitrogen and potash were applied during the first flowering.

3.6.4 Irrigation

The crop requires irrigation in regular interval as per the soil moisture status in the experimental plot. Critical stages of irrigation in dolichos bean are flowering and pod development stage. Therefore, the crop was irrigated through basin irrigation system at every two weeks interval as per the soil moisture status.

3.6.5 Intercultural Operations

Weeding: Weeds are the major problem for dolichos bean during their early growth. Hand weeding was done at periodic intervals for raising a successful crop.

Staking: As the fourteen genotypes of dolichos bean are of pole type, staking was given to each plant for the proper growth, support and fruiting of the dolichos bean.

Adequate plant protection measures were taken up by spraying necessary fungicides and insecticides at periodic interval for better yield of the crop. Aphid was a major problem and was controlled by spraying Imidachloprid as per requirement. Dose: 17.8 SL (3ml/4lit of water).

3.6.6 Harvesting

Tender pods were harvested as they are the edible part in dolichos bean from the month of December and continued till March depending on different genotypes.

3.7 Biometric observations recorded

3.7.1 Sampling procedure

Five plants were selected randomly from each entry and were tagged with yellow ribbons in each replication for recording observations on different parameters as described below and the mean table was prepared.

i. Vegetative growth parameters

a. Plant height

Plant height was taken at 30 days from planting and at the time of last harvest from each of the five tagged plants of every plots. It was measured from the base to the top of the plant and expressed in cm.

b. Number of primary branches

Number of primary branches from the base of each plant was counted for all the five tagged plants of every plots and the average was calculated.

c. Stem thickness

The thickness of stem of the plants was measured with the help of a thread and was put on the meter scale and expressed in cm for all the five tagged plants of each genotypes.

d. Internodal length

The intermodal length between the 10th and 11th node was measured for all the five tagged plants and the average was calculated.

e. Average leaf area

Five fully grown leaves were collected randomly from five tagged plants at active growth stage and leaf area was recorded with the help of leaf area meter in cm^2. The mean value was calculated as leaf area.

f. Average leaf weight

The same leaves taken for calculating leaf area were weighed in g and the average was calculated for every plots.

g. Inflorescence length

The length of each inflorescence from the five tagged plants was measured in cm and the average was calculated.

h. Fresh weight of roots

The roots of three tagged plants were uprooted at the final harvest and cut from the base of each plant. It was cleaned and fresh weight of the roots was measured in g.

i. Leaf shape

The leaf shape was observed for each genotype and classified accordingly.

j.. Leaf colour

According to leaf colour variation, leaves were categorised as light green, green and dark green colours.

k. Pod shape

The pods of each genotype were observed and were classified as flat or round in shape.

l. Pod colour

Pod colour was observed for all genotypes and classified as green, butter green, purple etc.

ii. Yield and yield attributing parameters

a. Days to 1st flowering

Days to first flowering was recorded by counting the number of days taken from date of planting to first flowering in all the five tagged plants of each plots.

b. Days to 50% flowering

Days to 50% flowering was recorded by counting the number of days from date of planting to 50% flowering of the plants for each genotype.

c. Pod length

The length of ten number of randomly selected pods from the five tagged plants of each plot were measured in cm and the average was calculated.

d. Pod width

The width of ten number of randomly selected pods from the five tagged plants of each plot were measured in cm and the average was calculated.

e. Pod weight

The ten number of pods selected for measuring the length and width were taken for measuring the weight in grams and the mean value was calculated.

f. Number of pods per plant

The total number of pods harvested at different pickings in the sample plants was counted and the mean values were calculated.

g. Number of seeds per pod

Ten number of randomly selected pods taken from the sample plants for earlier observation were taken to count the number of seeds per pod and average was calculated.

h. Pod yield per plant

This was recorded by weighing the harvested pods from the five tagged plants per plot at different harvests in each replication and the mean of five plants was expressed in terms of grams per plant.

i. Pod yield per hectare

The total yield obtained from each plot was converted to yield per hectare and was expressed in quintals per hectare.

3.8 Statistical analysis

The data recorded for various characters were put to statistical analysis based on their sample means (Gomez and Gomez, 1983). Observations of all the characters were analysed for variability and other genetic parameters related to pod yield were taken for the study of character association and path analysis.

3.8.1 Analysis of variance

The analysis of variance for each of the characters was calculated to find out the varietal differences. The analysis was done separately for each trait following the procedure of randomized block design analysis.

Analysis of variance was done on the basis of the following model.

$$Y_{ij} = m + g_i + r_j + e_{ij}$$

Where,

Y_{ij} = Phenotypic observation in the ith genotype and the jth replication

m = General mean

g_i = Effect of the ith genotype/treatment

r_j = Effect of jth replication

e_{ij} = Random error associated with i^{th} genotype and j^{th} replication

Table 3.3 Analysis of variance and expected mean sum of square

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	Expected MSS
eplication	(r-1)	RSS	RMSS	RMSS/EMSS
Genotype	(g-1)	GSS	GMSS	GMSS/EMSS
Error	(r-1) (g-1)	ESS	EMSS	-
Total	(rt-1)	TSS	-	-

Mean, range, standard error and critical differences

Sample mean values were calculated for each character by dividing the total by corresponding number of observations, while the highest and lowest values for each character were taken as the range. The S.E. and C.D. values were calculated by using the following formula.

Standard error mean (SEM) = $\sqrt{EMS/r}$

Critical difference (C.D.) = $\sqrt{2EMS/r}$ x t value at error df at 5% and 1% level of significance.

Where,

r = number of replications

EMS = Error Mean Sum of Square

Co-efficient of variation

For comparing the variability of two or more than two characters, co-efficient of variation was calculated by using the given formula:

$$\text{C.V.} = \frac{\text{SD}}{\text{X}} \times 100 = \sqrt{\frac{\text{EMS}}{\text{X}}} \times 100$$

Where,

S.D. = Standard deviation which is the square root of mean square due to error (EMS)

X = Experimental mean

3.8.2 Estimation of genotypic and phenotypic variances

Genotypic and phenotypic variances were estimated according to the formula which is given by Johnson *et al*. (1955).

Error variance = $\sigma^2 e = \frac{\mathbf{EMS}}{\mathbf{r}}$

Genotypic variance = $\sigma^2 g = \frac{\mathbf{GMS-EMS}}{\mathbf{r}}$

Phenotypic variance = $\boldsymbol{\sigma^2 p = \sigma^2 g + \sigma^2 e}$

Where,

EMS= Error mean sum of squares

GMS= Genotypic mean sum of squares

r = number of replications

3.8.3 Estimation of Genotypic and Phenotypic Coefficient of Variation

The genotypic co-efficient of variation (GCV) and the phenotypic co-efficient of variation (PCV) were calculated by the formula given by (Burton and Devane, 1953).

$$GCV\ (\%) = \frac{\text{Genotypic standard deviation}}{\text{Grand mean}} \times 100$$

$$PCV\ (\%) = \frac{\text{Phenotypic standard deviation}}{\text{Grand mean}} \times 100$$

3.8.4 Heritability

The heritability estimates were used to measure the degree of correspondence between phenotypic value and breeding value. It is worked out by using the formula suggested by Burton and Devane (1953) and expressed in percentage according to Weber and Moorty (1952).

$$h^2\ (\text{broad sense}) = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} = \frac{\sigma^2 g}{\sigma^2 p}$$

$$h^2\ (\text{broad sense in percentage}) = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100 = (\sigma^2 g / \sigma^2 p) \times 100$$

Variation in the quantitative traits occurs due to their degree of heritability. Heritability values are categorized as follows: (Robinson *et al*., 1949).

Percentage of heritability	**Category**
0-30	Low
31-60	Medium
>60	High

If the heritability percentage is observed as high, it indicates that characters are least influenced by environment and selection for this type of characters are fruitful for improvement purpose.

If the heritability percentage is observed as low, it indicates that characters are highly influenced by environment and selection for this type of characters is difficult for improvement programmes.

3.8.5 Expected genetic advance

Genetic advance was estimated as per the formula suggested by Johnson *et al*. (1955).

$$GA = K \times h^2 \times \sigma p$$

Where,

K = Selection differential in standard units (which is 2.06 per 5% selection intensity)

h^2 = Heritability in broad sense

σp = Phenotypic standard deviation

GA (expressed as percentage of mean) = GA/Mean x 100

The genetic advance as per cent over mean was categorized as mentioned below (Johnson *et al*., 1955).

Less than 10% = Low

10-20% =Moderate

More than 20%=High

3.8.6 Estimation of correlation co-efficient

Simple correlation co-efficient were computed at phenotypic and genotypic levels between pairs of important characters that contribute to pod yield using the following formula:

$$\text{Genotypic correlation } (r_g) = \frac{\sigma_g (xy)}{\sigma_g(x)} \times \sigma_g (y)$$

$$\text{Phenotypic correlation } (r_p) = \frac{\sigma_p(xy)}{\sigma_p(x)} \times \sigma_p (y)$$

Where,

$\sigma_g (xy)$ = Genotypic co-variance between the two traits x and y.

$\sigma_p(xy)$ = Phenotypic co-variance between the two traits x and y.

$\sigma_g(x)$ and $\sigma_g (y)$ = Genotypic standard deviation for x and y respectively.

$\sigma_p(x)$ and $\sigma_p (y)$ = Phenotypic standard deviation for x and y respectively.

The estimated values were compared with the table value at (n - 2) and at 5% and 1% levels of significance in order to test the significance of correlation co-efficient at phenotypic and genotypic levels.

3.8.7 Path co-efficient analysis

The cause and effect relationships among the various correlated characters are determined by path co-efficient analysis developed by Dewey and Lu (1959) using phenotypic correlation coefficient value. In path analysis, correlation coefficients between yield and yield attributing characters were partitioned into direct and indirect effects of yield attributing characters on pod yield per hectare. The path coefficients were obtained by solving the following simultaneous equations which give the basic relationship between correlations and path coefficients in a system of correlated causes.

$$r_{1.y} = P_{1.y} + r_{1.2} P_{2.y} + r_{1.3} P_{3.y} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + r_{1.10} P_{10.y}$$

$$r_{2.y} = r_{1.2} P_{1.y} + P_{2.y} + r_{2.3} P_{3.y} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + r_{2.10} P_{10.y}$$

$$r_{3.y} = r_{1.3} P_{1.y} + r_{2.3} P_{2.y} + P_{3.y} + \ldots\ldots\ldots\ldots\ldots\ldots + r_{3.10} P_{10.y}$$

$$r_{11.y} = r_{1.10} P_{1.y} + r_{2.10} P_{2.y} + r_{3.10} P_{3.y} + \ldots\ldots + P_{10.y}$$

Where,

$R_{1.y}$ = correlation coefficient between y and i^{th} character (y= pod yield)

$P_{i.y}$ = path coefficient due to i^{th} character (i= 1,2,3……..10)

Total correlation, say between 1 and y is thus partitioned as follows:

$P_{1.y}$ = Direct effect of 1 on y

$R_{1.2} P_{2.y}$ = Indirect effect of 1 via 2 on y

Where,

$P_{1.y}, P_{2.y}, P_{3.y}\ldots\ldots P_{10.y}$ = Path coefficient of the independent variables 1, 2, 3……,10 on the dependent variable y, respectively.

After calculating direct and indirect effect of the characters, residual effect (R) was calculated with the following formula:

$$P^2_{RY} (R^2) = 1-(r1.y + r2.y\ P2.y + \ldots\ldots\ldots\ldots\ldots + r10.y\ P10.y)$$

$$\mathbf{R= (P^2_{RY})^{1/2}}$$

RESULTS

The present study entitled **"Variability studies in pole type of Dolichos bean (*Lablab purpureus* L.)"** was conducted for evaluating the yield and yield attributing characters, for estimating the variability, heritability, genetic advance and the association between yield and yield attributing characters for an effective selection. The direct and indirect effect of these characters was also studied in path analysis. The result of the present study obtained is mentioned in this chapter under suitable sub headings.

4.1 Analysis of variance

The table 4.1 presents the analysis of variance i.e. the mean sum of squares between fourteen genotypes of pole type of dolichos bean for 17 characters to study the genetic variability. The data revealed the existence of significant differences among the genotypes for all the characters studied. The mean sum of square for genotypes was maximum in case of plant height followed by pod yield per plant. The characters like average leaf weight, stem thickness, number of primary branches showed minimum values for genotypic mean sum of squares.

Table 4.1 Analysis of variance (mean sum of squares) for 17 characters of 14 genotypes of dolichos bean

Sl. No.	Characters (df)	Mean sum of squares		
		Replications (2)	Genotypes (13)	Error (26)
1	Plant height(cm)	1860.21	34392.99**	1776.16
2	Number of primary branches	0.041	0.39	0.019
3	Stem thickness(cm)	0.066	0.17	0.04
4	Internodal length(cm)	1.93	10.66**	1.48
5	Average leaf area (cm^2)	46.17	146.27**	105.61
6	Average leaf weight(g)	0.064	0.14	0.10
7	Inflorescence length(cm)	1.72	91.33**	1.31
8	Fresh weight of root(g)	68.98	1722.52**	66.65
9	Days to first flowering	17.37	293.18**	11.39
10	Days to 50 % flowering	1.76	329.30**	15.60
11	Pod length(cm)	0.25	25.95**	0.69
12	Pod width(cm)	0.05	0.75	0.03
13	Pod weight(g)	13.54	17.83**	0.86
14	Number of pods per plant	229.74	1708.76**	92.52
15	Number of seeds per pod	0.02	0.81	0.06
16	Pod yield per plant(g)	28761.90	209857.18**	10656.40
17	Pod yield per hectare(q)	322.10	2592.14**	133.08

*significant at 5% level, **significant at 1% level

4.1.1 Mean performance of genotypes with respect to vegetative growth, yield and yield attributing parameters

The mean performance, standard error, critical difference and coefficient of variation values with respect to seventeen characters of 14 dolichos bean genotypes are presented in Table 4.2.

Growth parameters

Plant height

Wide variation was observed for plant height. Plant height varied from 274.67 to 632.67 cm, with an average plant height of 458.72 cm. 2016/DOLPVAR-9 (632.67cm) recorded the highest plant height followed by 2016/DOLPVAR-4 (603.5cm) and 2016/DOLPVAR-10 (596.67cm). The lowest plant height was observed in 2016/DOLPVAR-1 (274.67cm) followed by Pipili local (380.21cm).

Number of primary branches

2016/DOLPVAR-1 recorded maximum number of primary branches per plant (2.4) followed by 2016/ DOLPVAR-4 (2.2), 2016/ DOLPVAR-5 (2.07), 2016/ DOLPVAR-6 (2.07), 2016/DOLPVAR-9 (2.07). The lowest number of primary branches was observed in Athgarh local (1.2) followed by 2017/BDB-2 (1.33). The average mean value of the character was 1.78 which ranges from 1.2 to 2.4.

Stem thickness

2017/BDB-2 showed maximum stem thickness of 3.93cm followed by 2016/DOLPVAR-4 (3.91cm). The genotype Pipili local recorded lowest stem thickness of 3.03cm followed by Athgarh local (3.35cm). A range of 3.03 to 3.93cm was observed among the genotypes with an average of 3.58cm.

Internodal length

2016/DOLPVAR-10 recorded highest intermodal length of 18.25cm followed by 2016/DOLPVAR-8 (17.85cm), Athgarh local (17.59cm) and 2017/DOLPVAR-1 (17.11cm). The Lowest intermodal length was found in 2016/DOLPVAR-4 (11.67cm). A range of 11.67-18.25 cm was observed among the genotypes with an average of 15.74cm.

Average leaf area

2016/DOLPVAR-2 recorded significantly maximum average leaf area (100.48 cm^2) followed by 2017/DOLPVAR-1 (99.49 cm^2) and 2016/DOLPVAR-10 (98.07 cm^2) whereas, the lowest average leaf area was observed in the genotype Pipili local (81.17 cm^2) followed by 2017/BDB-2 (83.59 cm^2). Leaf area varied from 81.17 to 100.48 cm^2 with a mean value of 91.03 cm^2.

Average leaf weight

2016/DOLPVAR-10 showed maximum average leaf weight of (2.7 g) followed by 2016/DOLPVAR-8 (2.4 g). 2016/DOLPVAR-1 recorded the lowest average leaf weight of (1.87 g) followed by Athgarh local and 2016/DOLPVAR-4 (1.93 g). A range of 1.87 to 2.7 g was observed among the genotypes with an average of 2.13 g.

Inflorescence length

2017/DOLPVAR-1 showed maximum inflorescence length of 31.88cm among all the other genotypes. The genotype 2016/DOLPVAR-9 recorded lowest inflorescence length of 10.77cm followed by Athgarh local (12.71cm) and 2017/BDB-2 (12.61 cm). A range of 10.77 to 31.88 cm was observed among the genotypes with an average of 18cm.

Fresh weight of root

2017/BDB-2 showed maximum fresh weight of root of 160.18 g followed by 2016/DOLPVAR-8 (133.71). The genotype 2016/DOLPVAR-6 recorded lowest fresh weight of root of (73.18 g) followed by 2016/DOLPVAR-9 (73.62 g). A range of 73.18 to 160.18 g was observed among the genotypes with an average of 100.63 g.

Yield and yield attributing parameters

Days to first flowering

The days to first flowering ranged from 34.27 days to 67.1 days. 2016/DOLPVAR-6 (34.27) followed by 2016/ DOLPVAR-9 (41.15),

2016/DOLPVAR-4 (43.33) and 2016/DOLPVAR-1 (43.53) were earlier in flowering than the rest of the genotypes. The genotype 2017/BDB-2 (67.1) was found to be late in flowering followed by 2016/DOLPVAR-10 (64.53) and 2016/DOLPVAR-5 (62.6).

Days to 50% flowering

The results on days to 50% flowering revealed significant variation existing among the genotypes. Days to 50% flowering varied from 39.27 to 75.05 days. The genotype 2016/DOLPVAR-6 (39.27) is found to be earliest in days to 50% flowering followed by 2016/DOLPVAR-9 (46.28) and 2016/DOLPVAR-4 (48.26).The genotype 2017/BDB-2 (75.05) was found to be late in having 50% flowering followed by 2016/DOLPVAR-10 (70.26), 2016/DOLPVAR-5 (69.56) and Pipili local (69.4).

Pod length

Pod length was varied from 6.54 cm to 16.98 cm with an average value of 12.40 cm. The highest pod length was recorded in 2016/DOLPVAR-5 (16.98 cm) followed by 2016/DOLPVAR-9 (15.61 cm) and 2016/DOLPVAR-2 (15.34 cm). The lowest pod length was observed in 2016/DOLPVAR-4 (6.54 cm) followed by Athgarh local (7.1 cm).

Pod width

Pod width ranged from 2.05 cm to 3.79 cm. The highest pod width was observed in genotype 2016/DOLPVAR-12 (3.79 cm) followed by 2016/DOLPVAR-11 (3.49 cm. The lowest pod width was recorded in Pipili local (2.05 cm). The average fruit girth was 2.58 cm.

Pod weight

2016/DOLPVAR-12 recorded maximum pod weight of 14 g followed by 2016/DOLPVAR-11 (11.8 g), 2016/DOLPVAR-10 (11.67 g), and 2016/DOLPVAR-5 (11.63 g). On the other hand, the lowest pod weight was observed in Athgarh local (4.68 g) followed by 2016/DOLPVAR-4 (7.3 g), 2016/DOLPVAR-6 (7.83 g), and Pipili local (7.83 g). However, the range varied from 4.68 to 14 g with mean of 9.62 g of pod weight.

Number of pods per plant

Results on number of pods per plant recorded significant variation among the genotypes which range from 30.64 to 119.33, with a mean value of 66.43. Highest number of pods per plant was observed in 2016/DOLPVAR-4 (119.33) followed by 2016/DOLPVAR-9 (105). The lowest number of pods per plant was observed in Pipili local (30.64) followed by the genotype 2016/DOLPVAR-8 (34).

Number of seeds per pod

Seeds per pod ranged from 2.92 to 4.67 with an average of 3.98. Highest seeds per pod was recorded in 2016/DOLPVAR-5 (4.67) followed by 2016/DOLPVAR-10 (4.5) and 2016/DOLPVAR-9 (4.37). The lowest seeds per pod were recorded in Athgarh local (2.92) genotype followed by Pipili local (2.98).

Pod yield per plant

The results revealed that significant difference was found in between the genotypes for pod yield per plant which varied from 266.42 to 1185.58 g with mean value of 605.23 g. Five number of genotypes recorded more than the average value of 605.23 g per plant. Among the genotypes, 2016/DOLPVAR-9 (1185.58 g) produced maximum pod yield per plant followed by 2016/DOLPVAR-4 (1009 g) and 2016/DOLPVAR-12 (905.67 g). The lowest pod yield per plant was observed in genotype Pipili local (266.42 g) followed by Athgarh local (268.8 g).

Pod yield per hectare (q)

The pod yield per hectare ranged from 29.6 q/ha to 131.73 q/ha with an average of 67.29 q/ha. Among the genotypes, 2016/DOLPVAR-9 (131.73 q/ha) produced maximum pod yield per hectare followed by 2016/DOLPVAR-4 (112.12 q/ha) and 2016/DOLPVAR-12 (100.63 q/ha). The lowest pod yield per hectare was observed in genotype Pipili local (29.6 q/ha) followed by Athgarh local (29.86 q/ha).

4.1.2 Characterization of genotypes with respect to leaf and pod characteristics

Morphological characters like leaf shape, leaf colour, petiole colour, pod shape, pod size, pod colours of all accessions are given in Table 4.3.

Leaf shape

All the fourteen genotypes were found to be ovate in leaf shape.

Leaf colour

Based on leaf colour, the 14 genotypes were divided into two groups i.e. light green and green. Among them, 5 genotypes had leaves of light green in colour and rest had green coloured leaves.

Petiole colour

Based on petiole colour, the 14 genotypes were divided into three groups i.e. purple (5 genotypes), light green (6 genotypes) and green (3 genotypes).

Pod shape and size

Based on pod shape and size, the 14 genotypes were divided into pod shape as round (7 genotypes) and flat (7 genotypes) and pod size as long (10 genotypes), medium and short (2 genotypes each).

Pod colour

Based on pod colour, the 14 genotypes were divided into three groups *viz.*, green, purple and butter green. Among them, maximum genotypes had green pods, 2 genotypes had butter green pods and 1 genotype had purple pods.

Coefficient of variation

The estimation of Coefficient of variation (CV) ranged from stem thickness (5.38%) to pod yield per hectare (17.14 %). Relatively high CV value were observed for pod yield per plant (17.06 %), number of pods per plant (14.64 %), average leaf weight (14.62 %) and average leaf area (11.29%) then rest of the characters which recorded relatively lower CV.

Table. 4.2 Mean performance for 17 characters in 14 dolichos bean genotypes

Genotypes	Plant Height (cm)	Number of primary branches	Stem thicknes s (cm)	Internodal length (cm)	Average leaf Area (cm^2)	Average leaf weight (g)	Inflores-cence length (cm)	Fresh weight of root (g)	Days to first flowerin g	Days to 50% Flowerin g
2016/DOLPVAR-1	274.67	2.40	3.51	14.94	91.71	1.87	22.91	97.90	44.53	52.10
2016/DOLPVAR-2	382.20	1.67	3.45	14.88	100.48	2.09	21.18	115.79	53.67	58.28
2016/DOLPVAR-4	603.50	2.20	3.91	11.67	92.68	1.93	20.85	90.74	43.33	48.26
2016/DOLPVAR-5	401.67	2.07	3.67	15.03	84.05	2.07	22.33	83.29	62.60	69.56
2016/DOLPVAR-6	410.27	2.07	3.83	13.11	88.78	2.00	14.55	73.18	34.27	39.27
2016/DOLPVAR-8	392.33	1.53	3.69	17.85	93.65	2.40	16.13	133.71	61.13	65.26
2016/DOLPVAR-9	632.67	2.07	3.59	16.83	90.46	2.10	10.77	73.62	41.15	46.28
2016/DOLPVAR-10	596.67	1.47	3.73	18.25	98.07	2.70	17.37	115.32	64.53	70.26
2016/DOLPVAR-11	527.33	1.47	3.51	16.32	96.63	2.26	16.66	102.54	54.73	62.20
2016/DOLPVAR-12	564.40	2.02	3.47	16.13	84.49	2.13	14.11	96.41	44.70	52.80
2017/DOLPVAR-1	402.00	1.73	3.41	17.11	99.49	2.09	31.88	93.93	51.70	63.20
Pipili Local	380.21	1.67	3.03	14.15	81.17	2.15	17.92	84.91	60.20	69.40
2017/BDB-2	456.97	1.33	3.93	16.50	83.59	2.07	12.61	160.18	67.10	75.05
Athgarh Local	397.18	1.20	3.35	17.59	89.37	1.93	12.71	87.36	53.33	61.59
SE(m)	24.33	0.08	0.11	0.70	5.93	0.18	0.66	4.71	1.95	2.28
CD(0.05)	70.73	0.23	0.32	2.04	17.96	0.54	1.92	13.70	5.66	6.63
CV(%)	9.19	7.74	5.38	7.74	11.29	14.62	6.37	8.11	6.41	6.63

Table. 4.2 continued

Genotypes	Pod length (cm)	Pod width (cm)	Pod weight (g)	Number of pods per plant	Number of seeds per pod	Pod yield per plant(g)	Pod yield per hectare(q)
2016/DOLPVAR-1	13.12	2.14	8.13	89.33	4.25	492.21	54.69
2016/DOLPVAR-2	15.34	2.82	10.97	67.67	4.26	561.06	62.34
2016/DOLPVAR-4	6.54	2.61	7.30	119.33	3.45	1009.00	112.12
2016/DOLPVAR-5	16.98	2.19	11.63	58.17	4.67	561.06	62.34
2016/DOLPVAR-6	12.50	2.63	7.83	54.00	4.00	603.27	67.03
2016/DOLPVAR-8	13.20	2.44	8.60	34.00	4.00	456.66	50.74
2016/DOLPVAR-9	15.61	2.45	11.50	105.00	4.37	1185.58	131.73
2016/DOLPVAR-10	13.80	2.58	11.67	51.67	4.50	622.17	69.13
2016/DOLPVAR-11	12.45	3.49	11.80	71.00	4.08	639.54	71.60
2016/DOLPVAR-12	11.41	3.79	14.00	74.67	4.23	905.67	100.63
2017/DOLPVAR-1	12.37	2.31	9.67	46.97	4.01	409.33	45.48
Pipili Local	10.07	2.05	7.83	30.64	2.98	266.42	29.60
2017/BDB-2	13.13	2.46	9.08	66.61	4.07	492.47	54.71
Athgarh Local	7.10	2.18	4.68	60.94	2.92	268.80	29.86
SE(m)	0.48	0.09	0.53	5.55	0.14	59.60	6.66
CD(0.05)	1.39	0.27	1.55	16.14	0.40	173.25	19.36
CV(%)	6.68	6.22	9.61	14.64	5.99	17.06	17.14

Table 4.3 Leaf and pod characteristics

Varieties	LEAF CHARACTERISTICS			POD CHARACTERISTICS	
	Leaf Shape	**Leaf Colour**	**Petiole colour**	**Shape & Size**	**Colour**
2016/DOLPVAR-1	Ovate	Light Green	Purple	Round, Long	Green with purple edge
2016/DOLPVAR-2	Ovate	Green	Green	Round, Long	Green
2016/DOLPVAR-4	Ovate	Light Green	Purple	Flat, Short	Green with purple edge
2016/DOLPVAR-5	Ovate	Light Green	Light Green	Round, Long	Butter Green
2016/DOLPVAR-6	Ovate	Green	Light Green	Flat, Long	Green
2016/DOLPVAR-8	Ovate	Green	Purple	Flat, Long	Green with purple edge
2016/DOLPVAR-9	Ovate	Green	Green	Flat, Long	Green
2016/DOLPVAR-10	Ovate	Green	Light Green	Round, Long	Green
2016/DOLPVAR-11	Ovate	Light Green	Purple	Flat, Medium	Purple
2016/DOLPVAR-12	Ovate	Light Green	Purple	Flat, Medium	Butter Green with purple edge
2017/DOLPVAR-1	Ovate	Green	Light Green	Round, Long	Green
Pipili Local	Ovate	Green	Green	Round, Long	Green
2017/BDB-2	Ovate	Green	Light Green	Round, Long	Green
Athgarh Local	Ovate	Green	Light Green	Flat, Short	Green

Fig.4.1 Max. pod width and weight

Fig. 4.2 2016/DOLPVAR-8

Fig.4.3 Highest plant height and max. pod yield per plant

Fig. 4.4 Highest pod length and no. of seeds per pod

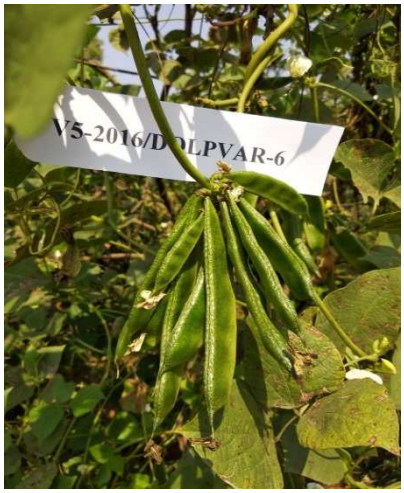

Fig.4.5 Least days to flowering

Fig.4.6 Lowest pod weight and no. of seeds per pod

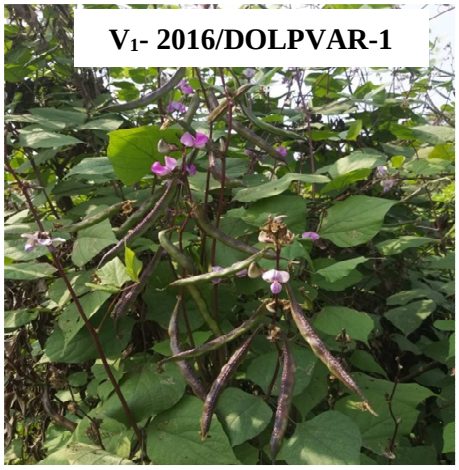

Fig.4.7 Max. no. of primary branches per plant

Fig.4.8 **Purple colour pods**

Fig.4.9 **Highest number of pods per plant**

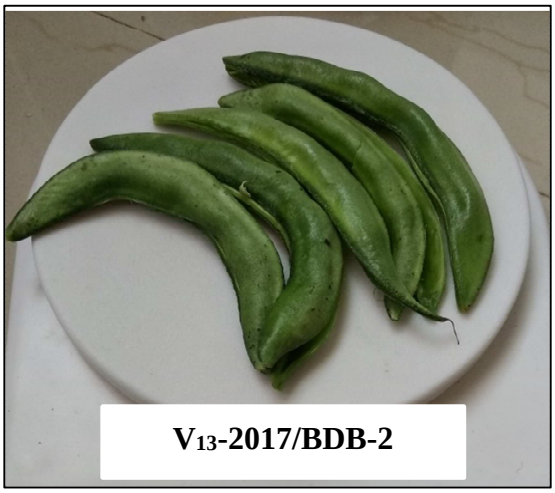

Fig.4.10 **Max. stem thickness**

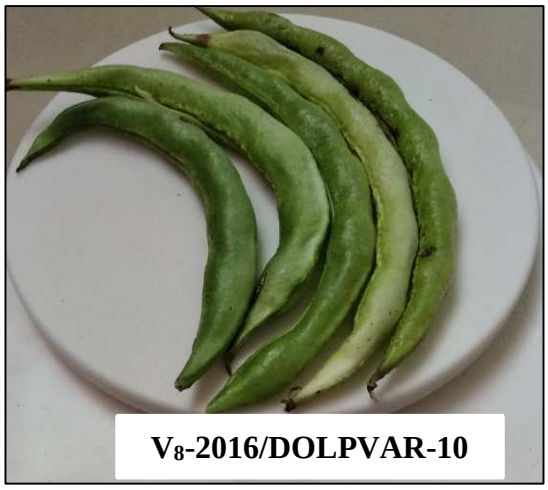

Fig.4.11 **Highest intermodal length**

Fig.4.12 **Maximum inflorescence length**

Fig.4.13 **Max. average leaf area**

4.2 Genetic variability

4.2.1 Estimation of genetic parameters

The estimation of genetic parameters such as mean, range, genotypic variance and phenotypic variance are presented in Table 4.4 and the respective genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense, genetic advance and genetic advance as percentage of mean of different characters are presented in Table 4.5.

Table 4.4 General mean, range, genotypic variance, phenotypic variance for 14 characters in pole type of dolichos bean genotypes

Sl. No.	Characters	General mean	Range	GV	PV
1.	Plant height (cm)	458.72	274.67 - 632.67	10872.28	11464.33
2.	Number of primary branches	1.78	1.2 - 2.4	0.12	0.13
3.	Stem thickness (cm)	3.58	3.03 - 3.93	0.05	0.06
4.	Internodal length (cm)	15.74	11.67 – 18.25	3.06	3.55
5.	Average leaf area (cm^2)	91.03	81.17 - 100.48	13.55	38.76
6.	Average leaf weight (g)	2.13	1.87 - 2.7	0.01	0.05
7.	Inflorescence length (cm)	18	10.77 - 31.88	30.01	30.45
8.	Fresh weight of root (g)	100.63	73.18 - 160.18	551.96	574.17
9.	Days to first flowering	52.64	34.27 - 67.1	93.93	97.73
10.	Days to 50 % flowering	59.54	39.27 - 75.05	104.57	109.77
11.	Pod length (cm)	12.40	6.54 - 16.98	8.42	8.65
12.	Pod width (cm)	2.58	2.05 - 3.79	0.24	0.25
13.	Pod weight (g)	9.62	4.68 - 14.00	5.66	5.94
14.	Number of pods per plant	66.43	30.64 - 119.33	538.75	569.59
15.	Number of seeds per pod	3.98	2.92 - 4.67	0.25	0.27
16.	Pod yield per plant (g)	605.23	266.42 - 1185.58	66400.26	69952.39
17.	Pod yield per hectare (q)	67.29	29.6 - 131.73	819.69	864.05

The general mean results indicated wide variation ranging from number of primary branches (1.78) to pod yield per plant (605.23 g). The range was highest in case of pod yield per plant (266.42 - 1185.58 g) and lowest range was observed in number of primary branches (1.2-2.4). Results from table 4.4 indicated that the genotypic variance ranged from 0.01 for average leaf weight to 66400.26 for pod yield per plant. The phenotypic variance ranged from 0.05 for average leaf weight to 69952.39 for pod yield per plant.

The study of data in table 4.5 revealed that the phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all the 17 characters taken. This happened because PCV estimates include variation due to environment (E) and genotype and environmental (GE) interaction. PCV was highest (43.70) for pod yield per plant followed by pod yield per hectare (43.69). PCV was lowest for stem thickness (6.71) followed by average leaf area (6.84) and average leaf weight (10.06) in ascending order. The characters like intermodal length (11.98), number of seeds per pod (13.05), days to 50% flowering (17.60), days to first flowering (18.78) and pod width (19.40) exhibited moderate values for PCV (10-20%). Relatively higher PCV (>20%) was observed in rest of the characters.

Relatively higher value of GCV was found for characters like pod yield per plant (42.58) followed by pod yield per hectare (42.55) and number of pods per plant (35.32). Moderate values were obtained in 6 characters. Average leaf area (2.07) exhibited the lowest value followed by average leaf weight (5.47) and stem thickness (5.95) in ascending order.

4.2.2 Heritability

The heritability (broad sense) estimates for 17 characters as presented in table 4.5 ranged from 9.17 % in average leaf area to 98.56 % in inflorescence length. Low heritability (<30%) was observed in average leaf weight (29.60%) and moderate heritability was observed in average leaf area (34.96%). Internodal length (86.08%) and stem thickness (78.54%) showed above 60% but below 90% heritability. All the other characters recorded above 90% heritability.

4.2.3 Genetic advance

The range of genetic advance (GA) among different characters as presented in table 4.5 varied from 0.13% in average leaf weight to 517.17 in pod yield per plant.

The GA as % of mean was found to be in a range of 1.29% in average leaf area to 85.45% in pod yield per plant. Expected GA was found to be low (<10%) for traits like average leaf weight (6.13%). Similarly moderate value of expected GA (10-20%) was recorded for stem thickness (10.85%) whereas relatively higher value of GA as % of mean (>20%) was recorded for rest of the characters.

Table 4.5 Genotypic coefficient of variation (GCV), Phenotypic coefficient of variation(PCV), Heritability(Broad sense), Genetic advance (GA), Genetic advance as % of mean(GAM) for 17 characters studied in dolichos bean

Sl. No.	Characters	PCV	GCV	Heritability (b.s.) (%)	GA (at 5% level)	GAM
1.	Plant height(cm)	23.34	22.73	94.84	209.18	45.60
2.	Number of primary branches	20.27	19.77	95.14	0.71	39.72
3.	Stem thickness(cm)	6.71	5.95	78.54	0.39	10.85
4.	Internodal length(cm)	11.98	11.11	86.08	3.34	21.23
5.	Average leaf area (cm^2)	6.84	2.07	34.96	1.18	1.29
6.	Average leaf weight(g)	10.06	5.47	29.60	0.13	6.13
7.	Inflorescence length(cm)	30.66	30.43	98.56	11.20	62.24
8.	Fresh weight of root(g)	23.81	23.35	96.13	47.45	47.15
9.	Days to first flowering	18.78	18.41	96.12	19.57	37.18
10.	Days to 50 % flowering	17.60	17.18	95.26	20.56	34.53
11.	Pod length(cm)	23.72	23.40	97.35	5.90	47.57
12.	Pod width(cm)	19.40	19.07	96.57	1.00	38.60
13.	Pod weight(g)	25.34	24.73	95.20	4.78	49.70
14.	Number of pods per plant	36.32	35.32	94.59	46.50	70.76
15.	Number of seeds per pod	13.05	12.58	92.98	1.00	24.99
16.	Pod yield per plant(g)	43.70	42.58	94.92	517.17	85.45
17.	Pod yield per hectare(q)	43.69	42.55	94.87	57.44	85.37

4.3 Character Association

The relationship of all the characters with yield at phenotypic and genotypic level is presented in Table 4.6 and Table 4.7. The correlation estimates at phenotypic level and at genotypic level showed close correspondence for all character under study.

4.3.1 Phenotypic correlation

Correlation of fruit yield with other yield component

The data presented in Table 4.6 exhibited that pod yield per plant was positively and significantly associated with characters like plant height (0.791), number of primary branches (0.521), stem thickness (0.426), pod width (0.460), pod weight (0.486), number of pods per plant (0.739), number of seeds per pod (0.392), pod yield per hectare (0.966). However, it had positive and non-significant correlation with other characters like average leaf area (0.056) and pod length (0.118). The traits like intermodal length, inflorescence length, fresh weight of root, days to first flowering and days to 50% flowering exhibited significantly negative correlation with pod yield per plant and only average leaf weight (-0.015) showed negative and non-significant correlation with pod yield per plant.

Correlation among other yield attributing traits

Plant height showed positive and significant correlation with stem thickness (0.350), average leaf weight (0.372), pod width (0.496), pod weight (0.454), number of pods per plant (0.450), yield per hectare (0.778), pod yield per plant (0.791) and positively associated with number of primary branches (0.001), intermodal length (0.077), average leaf area (0.083) and number of seeds per pod (0.173). Plant height was negatively correlated with the rest of the characters.

Number of primary branches was positively and significantly correlated with number of pods per plant (0.534), number of seeds per pod (0.317), pod yield per plant (0.521) and positively associated with stem thickness (0.155), inflorescence length (0.271), pod length (0.148) and pod weight (0.162). The trait is negatively correlated with the rest of the characters.

Stem thickness was positively and significantly correlated with fresh weight of root (0.347), number of pods per plant (0.387), number of seeds per pod (0.429), pod yield per plant (0.426) and positively correlated with average leaf area (0.073), average leaf weight (0.071), pod length (0.136), pod width (0.101) and pod weight (0.051).

Internodal length was positively and significantly correlated with average leaf weight (0.566), fresh weight of root (0.387), days to first flowering (0.483), days to 50% flowering (0.497) and positively correlated with average leaf area (0.246), pod length (0.277), pod width (0.030), pod weight (0.237) and number of seeds per pod (0.222). However, intermodal length was negatively and significantly correlated with number of pods per plant (-0.417) and pod yield per hectare (-0.358).

Average leaf area was positively and significantly correlated with inflorescence length (0.436), average leaf weight (0.321) and positively correlated with fresh weight of root (0.118), pod length (0.123), pod width (0.147), pod weight (0.114), number of pods per plant (0.083), number of seeds per pod (0.254) and pod yield per plant (0.056).

Average leaf weight was positively and significantly correlated with fresh weight of root (0.358), days to first flowering (0.530), days to 50% flowering (0.458), pod length (0.304), pod weight (0.449), number of seeds per pod (0.328) and positively correlated with pod width (0.208).

Inflorescence length was only positively correlated with days to first flowering (0.051), days to 50% flowering (0.130), pod length (0.084), pod weight (0.013) and number of seeds per pod (0.133).

Fresh weight of root was positively and significantly correlated with days to first flowering (0.651), days to 50% flowering (0.598) and only positively correlated with pod length (0.146), pod width (0.087), pod weight (0.071) and number of seeds per pod (0.172).

Days to first flowering was positively and significantly correlated with days to 50% flowering (0.981) and only positively correlated with pod length (0.210), pod

weight (0.086) and number of seeds per pod (0.038). Days to first flowering was negatively and significantly correlated with number of pods per plant (-0.528) and pod yield per hectare (-0.505).

Days to 50% flowering was positively correlated with pod length (0.155) and pod weight (0.071) and it was negatively and significantly correlated with number of pods per plant (-0.553) and pod yield per hectare (-0.569).

Pod length was positively and significantly correlated with pod weight (0.637), number of seeds per pod (0.855) and positively correlated with pod width (0.002) and pod yield per plant (0.118).

Pod width was positively and significantly correlated with pod weight (0.642), pod yield per plant (0.460) and positively correlated with number of pods per plant (0.230) and number of seeds per pod (0.278).

Pod weight was positively and significantly correlated with number of seeds per pod (0.765), pod yield per plant (0.486) and positively correlated with number of pods per plant (0.057).

Number of pods per plant was positively and significantly correlated with pod yield per plant (0.739) and positively correlated with number of seeds per pod (0.117).

4.3.2. Genotypic correlation

Correlation of fruit yield with other yield components

The data presented in Table 4.7 exhibited that pod yield per plant was positively and significantly associated with characters like plant height (0.832), number of primary branches (0.552), stem thickness (0.494), pod width (0.476), pod weight (0.529), number of pods per plant (0.766), number of seeds per pod (0.411) and pod yield per hectare (0.968). However, it had positive and non-significant correlation with other characters like average leaf weight (0.010) and pod length (0.125). The traits like intermodal length, inflorescence length, fresh weight of root, days to first flowering and days to 50% flowering exhibited significantly negative correlation with pod yield per plant and only average leaf area(-0.022) showed negative and non-significant correlation with pod yield per plant.

Correlation among other yield attributing traits

Plant height showed positive and significant correlation with stem thickness (0.421), average leaf weight (0.645), pod width (0.516), pod weight (0.474), number of pods per plant (0.478), yield per hectare (0.823), pod yield per plant (0.832) and positively associated with number of primary branches (0.001), intermodal length (0.069), average leaf area (0.198) and number of seeds per pod (0.187). Plant height was negatively correlated with the rest characters.

Number of primary branches was positively and significantly correlated with average leaf weight (0.894), number of pods per plant (0.562), number of seeds per pod (0.342), Pod yield per plant (0.552) and positively associated with stem thickness (0.168), inflorescence length (0.274), pod length (0.162) and pod weight (0.173). The trait was negatively correlated with the rest characters.

Stem thickness was positively and significantly correlated with fresh weight of root (0.393), number of pods per plant (0.432), number of seeds per pod (0.478), pod yield per plant (0.494) and positively correlated with average leaf weight (0.053), pod length (0.169), pod width (0.135) and pod weight (0.072).

Internodal length was positively and significantly correlated with average leaf area (0.368), average leaf weight (0.794), fresh weight of root (0.417), days to first flowering (0.531), days to 50% flowering (0.553) and positively correlated with pod length (0.295), pod width (0.050), pod weight (0.258) and number of seeds per pod (0.270).

Average leaf area was positively and significantly correlated with average leaf weight (0.910), inflorescence length (0.545), fresh weight of root (0.466), pod length (0.374), pod width (0.510), pod weight (0.729), number of seeds per pod (0.937) and positively correlated with number of pods per plant (0.057) and pod yield per hectare (0.037).

Average leaf weight was positively and significantly correlated with fresh weight of root (0.614), days to first flowering (0.959), days to 50% flowering (0.811), pod length (0.519), pod width (0.420), pod weight (0.922), number of seeds per pod (0.514) and positively correlated with pod yield per plant (0.010).

Inflorescence length was only positively correlated with days to first flowering (0.058), days to 50% flowering (0.145), pod length (0.084), pod weight (0.017), number of seeds per pod (0.142).

Fresh weight of root was positively and significantly correlated with days to first flowering (0.674), days to 50% flowering (0.632) and only positively correlated with pod length (0.152), pod width (0.084), pod weight (0.077), number of seeds per pod (0.174).

Days to first flowering was positively and significantly correlated with days to 50% flowering (0.986) and only positively correlated with pod length (0.206), pod weight (0.099) and number of seeds per pod (0.040).

Days to 50% flowering was positively correlated with pod length (0.154) and pod weight (0.084).

Pod length was positively and significantly correlated with pod weight (0.671), number of seeds per pod (0.899) and positively correlated with pod yield per plant (0.125).

Pod width was positively and significantly correlated with pod weight (0.683), pod yield per plant (0.476) and positively correlated with number of pods per plant (0.241) and number of seeds per pod (0.293).

Pod weight was positively and significantly correlated with number of seeds per pod (0.821), pod yield per plant (0.529) and positively correlated with number of pods per plant (0.083).

Number of pods per plant was positively and significantly correlated with pod yield per plant (0.766) and positively correlated with number of seeds per pod (0.118).

Table 4.6 Phenotypic correlation coefficient (r_p) between all pairs of 17 characters studied in dolichos bean genotypes

Character	Plant height (cm)	No. of primary branches	Stem thickness (cm)	Inter-nodal length (cm)	Avg. Leaf Area (cm^2)	Avg. leaf Weight (g)	Inflores-cence length (cm)	Fresh weight of root (g)	Days to first flowering	Days to 50% Flowering	Pod length (cm)	Pod width (cm)	Pod weight (g)	No. of pods per plant	Number of Seeds per pod	Pod yield per Hectare (q)	Pod yield per plant (g)
Plant height (cm)	**1.000**	0.001	0.350*	0.077	0.083	0.372*	-0.388*	-0.079	-0.134	-0.180	-0.089	0.496**	0.454**	0.450**	0.173	0.778**	0.791**
No.of primary branches		**1.000**	0.155	-0.616**	-0.140	-0.442**	0.271	-0.530**	-0.666**	-0.664**	0.148	-0.007	0.162	0.534**	0.317*	0.538**	0.521**
Stem thickness(cm)			**1.000**	-0.145	0.073	0.071	-0.179	0.347*	-0.064	-0.167	0.136	0.101	0.051	0.387*	0.429**	0.494**	0.426**
Internodal length(cm)				**1.000**	0.246	0.566**	-0.167	0.387*	0.483**	0.497**	0.277	0.030	0.237	-0.417**	0.222	-0.358*	-0.218^{NS}
Average leaf area(cm^2)					**1.000**	0.321*	0.436**	0.118	-0.067	-0.103	0.123	0.147	0.114	0.083	0.254	0.076	0.056^{NS}
Average leaf weight(g)						**1.000**	-0.114	0.358*	0.530**	0.458**	0.304*	0.208	0.449**	-0.463**	0.328*	-0.054	-0.015
Inflorescence length(cm)							**1.000**	-0.104	0.051	0.130	0.084	-0.247	0.013	-0.082	0.133	-0.179	-0.273
Fresh weight of root(g)								**1.000**	0.651**	0.598**	0.146	0.087	0.071	-0.187	0.172	-0.214	-0.251
Days to first flowering									**1.000**	0.981**	0.210	-0.226	0.086	-0.528**	0.038	-0.505**	-0.517**
Days to 50% Flowering										**1.000**	0.155	-0.236	0.071	-0.553**	-0.019	-0.569**	-0.579**
Pod length(cm)											**1.000**	0.002	0.637**	-0.195	0.855**	-0.040	0.118^{NS}
Pod width(cm)												**1.000**	0.642**	0.230	0.278	0.478**	0.460**
Pod weight(g)													**1.000**	0.057	0.765**	0.399**	0.486**
No. of pods per plant														**1.000**	0.117	0.792**	0.739**
No. of seeds per pod															**1.000**	0.301	0.392*
Pod yield per hectare																**1.000**	0.966**

*Significance level @ 5% and ** Significance level @ 1%

Table 4.7 Genotypic correlation coefficient (r_g) between all pairs of 17 characters studied in dolichos bean genotypes

Character	Plant height (cm)	No. of primary branches	Stem thickness (cm)	Inter-nodal length (cm)	Avg. Leaf Area (cm^2)	Avg. leaf Weight (g)	Inflores-cence length (cm)	Fresh weight of root (g)	Days to first flowering	Days to 50% Flowering	Pod length (cm)	Pod width (cm)	Pod weight (g)	No. of pods per plant	Number of Seeds per pod	Pod yield per Hectare (q)	Pod yield per plant (g)
Plant height (cm)	**1.000**	0.001	0.421**	0.069	0.198	0.645**	-0.399**	-0.071	-0.144	-0.194	-0.097	0.516**	0.474**	0.478**	0.187	0.823**	0.832**
No.of primary branches		**1.000**	0.168	-0.719**	-0.575**	0.894**	0.274	-0.552**	-0.689**	-0.692**	0.162	-0.014	0.173	0.562**	0.342*	0.573**	0.552**
Stem thickness(cm)			**1.000**	-0.199	-0.293	0.053	-0.207	0.393**	-0.088	-0.194	0.169	0.135	0.072	0.432**	0.478**	0.568**	0.494**
Internodal length(cm)				**1.000**	0.368*	0.794**	-0.164	0.417**	0.531**	0.553**	0.295	0.050	0.258	-0.479**	0.270	-0.365*	-0.209
Average leaf area(cm^2)					**1.000**	0.910**	0.545**	0.466**	-0.363*	-0.473**	0.374*	0.510**	0.729**	0.057	0.937**	0.037	-0.022
Average leaf weight(g)						**1.000**	-0.180	0.614**	0.959**	0.811**	0.519**	0.420**	0.922**	-0.973**	0.514**	-0.061	0.010
Inflorescence length(cm)							**1.000**	-0.109	0.058	0.145	0.084	-0.257	0.017	-0.084	0.142	-0.183	-0.282
Fresh weight of root(g)								**1.000**	0.674**	0.632**	0.152	0.084	0.077	-0.205	0.174	-0.226	-0.261
Days to first flowering									**1.000**	0.986**	0.206	-0.246	0.099	-0.553**	0.040	-0.545**	-0.559**
Days to 50% Flowering										**1.000**	0.154	-0.260	0.084	-0.578**	-0.024	-0.615**	-0.626**
Pod length(cm)											**1.000**	-0.002	0.671**	-0.211	0.899**	-0.033	0.125
Pod width(cm)												**1.000**	0.683**	0.241	0.293	0.495**	0.476**
Pod weight(g)													**1.000**	0.083	0.821**	0.434**	0.529**
No. of pods per plant														**1.000**	0.118	0.821**	0.766**
No. of seeds per pod															**1.000**	0.307*	0.411**
Pod yield per hectare																**1.000**	0.968**

*Significance level at 5% and ** Significance level at 1%

4.4 Path analysis

The path analysis on major yield contributing components was carried out by taking 16 characters in dolichos bean to have a clear view of the direct and indirect contribution of the individual characters to pod yield per plant. The phenotypic correlation coefficient was used in path analysis and the results are presented in Table 4.8.

Findings revealed that the correlation between plant height and pod yield per plant was positive (0.791) and its direct effects on yield per plant was also positive (0.833). Indirect effects of plant height via traits like days to 50% flowering (0.189), pod width (0.084), number of pods per plant (0.024), stem thickness (0.024), intermodal length (0.021), pod weight (0.017), average leaf area (0.004) and number of primary branches (0.001) were also positive whereas it exhibited negative indirect effect via traits like average leaf weight (-0.109), inflorescence length (-0.027), fresh weight of root (-0.011), days to first flowering (-0.127), pod length (-0.042) and number of seeds per pod (-0.089).

Number of primary branches exhibited positive direct effect (0.597) on pod yield per plant (0.521) and positive indirect effects through days to 50% flowering (0.698), average leaf weight (0.130), number of pods per plant (0.029), inflorescence length (0.019), stem thickness, pod length, pod weight, plant height and negative indirect effect with rest of the characters.

Stem thickness showed a positive direct effect (0.068) and positive correlation with yield per plant (0.426) via traits like plant height, days to 50% flowering, number of primary branches, pod length, fresh weight of root, number of pods per plant, pod width, average leaf area, pod weight (positive indirect effect) and negative indirect effect with rest characters.

A positive direct effect was reported by intermodal length (0.267) and negative correlation with the yield per plant (-0.218) via positive indirect effect of traits like plant height, days to first flowering, pod length, fresh weight of root, average leaf area, pod weight, pod width and negative indirect effect of rest characters.

Average leaf area showed positive direct effect (0.043) on yield per plant and it exhibited positive correlation with the yield (0.056) but average leaf weight showed negative direct effect (-0.294) and negatively correlated with pod yield per plant (-0.015).

Inflorescence length recorded positive direct effect (0.070) on pod yield per plant and was negatively correlated with yield per plant (-0.273).

Fresh weight of root had positive direct effect (0.134) on pod yield per plant and was negatively correlated with yield per plant (-0.251).

Days to first flowering showed positive direct effect on pod yield per plant (0.950) and it exhibited negative correlation with the yield (-0.517). Days to 50% flowering showed negative direct effect (-0.951) and negative correlation with the pod yield per plant (-0.579).

Pod length exerted positive direct effect (0.470) on pod yield per plant and it exhibited positive correlation with yield (0.118) via traits like days to first flowering (0.199).

Pod width showed positive direct effect (0.169) on pod yield per plant and it exhibited positive correlation with yield (0.460) via characters like plant height (0.413), days to 50% flowering (0.248).

The direct effect of pod weight (0.038) was positive and it showed significant positive correlation with yield per plant (0.486) via plant height (0.378), pod length (0.300) and pod width (0.109).

Number of pods per plant had the direct positive effect (0.053) on pod yield per plant. It exhibited significant positive correlation with yield (0.739) via positive indirect effects of traits like days to 50% flowering (0.581), plant height (0.375), number of primary branches (0.319), average leaf weight (0.136), pod width (0.039), stem thickness (0.026), average leaf area (0.004) and pod weight (0.002) and negative indirect effects with rest characters.

Number of seeds per pod recorded negative direct effect (-0.517) on pod yield per plant and it exhibited positive correlation with yield (0.392) via positive indirect effects of traits like pod length (0.402), number of primary branches (0.189), plant height (0.144) and negative indirect effects of traits like average leaf weight (-0.096).

Table 4.8: Estimate of direct (diagonal) and indirect effect of component characters on yield in dolichos bean genotypes

Character	Plant height (cm)	No. of primary branches	Stem thickness (cm)	Inter-nodal length (cm)	Avg. Leaf Area (cm^2)	Avg. leaf Weight (g)	Inflores-cence length (cm)	Fresh weight of root (g)	Days to first flowering	Days to 50% Flowering	Pod length (cm)	Pod width (cm)	Pod weight (g)	No. of pods per plant	Number of Seeds per pod	Pod yield per plant (g)
Plant height (cm)	**0.833**	0.001	0.024	0.021	0.004	-0.109	-0.027	-0.011	-0.127	0.189	-0.042	0.084	0.017	0.024	-0.089	0.791**
No.of primary branches	0.001	**0.597**	0.011	-0.164	-0.006	0.130	0.019	-0.071	-0.633	0.698	0.070	-0.001	0.006	0.029	-0.164	0.521**
Stem thickness(cm)	0.292	0.092	**0.068**	-0.039	0.003	-0.021	-0.013	0.047	-0.061	0.176	0.064	0.017	0.002	0.021	-0.222	0.426**
Internodal length(cm)	0.064	-0.368	-0.010	**0.267**	0.011	-0.166	-0.012	0.052	0.459	-0.522	0.130	0.005	0.009	-0.022	-0.115	-0.218
Average leaf area(cm^2)	0.069	-0.083	0.005	0.066	**0.043**	-0.094	0.030	0.016	-0.064	0.108	0.058	0.025	0.004	0.004	-0.131	0.056
Average leaf weight(g)	0.310	-0.264	0.005	0.151	0.014	**-0.294**	-0.008	0.048	0.503	-0.481	0.143	0.035	0.017	-0.025	-0.170	-0.015
Inflorescence length(cm)	-0.323	0.162	-0.012	-0.045	0.019	0.033	**0.070**	-0.014	0.048	-0.136	0.040	-0.042	0.001	-0.004	-0.069	-0.273
Fresh weight of root(g)	-0.066	-0.317	0.024	0.103	0.005	-0.105	-0.007	**0.134**	0.618	-0.628	0.069	0.015	0.003	-0.010	-0.089	-0.251
Days to first flowering	-0.111	-0.398	-0.004	0.129	-0.003	-0.156	0.004	0.087	**0.950**	-1.030	0.099	-0.038	0.003	-0.028	-0.020	-0.517**
Days to 50% Flowering	-0.150	-0.397	-0.011	0.132	-0.004	-0.134	0.009	0.080	0.931	**-0.951**	0.073	-0.040	0.003	-0.030	0.010	-0.579**
Pod length(cm)	-0.074	0.088	0.009	0.074	0.005	-0.089	0.006	0.020	0.199	-0.163	**0.470**	0.000	0.024	-0.010	-0.442	0.118
Pod width(cm)	0.413	-0.004	0.007	0.008	0.006	-0.061	-0.017	0.012	-0.215	0.248	0.001	**0.169**	0.025	0.012	-0.144	0.460**
Pod weight(g)	0.378	0.097	0.004	0.063	0.005	-0.132	0.001	0.010	0.082	-0.074	0.300	0.109	**0.038**	0.003	-0.396	0.486**
No. of pods per plant	0.375	0.319	0.026	-0.111	0.004	0.136	-0.006	-0.025	-0.501	0.581	-0.092	0.039	0.002	**0.053**	-0.061	0.739**
No. of seeds per pod	0.144	0.189	0.029	0.059	0.011	-0.096	0.009	0.023	0.037	0.020	0.402	0.047	0.029	0.006	**-0.517**	0.392*

Residual effects: 0.05

DISCUSSION

The success of any breeding programme in general and improvement of specific trait through selection in particular totally depends upon the genetic variability present in the available germplasm. Variability refers to the presence of differences among the individuals of plant population. Variability results due to differences either in the genetic constitution of the individual of a population or in the environment in which they are grown. Genotypic and phenotypic coefficient of variation allows us to know the extent of variability present in material under investigation. The characters for which variability is present should be highly heritable for the success of crop improvement programme as several plant characters are governed by polygenes which are influenced by environmental conditions. Knowledge of heritability is essential for selection based improvement as it indicates the extent of transmissibility of a character in future generations. As the knowledge of heritability alone does not help in formulating concrete breeding programme, so genetic advance along with heritability will help to ascertain the possible genetic control for any particular character. The association between yield and yield attributing characters and partitioning of these correlation coefficients into direct and indirect effects through path analysis explain the nature of dependency of yield and yield contributing characters on each other hence making the selection more effective.

Realising the importance of the above factors for improvement in dolichos bean the present experiment on "Variability studies in pole type of Dolichos bean (*Lablab purpureus* L.) was conducted during the Rabi season of 2018-19 at All India Coordinated Research Project on Vegetable Crops (AICRP), Bhubaneswar, to study the variability for 17 quantitative characters among the fourteen genotypes and to select the superior genotype on the basis of their performance and adaptability under Bhubaneswar condition of Odisha. The obtained results of the above study have been discussed and interpreted in the preceding pages under appropriate sub-headings.

5.1 Variability and Heritability

In the present investigation, on examining the ANOVA Table 4.1, the nature and magnitude of variability for different quantitative characters were

significant except number of primary branches, stem thickness, average leaf weight, pod width and number of seeds per pod that are clearly observed among the dolichos bean genotypes. The value shows highly significant differences among the genotypes under study, thereby indicating the existence of large amount of variation in all the characters studied. So, there is ample scope for improvement in this crop through these characters studied.

A wide range of variability was observed for pod yield per plant, plant height, pod yield per hectare, number of pods per plant, Fresh weight of root, days to 50% flowering, days to first flowering. These statistics provide an opportunity for selecting initial breeding material as per our objectives in crop improvement programme. Similar to the present findings, investigations carried out earlier also revealed wide variations for various characters (Verma *et al*., 2015 and Kambale *et al*., 2016). The coefficient of variation (C.V.) is less than 18% for all the 17 characters studied, indicating that good precision was maintained while conducting the experiment.

The genotype 2016/DOLPVAR-9 showed highest pod yield per plant (1185.58 g) followed by 2016/DOLPVAR-4 (1009 g) and 2016/DOLPVAR-12 (905.67 g) which performed better than the rest suggesting better adaptability and performance of these genotypes for cultivation in the local agro climatic condition. But, highest number of pods per plant was observed in the genotype 2016/DOLPVAR-4 followed by 2016/DOLPVAR-9. Therefore, these genotypes can be used in breeding programme as high yielding genotype after having multi location yield trial and can also be used as donor parent for improvement in pod and yield trait in breeding programmes. Similar pattern of variability for different traits was also reported by (Parmar *et al*., 2013; Sharma *et al*., 2014).

For understanding the breeding principles in any crop improvement programme, two aspects are most important i.e. (i) selection cannot create new variability by itself but can only be possible where the variability already exists in the experimental material. (ii) Selection for any character can act effectively only on heritable differences (Allard, 1960). Thus the first and foremost factor necessity for selection is to ascertain whether the genetic variability for these characters is present in the population at significant level or not. Further, the phenotypic mean values

which are basis of comparison, may be misleading while analysing the data as the phenotypic expressions are sometimes influenced by environment. To minimise the environmental effect and to avoid this misleading information by obtaining correct interpretation of data, statistics such as variance and coefficient of variation are taken into consideration and calculated for proper evaluation.

Burton and Devane (1953) suggested method for calculating the genetic parameters such as phenotypic and genotypic variance along with the coefficients of variation which provides a sound basis to determine the variability components as well as to know the relative amounts of heritable and non-heritable variation for each of these characters studied.

Present study revealed that the PCV estimates of all the 17 characters were slightly higher than that of GCV indicating lesser influence of environment on their expression. The magnitude of differences between PCV and GCV were observed to be narrow for all the studied characters except average leaf area and average leaf weight which indicates lesser influence of environment in the expression of these characters and selection of these traits based on phenotype would be effective. Similar findings were also reported by (Singh *et al*., 2015 and Magalingam *et al*., 2013).

GCV represents the heritable components of total variation. So, it is an important parameter for comparing variability of different characters among the 14 genotypes of dolichos bean. The highest genetic coefficient of variation was observed for pod yield per plant (42.58) followed by pod yield per hectare (42.55) and number of pods per plant (35.32) which indicated maximum variability existing in the genotypes that provides better scope for genetic improvement in the character through effective simple selection. The high GCV for yield per plant and number of pods per plant were also reported by (Singh *et al*., 2011 and Mohan *et al*., 2014). Lowest GCV were observed for average leaf area (2.07) followed by average leaf weight (5.47) and stem thickness (5.95) which reveals that the extent of response of these traits for selection would be less than that of other traits. High GCV alone is not sufficient for determination of heritable variation. So, GCV along with heritability would give the best view of the advance to be expected by selection.

Heritability is an index of transmissibility of characters from parents to their offsprings and is of primary interest to plant breeder for selection of elite genotypes from diverse genetic population. Poehlman and Borthakur (1972) stated that the characters not influenced by environment will have high heritability. In the present experiment, the highest estimates of heritability in broad sense was observed for 98.56 % in inflorescence length followed by pod length (97.35 %), pod width (96.57 %), fresh weight of root (96.13 %), days to first flowering (96.12 %), days to 50% flowering (95.26 %), pod weight, number of primary branches, pod yield per plant, plant height indicating that these characters are less affected by environment. Similar findings were reported by (Ali *et al*., 2005; Dhillon and Kumar, 2015; Dewangan *et al*., 2017). Moderate heritability was recorded for average leaf area (34.96%) and low heritability was observed in average leaf weight (29.60%) indicating high influence of environment.

Heritability estimates along with genetic advance are more valuable than heritability alone in predicting the response of selection. Genetic advance is the quantum of genetic gain expected during a selection process. High heritability coupled with high genetic advance as per cent of mean was recorded for most of the characters, highest in pod yield per plant followed by number of pods per plant, inflorescence length, pod weight, pod length, fresh weight of root, plant height, number of primary branches, pod width, days to first and 50% flowering, number of seeds per pod except stem thickness, average leaf area and average leaf weight These characters had also high GCV which indicated that these characters were least influenced by environmental effects and were governed by additive genes and selection on the phenotypic performance will be rewarding for improvement of such traits. These findings were also reported by (Ali *et al*., 2005; Lal *et al*., 2005 and Magalingam *et al*., 2013). High heritability and moderate GA as per cent mean values were observed for stem thickness which indicates the influence of non-additive gene action and considerable influence of environment on the expression of this trait and genetic improvement of this trait would be effective on a moderate scale. Similar trends were observed by Bendale *et al*. (2004). Average leaf weight recorded low heritability accompanied by low GA which indicates that these characters are highly influenced by environment and selection of these traits will be less effective.

5.2 Character association

In dolichos bean, pod yield is the economic character. The total pod yield is the ultimate effect of the positive and negative interaction of several quantitative characters with the yield trait that is highly susceptible to changes in the environment. Hence, selection based on yield alone may not be a very sound proposition for effective selection rather the extent and nature of relationship between the characters i.e. the characters which possess direct and positive correlation with yield trait can be picked up for effective selection. Robinson (1966) proposed that correlation study helps in selecting superior genotypes based on phenotypic expression.

According to the results of the present investigation, it was found that the genotypic correlation coefficients were higher than the respective phenotypic correlation coefficients as presented in Table 4.6 and 4.7, indicating a strong inherent association among the various characters studied.

In the present investigation, the pod yield per plant exhibited highly significant positive correlation with pod yield per hectare, plant height, number of pods per plant, number of primary branches, pod weight, pod width, stem thickness and number of seeds per pod at both phenotypic and genotypic level. These results are in accordance with the findings of (Basavarajappa and Byre Gowda, 2004; Rai *et al*., 2008 and Singh *et al*., 2011). These findings indicate the importance of these traits in selection for simultaneous improvement of aforesaid traits along with pod yield per plant in dolichos bean.

Low positive correlation with yield per plant was observed with average leaf area at phenotypic level, average leaf weight at genotypic level and pod length at both phenotypic and genotypic level. Similar trend was observed by Ali *et al*., 2005 and Kiran *et al*., 2014.

Some attributes like intermodal length, inflorescence length, fresh weight of root showed negative correlation with yield per plant suggesting that these characters will be taken into consideration for improvement of dolichos bean for earliness. Traits like days to first flowering and days to 50% flowering exhibited negative significant correlation with pod yield per plant at both genotypic and phenotypic level which

implies least importance for effective selection based on these characters. These results are in agreement with (Chaitanya *et al*., 2014 and Verma *et al*., 2015).

Pod weight shows positive and significant correlation with pod width, pod length, pod yield per plant and plant height at both phenotypic and genotypic level. This result is in accordance with Parmer *et al*. (2013). Pod weight was positively non-significantly correlated with rest of the characters at both levels.

The number of pods per plant showed positive and significant correlation with number of primary branches, plant height and stem thickness at both phenotypic and genotypic levels. Number of pods per plant was negatively and significantly correlated with the traits like days to 50% flowering, days to first flowering, average leaf weight and intermodal length. This result was also reported by (Patil *et al*., 2017).

From the above discussion on correlation it may be inferred that pod yield per hectare, plant height, number of pods per plant, number of primary branches, pod weight, pod width, stem thickness and number of seeds per pod are the important correlated characters where number of pods per plant seems to have predominant effect on pod yield per plant and simultaneous improvement in these characters will be helpful in dolichos bean improvement programme.

5.3 Path analysis

Correlation coefficient which measures the association between any two characters may not give a true comprehensive picture in a complex situation which creates a difficulty in deciding the breeding procedure to be adopted or making simultaneous selection for crop improvement. Therefore, the path coefficient analysis as proposed by Deway and Lu (1959) was adopted to split the interrelationship between two characters into direct and indirect effects. Path analysis helps in identifying the most promising components and minimises undesired characters in selection process through partitioning the total correlation into direct and indirect effects of different components (Wright, 1971).

In the present study as per the data presented in Table 4.8, it was found that days to first flowering exerted maximum positive direct effect on yield per plant followed by plant height, number of primary branches, pod length and intermodal

length, pod width, fresh weight of root, inflorescence length, number of pods per plant. This suggested that direct selection based on these traits will be rewarding for crop improvement. These findings are in agreement with the observations of (Lal *et al*., 2005 and Sharma *et al*., 2014).

Days to 50% flowering, number of seeds per pod and average leaf weight showed negative direct effect on pod yield per plant. These observations find support from previous findings of (Singh *et al*., 1979 and Chattopadhyay and Dutta, 2010). However number of seeds per pod had positive correlation with yield.

Plant height exhibited positive indirect effects via days to 50% flowering, pod width, stem thickness, intermodal length, pod weight and number of pods per plant.

Significant genotypic correlation of pod weight with dependent variable was recorded to be mainly due to strong positive indirect effects via plant height, pod length, pod width.

Highly significant and negative correlation of days to 50% flowering with pod yield per plant was supported by strong indirect negative effects via number of primary branches, plant height, average leaf weight, number of pods per plant. The indirect effect of various characters of pod yield per plant was reported by many workers such as (Chattopadhyay and Dutta, 2010 and Singh *et al*., 1979).

Highly significant and positive correlation of number of pods per plant with pod yield per plant was supported by positive indirect effects of days to 50% flowering, plant height, number of primary branches, average leaf weight, pod width, stem thickness, average leaf area and pod weight.

From the correlation and path analysis it can be concluded that the traits such as plant height, number of primary branches, stem thickness, pod width, pod weight, number of pods per plant which showed significant positive correlation and also had positive direct effect on pod yield per plant. Therefore these characters rewarding to give more focus while selection of genotypes for increasing yield of dolichos bean crop. However, the trait like days to 50% flowering recorded significant negative correlation and also had negative direct effect on pod yield per plant.

SUMMARY AND CONCLUSION

The present investigation entitled "**Variability studies in pole type of Dolichos bean (*Lablab purpureus* L.)"** was conducted at AICRP on Vegetable crops, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha during Rabi season of 2018-19 with an objective to evaluate the yield and yield attributing characters and to estimate the variability, character association and path analysis in pole type of dolichos bean. Fourteen genotypes were evaluated by laying out in randomized block design with three replications. The genotypes were evaluated on the basis of seventeen parameters. The silent findings of the present investigation are summarized below.

- The Analysis of Variance (mean square values) revealed existence of significant differences among the 14 genotypes for all the characters studied except number of primary branches, stem thickness, average leaf weight, pod width and number of seeds per pod indicating the presence of variability in the studied material.

- Highest plant height was recorded in the genotype 2016/DOLPVAR-9 (632.67cm) followed by 2016/DOLPVAR-4 (603.5cm) and 2016/DOLPVAR-10 (596.67cm).

- Maximum number of primary branches was seen for 2016/DOLPVAR-1 (2.4) followed by 2016/DOLPVAR-4 (2.2), 2016/DOLPVAR-5 (2.07), 2016/ DOLPVAR-6 (2.07) and 2016/DOLPVAR-9 (2.07).

- The genotype 2017/BDB-2 showed maximum stem thickness of 3.93cm followed by 2016/DOLPVAR-4 (3.91cm) and 2016/DOLPVAR-6 (3.83).

- The genotype 2016/DOLPVAR-6 (34.27) recorded earliest for days to first flowering followed 2016/DOLPVAR-9 (41.15), 2016/DOLPVAR-4 (43.33) and 2016/DOLPVAR-1 (43.53).

- The genotype 2016/DOLPVAR-6 (39.27) is found to be earliest in days to 50% flowering followed by 2016/DOLPVAR-9 (46.28) and 2016/DOLPVAR-4 (48.26).

- The highest pod length was recorded in the genotype 2016/DOLPVAR-5 (16.98 cm) followed by 2016/DOLPVAR-9 (15.61 cm) and 2016/DOLPVAR-2 (15.34 cm).

- Genotype 2016/DOLPVAR-12 (3.79 cm) showed maximum pod width followed by 2016/DOLPVAR-11 (3.49 cm) and 2016/DOLPVAR-2 (2.82 cm).

- Pod weight was maximum for the genotype 2016/DOLPVAR-12 (14 g) followed by 2016/DOLPVAR-11 (11.8 g), 2016/DOLPVAR-10 (11.67 g), and 2016/DOLPVAR-5 (11.63 g).

- Highest number of pods per plant was observed in 2016/DOLPVAR-4 (119.33) followed by 2016/DOLPVAR-9 (105).

- Highest seeds per pod was recorded in 2016/DOLPVAR-5 (4.67) followed by 2016/DOLPVAR-10 (4.5) and 2016/DOLPVAR-9 (4.37).

- Among the genotypes, 2016/DOLPVAR-9 (1185.58 g) produced maximum pod yield per plant followed by 2016/DOLPVAR-4 (1009 g) and 2016/DOLPVAR-12 (905.67 g).

- A wide range of variability was observed for pod yield per plant, plant height, pod yield per hectare, number of pods per plant, Fresh weight of root, days to 50% flowering, days to first flowering.

- High CV value was observed for pod yield per hectare (17.14), pod yield per plant (17.06 %), number of pods per plant (14.64 %), average leaf weight (14.62 %) and average leaf area (11.29%).

- The genotypic variance ranged from 0.01 for average leaf weight to 66400.26 for pod yield per plant. The phenotypic variance ranged from 0.05 for average leaf weight to 69952.39 for pod yield per plant.

- Phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all the 17 characters taken.

- PCV was highest (43.70) for pod yield per plant followed by pod yield per hectare (43.69) and number of pods per plant (36.32) indicating the existence of wide range of genetic variability in the germplasm for these traits.

- Higher value of GCV was found for characters like pod yield per plant (42.58) followed by pod yield per hectare (42.55) and number of pods per plant (35.32).

- Highest estimates of heritability in broad sense was observed in inflorescence length (98.56 %) followed by pod length (97.35 %), pod width (96.57 %), fresh weight of root (96.13 %), days to first flowering (96.12 %), days to 50% flowering (95.26 %), pod weight (95.20), number of primary branches (95.14), pod yield per plant (94.92), plant height (94.84) indicating that these characters are less affected by environment.

- High heritability coupled with high genetic advance as per cent of mean was recorded for pod yield per plant followed by number of pods per plant, inflorescence length, pod weight, pod length, fresh weight of root, plant height, number of primary branches, pod width, days to first and 50% flowering, number of seeds per pod except stem thickness, average leaf area and average leaf weight. These characters had also high GCV which indicated that these characters were least influenced by environmental effects and were governed by additive genes and selection on the phenotypic performance will be rewarding for improvement of such traits.

- Studies on character association indicated that the genotypic correlation coefficients were higher than the respective phenotypic correlation coefficients indicating a strong inherent association among the various characters studied.

- Pod yield per plant exhibited highly significant positive correlation with pod yield per hectare, plant height, number of pods per plant, number of primary branches, pod weight, pod width, stem thickness and number of seeds per pod at both phenotypic and genotypic level indicating the importance of these traits in selection.

- Low positive correlation with yield per plant was observed with average leaf area at phenotypic level, average leaf weight at genotypic level and pod length at both phenotypic and genotypic level.

- Attributes like intermodal length, inflorescence length, fresh weight of root showed negative correlation with yield per plant suggesting that these characters will be taken into consideration for improvement of dolichos bean for earliness.

- The path analysis revealed days to first flowering exerted maximum positive direct effect on yield per plant followed by plant height, number of primary branches, pod length and intermodal length, pod width, fresh weight of root, inflorescence length, number of pods per plant indicating that direct selection based on these traits may be helpful in evolving high yielding genotypes.

On the basis of findings obtained from present investigation, it can be concluded that the traits like plant height, number of primary branches, stem thickness, pod length, pod width, pod weight, number of pods per plant exhibited positive direct effects on pod yield per plant and selection based on these characters will result in the development of high yielding superior genotypes of dolichos bean. Among the genotypes studied, three genotypes *viz*., 2016/DOLPVAR-9, 2016/DOLPVAR-4 and 2016/DOLPVAR- 12 showed significantly higher pod yield per plant. There is need to evaluate these high yielding genotypes in large plots and over multi locations in Odisha for their commercial utilization in breeding programme.

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