GENETIC DIVERSITY, CORRELATION AND PATH CO-EFFICIENT ANALYSIS IN COUNTRY BEAN

(*Dolichos lablab* L.)

BY

FATEMA BEGUM

REGISTRATION NO. 08-3216

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

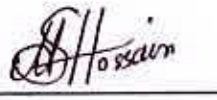
MASTER OF SCIENCE

IN

GENETICS AND PLANT BREEDING

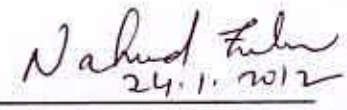
SEMESTER: JANUARY-JUNE, 2010

Approved by:



(Prof. Dr. Md. Sarowar Hossain)
Supervisor

(Dr. Firoz Mahmud)
Professor
Co-supervisor



(Prof. Dr. Naheed Zeba)
Chairman
Examination Committee

Prof. Dr. Md. Sarowar Hossain,
Department of Genetics and Plant Breeding
Sher-e-Bangla Agricultural University
Dhaka-1207, Bangladesh

Mob: +8801552499169
E-mail : sarowar2001@rediffmail.com

CERTIFICATE

This is to certify that thesis entitled, ***"Genetic diversity, correlation and path co-efficient analysis in Country Bean (Dolichos lablab L.)"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***GENETICS AND PLANT BREEDING,*** *embodies the result of a piece of bonafide research work carried out by* ***Fatema Begum,*** *Registration No.* ***08-3216*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: June, 2010
Place: Dhaka, Bangladesh

(Prof. Dr. Md. Sarowar Hossain)
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises to Almightly and Kindfull trust on to "Allah" for his never-ending blessing, it is a great pleasure to express profound thankfulness to my respected parents, who entiled much hardship inspiring for prosecuting my studies, thereby receiving proper education.

I would like to express my heartiest respect, my deep sense of gratitude and sincere, profound appreciation to my supervisor, ***Prof. Dr. Md. Sarowar Hossain,*** *Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for his sincere guidance, scholastic supervision, constructive criticism and constant inspiration throughout the course and in preparation of the manuscript of the thesis.*

I would like to express my heartiest respect and profound appreciation to my Co-supervisor, ***Dr. Firoz Mahmud , Professor*** *, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for his utmost cooperation and constructive suggestions to conduct the research work as well as preparation of the thesis.*

I am grateful to ***prof. Dr. Md. Shah-E-Alam,*** *honorable Vice Chancellor, Sher-e-Bangla Agricultural University, Dhaka for providing me with all possible help during my studies.*

It is great pleasure for me to express my sense of gratitude to the honorable minister of Science, Information and Communication Technology of People's Republic of Bangladesh for give me opportunity of M.S. study under the National Science, Information and Communication Technology Scholarship.

I am highly grateful to my honorable teachers ***Prof. Dr. Naheed Zeba*** *,chairman and* ***Md. Kazi Kamrul Huda, Assistant professor,*** *Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for providing me information by which my experiment was successful.*

I express my sincere respect to the teachers of ***Prof. Dr. Md. Shahidur Rashid Bhuiyan, Prof. Abu Akber Mia*** *and* ***Md. Abdur Rahim, Assistant professor,*** *Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.*

I am pleased to all stuff and workers of Genetics and Plant Breeding Department and all farm labors and stuff of Sher-e-Bangla Agricultural University, Dhaka for their valuable and sincere help in carrying out the research work.

I would like to thank Rabiul Islam who has helped me with technical support to prepare this thesis paper. I also thank all of my roommates and friends especially Mohosina, Tangima, Sweety, Sharmin, Munni, Tania, Sheuli, Bably and Shuva and senior sister and brother (Mumtaz parvin, Saleh, Rafiq, Syed) to help me in my research work.

Mere diction is not enough to express my profound gratitude and deepest appreciation to my father (Sultan Ahmed), mother (Bilkis Akter), brother (Md.Rejaul Karim Tanvir), cousins (Ishraq, Ishmam, Shadman, Sunny, Shimul, Julie, Pumon, Lima, Atiyah, Tisa, Yuki, Noushin, Amira, Arifa, Naba and Saba) and friends for their ever ending prayer, encouragement, sacrifice and dedicated efforts to educate me to this level.

June , 2010
SAU, Dhaka

The Author

GENETIC DIVERSITY, CORRELATION AND PATH CO-EFFICIENT ANALYSIS IN COUNTRY BEAN

(*Dolichos lablab* L.)

BY

FATEMA BEGUM

ABSTRACT

Twenty six genotypes of Country bean (*Dolichos lablab* L.) were studied at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during October 2009 to March 2009. The objectives of the study were to measure the variability among the genotypes for yield and yield contributing characters, estimate genetic parameters, association among the characters and their contribution to yield. There was a great deal of significant variation for all the characters among the genotypes. High genotypic co-efficient of variation (GCV) was observed for pod width, inflorescence length, pod per inflorescence whereas low genotypic co-efficient of variation (GCV) was observed for seed width, seed length, days to first flowering. In all cases, phenotypic variances were higher than the genotypic variance. Heritability with low genetic advance in percent of mean was observed in seed width which indicated that non-additive gene effects were involved for the expression of this character and selection for such trait might not be rewarding. High heritability with high genetic advance in percent of mean was observed for pod width, inflorescence length indicated that this trait was under additive gene control and selection for genetic improvement for this trait would be effective. Correlation studies revealed that the highest significant association of yield per plant was observed with pod length, pod weight, pods per plant, inflorescence per plant. Path co-efficient analysis revealed the maximum direct contribution towards yield per plant was with pod weight followed by pods per plant, pod width and number of flower per inflorescence. The highest intra-cluster distance was found in cluster IV and lowest in cluster I. Among five clusters, the highest inter-cluster distance was observed between cluster I and cluster II and the lowest between cluster III and cluster IV. Considering all the characters the G_7 (BD-8832), G_6 (BD-7985), G_{13} (BD-8034) and G_{15} (BD-8816) were selected for future breeding programme.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

TABLE OF CONTENTS (Cont'd.)

TABLE OF CONTENTS (Cont'd.)

TABLE OF CONTENTS (Cont'd.)

LIST OF TABLES

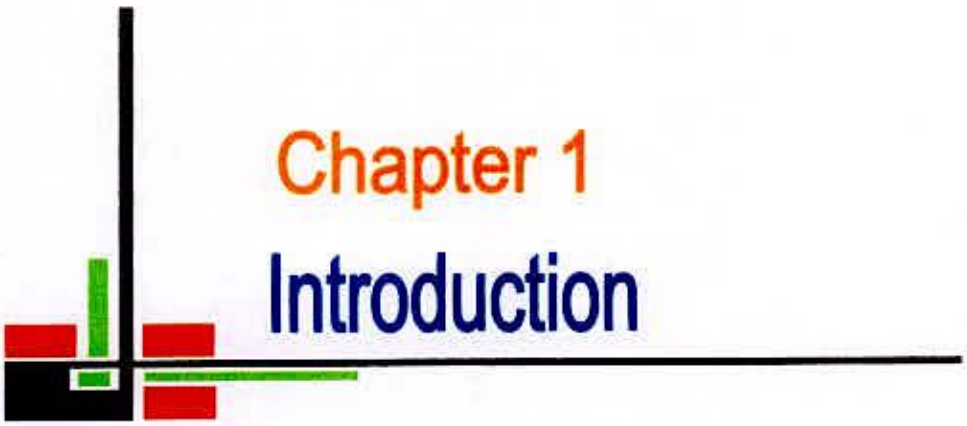
LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATED TERMS

ABBREVIATION	FULL WORD
AEZ	Agro-Ecological Zone
et al.	And others
ACC	Accessions
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
CV	Co-efficient of Variation
etc.	Etcetera
Fig.	Figure
G	Genotype
GA	Genetic Advance
GCV	Genotypic Co-efficient of Variation
δ^2_g	Genotypic Variance
g	Gram
h^2b	Heritability in broad sense
J.	Journal
Kg	Kilogram
m	Meter
MSS	Mean Sum of Square
mm	Millimeter
MP	Muriate of Potash
No.	Number
%	Percent
PCV	Phenotypic Co-efficient of Variation
δ^2_p	Phenotypic variance
RCBD	Randomized Complete Block Design
R	Replication
Res.	Research
SAU	Sher-e-Bangla Agricultural University
SE	Standard Error
m^2	Square meter
TSP	Triple Super Phosphate



Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Lablab bean *[Dolichos lablab* L. (Sweet)], commonly known as 'Seem' or Country bean, hyacinth bean, is an indigenous vegetable of Indo-Bangladesh region (Ahmed, 1982). It is a self-pollinated crop and belongs to the family leguminosae, sub-family papilionaceae. This crop is grown in a few countries like Bangladesh, India, Philippines, Malaysia, Japan, Egypt and Sudan. Some people believe that this crop is originated in Africa (Rashid, 1976). Katyal and Chadha (1985) and Chowdhury *et al.* (1989) mentioned that India to be the place of its origin from where it is spread to the other parts of the world. Lablab bean is a suitable companion forage crop. It is one of the important legume vegetables cultivated in India and Bangladesh. The tender green pods and immature green seeds are used as vegetables and dry seeds are used as pulse. Besides, this crop is grown worldwide for various purposes. In South and South East Asia, hyacinth bean is traditionally used as a pulse crop and the immature pods serve as a vegetable (Duke *et al.*, 1981). Similarly, in Africa both the grain and the immature pods are a minor human food source (Smartt, 1985) and it has become an important annual forage crop in Australia (English, 1999) and America (Maass *et al.*, 2003). Despite its wide distribution in the tropics, its adaptability and diversity, it is considered as a neglected crop with underused potential (NAS, 1979; Smartt, 1985).

The present nutritional situation of Bangladesh is a matter of great concern. The prime nutritional problem of the country is that of protein-energy malnutrition. Most of our people are suffering from malnutrition. There are two sources of protein, viz. animal and plant protein. Leguminous crops play an important role to meet up the protein deficiency problem. Pulses and bean contain 20-30% protein on a dry weight basis which is nearly three times that in most cereals. Vegetables can play an important role in human nutrition. It is of economic importance for seed and pod in Bangladesh. It is a nutritional vegetable. Its green pods provide good amount of protein in addition to vitamins and minerals (Gopalan *et al.*, 198). One hundred grams of young pods contain 83% water, 4.50 g protein, 10.00 g carbohydrate, 1.00 g fat, 2.00 g fiber, 0.05 mg thiamine, 0.01 mg riboflavin and little amount of vitamin C. The dry seed contains

8% water, 25.00 g protein. 60.00 g carbohydrate, 0.80 g fat, 1.40 g fiber, 100 IU of vitamin A, 0.50 mg thiamine, 0.10 mg riboflavin, 1.80 mg niacin and slight amount of vitamin C (Rashid, 1976). In Bangladesh India and some other countries, the young pods developed unripe seeds are used as vegetables and the ripe seeds are used as pulse. Both the pod and seeds are delicious and are liked by all Bangladeshi people. This crop has the potential to reducing the protein deficiency of our people (Matin, 1989). People, in Bangladesh consume 104 g vegetable per head per day (Anon, 1991) but the minimum requirement is 200 g (Rashid, 1993). Massive production of country bean can fulfill the minimum requirement of vegetables and also the protein requirement. It is grown on approximately 11 000 ha across the country during the winter season, yielding an average of 4.53 t of fresh pods per ha for a total yield of about 50 000 t (BBS 2004).It is comparatively lower than other developed country and the main reason behind this are use of low yielding local indigenous cultivars, unavailability of locally developed high yielding variety and low management practices. So important objective of country beans breeding programs in Bangladesh and other countries should be to increasing the genetic potential of yield, tolerance to biotic and abiotic stress.

Knowledge of genetic diversity within a crop and correlation among the yield contributing characters is essential for the long-term success of a breeding programme and maximizes the exploitation of germplasm resources. These indigenous types of country bean contribute considerable degree of variability in respect to qualitative and quantitative characters. A successful hybridization programme for varietal improvement depends mainly on the selection of the parents having high genetic divergence (Upadhyay & Mehta, 2010).

Knowledge of the structure of genetic diversity within a large germplasm collection is very important in making decisions on germplasm management, as well as in developing breeding strategies. Recently, some attempts have been made to use molecular markers to study genetic diversity in hyacinth bean. For example, Liu (1996) studied genetic variation among 40 accessions of hyacinth bean using random amplified polymorphic DNA. A high level of genetic variation was detected but mainly between cultivated and wild forms and not within cultivated forms. Genetic variation was significantly greater among Asian accessions of the cultivated

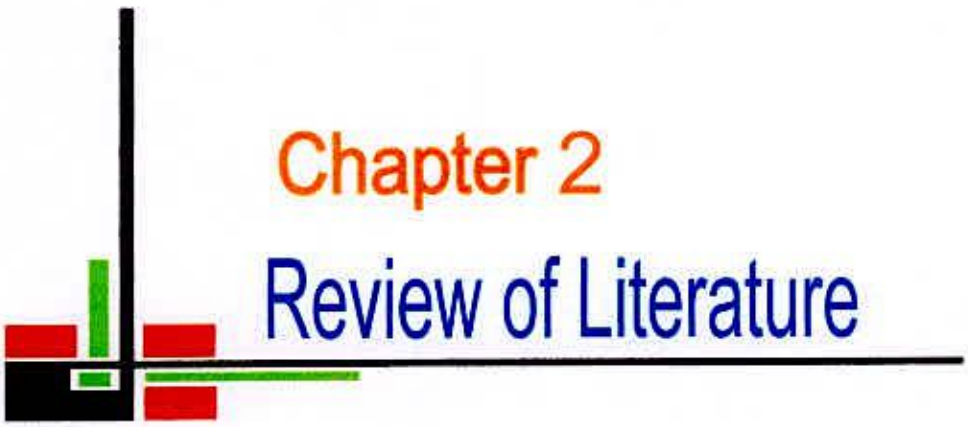
genotypes than among African accessions. Pengelly and Maass (2001), using morphological and agronomic characters, found greater variation in wild forms from eastern and southern Africa than within cultivated landraces collected from Africa and Asia. They also found that the wild and cultivated forms from the East African highlands, particularly Ethiopia, belonged exclusively to subsp. *uncinatus* and were distinct from the remainder of the collection studied.

Among the quantitative characters, yield is a complex character, which is dependent on a number of yield contributing characters. The knowledge of the association of yield componentsand their relative contribution shown by path analysis has practical significance in selection (Upadhyay & Mehta, 2010).

Since wide genetic diversity exists within the country bean for almost all the characters (Ismunadji and Arsyad, 1990), there is a need of the information on the nature and magnitude of the variation available in the materials and role played by the environment in expression of different characters.

Keeping in view the above facts, the present investigation was therefore undertaken to quantify the genetic divergence and variability in a diverse local collection of *Dolichos lablab* L. (Sweet) genotypes with the following objectives

- To assess the genetic diversity among the genotypes,
- To know the association of traits with yield and its contributing traits,
- To know the yield potentiality of genotypes and
- To screen out the suitable parental groups which are likely to provide superior segregates on hybridization.



Chapter 2

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Country bean is one of the most important vegetables in Bangladesh. Country bean is a good source of protein and carbohydrate. The seeds of this bean have high nutritive value and are good source of protein and carbohydrate. Some studies on the variability, interrelationship, path co-efficient analysis, heritability and genetic advance have been carried out in many countries of the world. The available literature on the variability, interrelationship, path co-efficient analysis, heritability and genetic advance of country bean has been briefly reviewed under the following headings.

2.1 Variability, heritability and Genetic Advance

2.2 Correlation Co-efficient

2.3 Path Co-efficient

2.4 Genetic divergence.

2.1 Variability, heritability and Genetic Advance:

A thorough understanding of the genetic variation for different traits and their heritability is important for successful crop improvement programme. In country bean, a wide variability has been noticed for various traits. A summary of literature available on this aspect is presented below.

Joshi (1971) studied important characters like seed yield per plant, number of pods per plant, number of seeds per plant, number of fruit bearing branches per plant and weight of 100 seeds of twenty established varieties. The number of seeds per plant showed a large amount of genetic variability compared with the number of branches and 100 seed weight. The number of branches per plant and 100 seed weight had highest heritability values. High genetic advance was noticed for the weight of seeds, number of pods and number of seeds per plant. Number of pods and number of seeds per plant showed high heritability and greater genetic advance indicating additive gene effects.

Pandey and Dubey (1972) reported a wide range of variability in pod size, number of pods per plant, seed number per pod, 100 seed weight and average yield per plant.

Arunachala (1979) reported that yield per plant, pod number and plant height had high genetic coefficient of variation (GCV). He also reported high heritability for pod yield and pod number depicting additive gene action for these characters.

Mallareddy (1979) estimated very low GCV, high heritability and high genetic advance values for days to maturity, plant height, number of inflorescence per plant and number of nodes per inflorescence. He also reported high estimates of GCV and combination of high heritability and genetic advance for pod yield per plant and seed yield per plant.

Rao (1979) recorded a large GCV for pod yield per plant, number of pods per plant, seed yield per plant, inflorescence length, pods per inflorescence and plant height. High heritability (broad sense) and genetic advance were observed for seed yield and pods per plant.

Baswana *et al.* (1980) observed a high GCV for weight of pod yield per plant, width of pod, flowers per inflorescence, length of inflorescence, pods per cluster and thickness of pod in 39 genotypes of Indian bean (*Dolichos lablab* var. *lignosus* L.). Yield per plant, pod weight, pod width and flowers per inflorescence exhibited high heritability along with high genetic advance indicating predominance of additive gene action.

Muralidharan (1980) reported that in eighty one genotypes of field bean comprising 32 exotic and 49 indigenous collections, a high heritability and high genetic gain were observed for number of pods per plant, seed yield per plant, weight of pods and length of inflorescence. Days to flower, days to maturity and seed protein had high heritability but low genetic advance.

From a genetic variability study in field bean, Pandita *et al.* (1980) reported a wide range of variability for most of the characters. Pod width, pod length and grain yield

per plant showed higher genetic gain values associated with higher heritability estimates.

In F_2 populations of three intervarietal crosses, Jacob (1981) estimated moderate to high heritability with high genetic gain for number of pods. Seed yield per plant showed a wide range of variability with high heritability.

Nayar (1984) reported a high GCV for seed yield per plant. High heritability was estimated for pods per plant, seed yield per plant and pod weight.

In a study involving 18 genotypes, Singh *et al.* (1985) observed higher heritability estimates and high genetic gains for pod width and number of pods per plant.

Kabir and Sen (1987) found high GCV and PCV for pod yield per plant and the estimates of heritability (broad sense) were high for all the characters studied.

Genetic variability, heritability (broad sense) and genetic advance for pod yield per plant and seven other characters were studied in 16 genotypes by Das *et al.* (1987). GCV was found to be high for pod yield per plant, number of pods per plant and breadth of pod. High heritability estimates associated with greater genetic advance were observed for pod yield per plant and number of pods per plant.

Khurana and Singh (1987) conducted a field trial at Hissar with 9 cultivars, HD-18 gave the best overall performance followed by DH-60. These two cultivars had high pod yield (182.6 and 173.3, respectively) coupled with high values for number of pods per plant.

Dahiya and Pandita (1989) recorded eight characters in 34 lines wherein significant differences for all the characters were found. Maximum range of variation was found with pod yield per plant, the minimum range of variation by pod width. The phenotypic coefficient of variation for all the characters was found to be more than genotypic coefficient of variation, indicating influence of environment on the expression of characters. They also reported high heritability and high genetic

advance values for pod yield per plant, number of pods per plant, pod weight, pod width and branches per plant.

Borah and Shadeque (1992) reported a high GCV for inflorescence length, pod weight, vitamin C content, pod breadth, flowers per inflorescence, pod yield per plant and pod length in 12 genotypes collected from different places of Assam.

Reddy *et al.* (1992) studied 196 germplasm accessions from exotic and indigenous source and noted high genetic gain for pods per plant, pod yield per plant and number of productive pods per plant which indicated the influence of additive gene effects on expression in these traits.

Shivashankar *et al.* (1993) reviewed the literature on genetic variability studies for different characters in field bean and observed that wide variability was seen for many of the economic characteristics. Estimates of high GCV and heritability for pods per plant and seed yield per plant have been reported by Rao (1979) and Rajashekharaiah (1979).

Uddin and Newaz (1997) estimated genetic variability among 15 genotypes of hyacinth bean. High GCV was found for green pod yield and number of green pods per plant. High heritability as well as high genetic advance was found for pod yield per plant, number of pods per plant and number of inflorescence per plant.

Basavarajappa and Byre Gowda (2004) reported that in one hundred and forty four genotypes studied wide variability was present for pods per plant, pod yield per plant, seed yield per plant and these characters also exhibited high heritability with high genetic advance indicating additive gene effects.

In 20 genotypes collected from different regions of Bangladesh, Ali *et al.* (2005) recorded higher GCV for number of pods per inflorescence, pod length, number of flowers per inflorescence and yield per plant. They also reported highest heritability in broad sense for number of flowers per inflorescence (96.21) followed by pod weight (92.03), number of pods per inflorescence (91.08), yield per plant (88.67) and pod diameter (66.57).

Mohan and Aghora (2006) evaluated 97 pole type, vegetable poded *Dolichos* land races of Tamil Nadu and revealed that there is high variability for pod length, pod width, pod weight and pod colour among these land races.

Maass (2006) studied morphological and physiological seed characteristics of the hyacinth bean (*Lablab purpureus* L.) in a set of eighteen different germplasm accessions, from wild over semi-domesticated forms to landraces and current cultivars. Seed morphology varied considerably not only between but also within types of cultivated, semi-cultivated and wild hyacinth bean germplasm. Seed size ranged from 5.7 to 14.3 mm in length and 4.0 – 8.6 mm in width.

Uddin and Newaz (1997) studied on Variability of Eleven faba bean (*Vicia faba* L.) and found highly significant differences among populations under study and for all characteristics studied, except number of yielded branches per plant where differences were only significant.

2.2 Correlation Co-efficient

The interrelationship of different characters with yield determines the efficiency of selection in breeding programmes. It merely indicates the intensity of association. Phenotypic correlation reflects the observed relationship, while genotypic correlation underline the true relationship among characters. Selection procedures could be varied depending on the relative contribution of each. The following paragraphs give review of literature on correlation between different characters in country bean.

Joshi (1971) observed that the correlation of number of seeds, number of pods, and number of branches was positive and significant with seed yield per plant. He also reported a negative association between 100 seed weight and number of pods per plant.

Hiremath *et al.* (1979) reported a strong and positive association of grain yield per plant with 100 seed weight in 15 varieties of *Dolichos lablab* L.

In a study with 196 collections of *Lablab purpureus*, Arunachala (1979) reported that pod yield per plant was positively correlated with number of pods per plant, plant height, and pod length and pod width. It was negatively correlated with crude fibre and protein content.

Singh *et al.* (1979) found that values of genotypic correlation were higher than phenotypic correlation. Grain yield per plant was positively and significantly associated with number of seeds per pod.

Gangadharappa (1979) reported positive correlation between number of pods per plant and green pod yield. In a 10 x 10 diallel experiment, Rao (1979) observed that days to flowering had positive and highly significant correlation with plant height, number of pods per plant and grain yield per plant. The correlation was also highly positive and significant between pod length and seeds per pod.

Mallareddy (1979) reported a significant positive correlation between days to 50 per cent flowering and number of seeds per pod. Positive correlation was also seen between number of pods per plant and green pod yield.

Pandey *et al.* (1980) reported that in 36 varieties for twelve characters, yield was positively and significantly correlated with days to flowering (0.5038) and 100 seed weight (0.5132). Significant correlation to a lesser extent was observed between yield and protein content (0.3938).

Baswana *et al.* (1980) indicated positive association of grain yield with weight of pods, pod length, pod width and seeds per pod.

Kabir and Sen (1987) reported that pod yield was strongly correlated with pod number, pod length, pod width, seeds per pod and 100 seed weight.

Dahiya *et al.* (1991) revealed in 36 genotypes a positive and significant association of height of plant, number of pods per plant, pod weight with grain yield and the magnitude of genotypic correlation was higher than the phenotypic correlation.

Uddin and Newaz (1997) noticed that green pod yield had strong significant positive association with pod number, inflorescence per plant and pod width.

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% flowering, days to maturity, plant height, inflorescence per plant and 100 seed weight.

Ali *et al.* (2005) reported that among six characters studied in twenty genotypes, pod weight showed significant positive correlation with pod diameter and yield per plant, but showed negative, significant correlation with flowers per inflorescence and number of pods per inflorescence. Pod length displayed positive, significant correlation with yield per plant.

Uddin and Newaz (1997) study on correlation of yield and some yield components in faba bean (*Vicia faba* L.) . Eleven faba bean (*Vicia faba* L.) populations were planted in an experiment designed randomized complete blocks design with three replications. The objectives were to investigate phenotypic variance among populations studied and determine the relationship among number of yielded branches per plant , number of pods per plant , number of seeds per pod , 10- green pod weight (g) and yield of green pods per plant (g) using correlation and path coefficient analysis. The correlation and path coefficient analysis studies revealed that negative and highly significant relationship was found between number of yielded branches per plant and yield of green pods per plant, while it was positive and highly significant between yields of green pods per plant and10-green pod weight. All direct effects of components studied were negative in both seasons, except 10-green pod weight ,and these results suggested adopting the last component as a selection index during making selection of high yielding genotypes in faba bean populations.

2.3 Path coefficient analysis

Assuming yield is a contribution of several characters which are correlated among themselves and to the yield, path coefficient analysis was developed (Wright, 1921, Dewey and Lu, 1959). Unlike the correlation coefficient which measures the extent of relationship, path coefficient measures the magnitude of direct and indirect contribution of a component characters to a complex character and it has been defined as a standardized regression coefficient which splits the correlation coefficient into direct and indirect effects.

Duarte and Adams (1972) reported that number of pods per plant, number of seeds per pod and seed weight had high positive and direct effect on yield.

Gangadharappa (1979) observed high positive indirect effect through number of pods per plant and number of fruiting nodes per fluorescence on grain yield.

A path coefficient analysis by Mallareddy (1979) on 15 yield contributing characters revealed that number of pods per plant had the highest direct effect while the number of seeds per pod, days to 50 per cent flowering, plant height and 100 seed weight had low positive direct effects on seed yield.

Rao (1979) studied the path coefficient analysis for six important quantitative characters in field bean and noticed that pods per plant had high direct effect on seed yield at both genotypic and phenotypic levels, followed by number of inflorescence per plant. Of all the characters which influenced seed yield per plant, pods per plant, inflorescence per plant and pod yield per plant showed high positive indirect effects.

Singh *et al.* (1979) observed in field bean that highest direct path was for number of seeds per pod followed by pod width. Indirect effect of fairly high magnitude was exerted by number of seeds per pod in relation to other yield components.

Baswana *et al.* (1980) analyzed the path coefficient in 39 diverse lines of *Dolichos lablab* L. Analysis revealed that improved yields would result from selection based on plant height, number of pods per plant and pod weight.

Rathnaiah (1986) reported that the number of pods per plant exhibited the highest positive and direct effect on green pod yield per plant.

Das *et al.* (1987) reported direct negative effects for all the characters on green pod yield.

Kabir and Sen (1987) studied the path analysis for important yield attributes in *Lablab niger* and found that pod length had the largest direct effect on yield followed by pod

number and width and seeds per pod, while 100 seed weight and days to flowering exhibited negative direct effects.

Dahiya *et al.* (1991) observed that among eight characters studied, pods per plant showed highest direct contribution (0.8918) towards pod yield per plant.

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

Uddin and Newaz (1997)) study on correlation of yield and some yield components in Faba bean (*Vicia faba* L.) . Eleven faba bean (*Vicia faba* L.) populations were planted in an experiment designed randomized complete blocks design with three replications. The objectives were to investigate phenotypic variance among populations studied and determine the relationship among number of yielded branches per plant , number of pods per plant , number of seeds per pod , 10- green pod weight (g) and yield of green pods per plant (g) using correlation and path coefficient analysis. The correlation and path coefficient analysis studies revealed that negative and highly significant relationship was found between number of yielded branches per plant and yield of green pods per plant, while it was positive and highly significant between yield of green pods per plant and10-green pod weight. All direct effects of components studied were negative in both seasons, except 10-green pod weight ,and these results suggested adopting the last component as a selection index during making selection of high yielding genotypes in faba bean populations.

2.4 Genetic divergence

The assessment of genetic diversity using quantitative traits has been of prime importance in many contexts particularly in differentiating well defined populations. The germplasm in a self pollinated crop can be considered as heterogeneous sets of groups, since each group being homozygous within itself. Selecting the parents for breeding program in such crops is critical because, the success of such programme depends upon the segregants of hybrid derivatives between the parents, particularly when the aim is to improve the quantitative characters like yield. To help the breeder

in the process to identify the parents that nick better better, several methods of divergence analysis based on quantitative traits have been proposed to suit various objectives. Among them, Mahalanobis' generalized distance occupies a unique place and an efficient method to gauge the extent of diversity among genotypes, which quantify the difference among several quantitative traits. A summary of literature available on this aspect in country bean is presented below.

Muralidharan (1980) analyzed 81 genotypes for 20 characters and reported that, days to flower, days to maturity, length of pods and seed protein contributed maximum towards divergence.

Pandey *et al.* (1983) studied commonly grown varieties of *Dolichos lablab* of Madhya Pradesh along with some improved ones wherein the genotypes formed 13 clusters. The genetic distance was found to be maximum (72.4) between groups VI (Jabalpur-10, Jabalpur 11) and XIII (CBS-32) followed by single variety groups-Jabalpur-8 and Sargeja-1 indicating that these varieties were found to be closer with each other. The highest contribution towards genetic divergence among the genotypes was attributed to 100 seed weight (12.85%), seed: pod ratio (12.38%), pod length (12.06%) and protein content (11.90%).

Nayar (1984) from the genetic divergence analysis using D^2 statistics in 81 genotypes of field bean indicated that days to flowering and days to maturity contributed most to divergence. The genotypes were grouped into 16 clusters by multivariate analysis. Divergence was more influenced by pods per plant, pod weight and seed weight per plant.

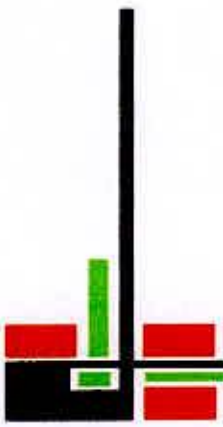
Singh (1991) recorded data on six agronomically important traits in 48 strains collected from eight Indian states and strains were grouped into 10 clusters with days to flowering and number of pods per bunch contributing most to genetic divergence.

Nandi *et al.* (2000) studied twenty eight genotypes from different states which fell into five clusters based on D^2 values and concluded that differences in cluster means existed for almost all eight characters studied. Cluster I had low mean values for days to first flowering (63.91), Cluster-II had both highest pods per plant as well as high

100 seed weight. Higher mean pod girth was associated with cluster IV. Cluster V had maximum mean pod length, pod weight, seeds per pod and total green pod yield per plant.

Basavarajappa and Gowda (2000) reported that in 144 germplasm lines collected from Southern Karnataka, phenotypic characters viz., seed yield, pods per plant, inflorescence per plant, branches per plant and days to 50 per cent flowering contributed substantially to the genetic divergence.

Pujari (2000) classified 60 genotypes on the basis of morphological traits, seed albumin and seed globulin marker. Clustering patterns evidenced for a relative genetic proximity of genotypes true to their closeness in terms of geographical origin or pedigree, barring a few cases of grouping of apparently distant genotypes together indicating free flow of gene pools through seeds across distinct states or institutions.



Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The investigation was carried out at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2009 to March 2010 to study on the genetic diversity, correlation and path analysis in Country Bean. A brief description about the locations of the experimental site, characteristics of soil, climate, materials, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, data recording procedure, economic and statistical analysis etc., which are presented as follows:

3.1 Experimental site

The research work was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207 during October 2009 to March 2010.

3.2 Geographical Location

The experimental area was situated at 23°77'N latitude and 90°33'E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004). The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in (Appendix I).

3.3 Climate

Area has subtropical climate, characterized by high temperature, high relative humidity and heavy rainfall in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March). Meteorological information regarding temperature, relative humidity, rainfall and sunshine hours prevailed at the experimental site during the study period was presented in Appendix II.

Plate 1a. Field view of the experimental site

Plate 1b. Field view of the experimental field

3.4 Characteristics of soil

Soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 6.0- 6.6 and had organic matter 0.84%. Experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resource and Development Institute (SRDI), Dhaka. Physicochemical properties of the soil are presented in (Appendix III).

3.5 Planting materials

Twenty six genotypes of Country Bean were used for the present research work. The purity and germination percentage were leveled as around 100 and 80, respectively. The genetically pure and physically healthy seeds of these genotypes were collected from Plant Genetic Resources Centre (PGRC) of Bangladesh Agricultural Research Institute (BARI), Gazipur. The name and origin of these genotypes are presented in (Table 1).

3.6 Design and layout of the experiment

The experiment was laid out Randomized Complete Block Design (RCBD) with three replications. The genotypes were distributed into the pit of each block of the prepared layout of the experiment. The Twenty six genotypes of the experiment were assigned at random into pits of each replication. The distance maintained spacing pit to pit 3 m. The distance maintained between two blocks was 1 m.

3.7 Poly bag preparation and raising seedling

Due to uncertain rainfall during the period of the study, the seeds were dibbled in Poly bag for higher germination percentage and to get healthy seedlings and when the seedlings become 20 days old; those were transplanted in the main field in the pit. Seeds were sown 15th October, 2009, before sowing seeds were treated with Bavistin for 5 minutes.

Table 1. Name and origin of twenty six genotypes of country bean used in the present study

Sl. No.	Genotypes No.	BARI ACC Number	Origin
1	G_1	BD-8737	PGRC, BARI
2	G_2	BD-1816	PGRC, BARI
3	G_3	BD-808	PGRC, BARI
4	G_4	BD-8312	PGRC, BARI
5	G_5	BD-7978	PGRC, BARI
6	G_6	BD-7985	PGRC, BARI
7	G_7	BD-8832	PGRC, BARI
8	G_8	BD-1805	PGRC, BARI
9	G_9	BD-7995	PGRC, BARI
10	G_{10}	BD-7977	PGRC, BARI
11	G_{11}	BD-7998	PGRC, BARI
12	G_{12}	BD-113	PGRC, BARI
13	G_{13}	BD-8034	PGRC, BARI
14	G_{14}	BD-130	PGRC, BARI
15	G_{15}	BD-7999	PGRC, BARI
16	G_{16}	BD-8027	PGRC, BARI
17	G_{17}	BD-137	PGRC, BARI
18	G_{18}	BD-8001	PGRC, BARI
19	G_{19}	BD-1830	PGRC, BARI
20	G_{20}	BD-132	PGRC, BARI
21	G_{21}	BD-1809	PGRC, BARI
22	G_{22}	BD-8729	PGRC, BARI
23	G_{23}	BD-8813	PGRC, BARI
24	G_{24}	BD-7988	PGRC, BARI
25	G_{25}	BD-6	PGRC, BARI
26	G_{26}	BD-8816	PGRC, BARI

Here, PGRC = Plant Genetic Resources Centre, BARI = Bangladesh Agricultural Research Institute

3.8 Land preparation

The experiment plot was prepared by several ploughing and cross ploughing followed by laddering and harrowing with tractor and power tiller to bring about good tilth in the first week of October 2008. Weeds and other stables were removed carefully from the experimental plot and leveled properly.

3.9 Pit preparation

After final land preparation, pits of 55 cm × 55 cm × 45 cm were prepared in each block with a spacing of 3 m × 1 m. Pits were kept open in the sun for 7 days to kill harmful insect and microorganisms. To control field cricket 5 mg Furadan was also mixed with the soils of each pit before making it ready for dibbling.

3.10 Manure and fertilizers application

Total cowdung, half of TSP and one third MOP were applied in the field during final land preparation. Remaining TSP and one third MOP and whole gypsum and zinc oxide and one third of urea were applied in pit one week prior to transplantation. Remaining urea and MOP were applied as top dressing in four installments at 20, 40, 60 and 75 days after transplanting. (Table 2) showing doses of manure and fertilizers used in the study.

Table 2. Doses of manure and fertilizers used in the study

Sl. No.	Fertilizer/Manure	Dose
1.	Cow dung	10 ton/ha
2.	Urea	45-55 kg/ha
3.	TSP	140-160 kg/ha
4.	MOP	140-160 kg/ha
5.	Gypsum	75 kg/ha
6.	Zinc Oxide	10 kg/ha

3.11 Transplanting of seedlings

Germination of seeds was completed within 12 days and the seedlings of different accessions were planted in the pit on 5th November, 2009. In each pit two seedlings were planted and the soil around the plant was firmly pressed by hand.

3.12 Intercultural operations

The following intercultural operations were done from time to time throughout the cropping season for proper growth and development of the plants.

3.12.1 Thinning and gap filling

Only one healthy seedling was kept per pit for the proper development and avoid crowd environment. For this whatever its need thinning and gap filling was done.

3.12.2 Weeding and mulching

Several weeding and mulching were done as per requirement. At the very first stage weeding was done for ease of aeration and less competition seedling growth and mulch was provided after an irrigation to prevent crust formation and facilitate good aeration.

3.12.3 Irrigation and after-care

In the early stage irrigation was done twice daily by water cane. In mature stage flood irrigation was done when ever it's necessary.

3.12.4 Pesticide application

At the seedling stage red aphid attacked tender leaves and also after the initial stage they attacked plants several times for this Malathion was sprayed in the field. In mature stage fruit fly caused severe damage to the fruit. For protection from fruit fly, MSGT (Mashed Sweet Gourd Trap) and Pheromone bait was used along with ripcord, Savin powders.

3.13 Harvesting

Fruits were picked on the basis of horticultural maturity, size, color and age being determined for the purpose of consumption as the fruit grew rapidly and soon get beyond the marketable stage, frequent picking was done throughout the harvesting period. Fruits were picked and care was taken to avoid injury of the vine.

3.14 Data recording

Data were recorded on following parameters from the studied plants during the experiment. The details of data recording are given below on individual plant basis.

3.14.1. Inflorescence characteristics

3.14.1.1 Days to first flowering

The number of days required for first flowering was counted for three replications separately and average data was recorded.

3.14.1.2 Days to first fruiting

The number of days required for first fruiting was counted for three replications separately and average data was recorded.

3.14.1.3 Number of inflorescence per plant

Number of Inflorescence was measured in each germplasm and average data was recorded.

3.14.1.4 Number of flower per inflorescence

Number of flowers per Inflorescence was measured in three to five Inflorescences in each germplasm and average data was recorded.

3.14.1.5 Number of pod per inflorescence

Number of pods per Inflorescence was measured in three to five Inflorescences in each germplasm and average data was recorded.

3.14.1.6 Inflorescence length (cm)

Inflorescence length was measured in three to five fruits in cm in each germplasm and average data was recorded.

3.14.2 Fruit characteristics

3.14.2.1 Pod length (cm)

Pod length was measured in three to five fruits in cm in each germplasm and average data was recorded during fruit harvest for vegetable use.

3.14.2.2 Pod breadth (cm)

Pod diameter was measured in three to five fruits in each germplasm in cm, and average data was recorded during fruit harvest for vegetable use.

3.14.2.3 Pod weight (g)

Weight of three to five pods in each germplasm during harvest for vegetable use was measured in gram (gm).

3.14.2.4 Seed length (mm)

Seed length was measured in three to five fruits in mm in each germplasm and average data was recorded during fruit harvest for vegetable use.

3.14.2.5 Seed width (mm)

Seed width was measured in three to five fruits in mm in each germplasm and average data was recorded during fruit harvest for vegetable use.

3.14.2.6 Number of pod per plant

The number of pod per plant was counted and average data was recorded.

3.14.2.7 Pod yield per plant (g)

Weight of edible fruits of selected plants from each accession was weighed in gram (g).

3.15.1 Statistical analysis

Mean data of the characters were subjected to multivariate analysis. Univariate analysis of the individual character was done for all characters under study using the mean values (Singh and Chaudhury, 1985) and was estimated using MSTAT-C computer programme. Duncan's Multiple Range Test (DMRT) was performed for all the characters to test the differences between the means of the genotypes. Mean, range and co-efficient of variation (CV %) were also estimated using MSTAT-C. Multivariate analysis was done by computer using GENSTAT 5.13 and Microsoft Excel 2000 software through four techniques viz., Principal Component Analysis (PCA), Principal Coordinate Analysis (PCO), Cluster Analysis (CA) and Canonical Vector Analysis (CVA).

3.15.1.1 Estimation of genotypic and phenotypic variances

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

$$\text{Genotypic variance } (\sigma^2_g) = \frac{GMS - EMS}{r}$$

Where,

GMS = Genotypic mean sum of squares

EMS = Error mean sum of square

r = number of replications

$$\text{Phenotypic variance } (\sigma^2_{ph}) = \sigma^2_g + EMS$$

Where,

σ^2_g = Genotypic variance

EMS = Error mean sum of square

3.15.1.2 Estimation of genotypic and phenotypic correlation co-efficient

For calculating the genotypic and phenotypic correlation co-efficient for all possible combinations the formula suggested by Miller *et al.* (1958), Johnson *et al.* (1955) and Hanson *et al.* (1956) were adopted.

The genotypic co-variance component between two traits and have the phenotypic co-variance component were derived in the same way as for the corresponding variance components. The co-variance components were used to compute genotypic and phenotypic correlation between the pairs of characters as follows:

$$\text{Genotypic correlation } (r_{gxy}) = \frac{\sigma_{gxy}}{\sqrt{(\sigma^2_{gx} . \sigma^2_{gy})}}$$

Where,

σ_{gxy} = Genotypic co-variance between the traits x and y

σ^2_{gx} = Genotypic variance of the trait x

σ^2_{gy} = Genotypic variance of the trait y

$$\text{Phenotypic correlation } (r_{pxy}) = \frac{\sigma_{pxy}}{\sqrt{(\sigma^2_{px} . \sigma^2_{py})}}$$

Where,

σ_{pxy} = Phenotypic covariance between the traits x and y

σ^2_{px} = Phenotypic variance of the trait x

σ^2_{py} = Phenotypic variance of the trait y

3.15.1.3 Estimation of genotypic and phenotypic co-efficient of variation

Genotypic and phenotypic co-efficient of variation were calculated by the formula suggested by Burton (1952)

Genotypic co-efficient of variation (GCV %) = $\sqrt{\frac{\sigma^2_g}{\bar{x}}} \times 100$

Where,

σ^2_g = Genotypic variance

$\bar{x}$ = Population mean

Similarly,

The phenotypic co-efficient of variation was calculated from the following formula.

Phenotypic co-efficient variation (PCV) = $\sqrt{\frac{\sigma^2_{ph}}{\bar{x}}} \times 100$

Where,

σ^2_{ph}= Phenotypic variance

$\bar{x}$ = Population mean

3.15.1.4 Estimation of heritability

Broad sense heritability was estimated (Lush, 1943) by the following formula, suggested by Johnson *et al.* (1955).

$$h^2_b\% = \frac{\sigma^2_g}{\sigma^2_{ph}} \times 100$$

Where,

h^2_b = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_{ph} = Phenotypic variance

3.15.1.5 Estimation of genetic advance

The expected genetic advance for different characters under selection was estimated using the formula suggested by Lush (1943) and Johnson *et al.* (1955).

Genetic advance (GA) = $K. h^2_b. \sigma_{ph}$

$$GA = K. \frac{\sigma^2_g}{\sigma^2_{ph}}. \sigma_{ph}$$

Where,

K = Selection intensity, the value which is 2.06 at 5% selection intensity

σ_{ph} =Phenotypic standard deviation

h^2_b = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_{ph} = Phenotypic variance

3.15.1.6 Estimation of genetic advance in percent of mean

Genetic advance in percent of mean was calculated from the following formula as proposed by Comstock and Robinson (1952):

$$\text{Genetic advance (\% of mean)} = \frac{\text{Genetic Advance (GA)}}{\text{Population mean } (\bar{x})} \text{ X } 100$$

3.15.2 Multivariate analysis

The genetic diversity among the genotypes was assessed by Mahalanobis's (1936) general distance (D^2) statistic and its auxiliary analyses. The parent's selection in hybridization programme based on Mahalanobis's D^2 statistic is more reliable as requisite knowledge of parents in respect of a mass of characteristics is available prior to crossing. Rao (1952) suggested that the quantification of genetic diversity through biometrical procedures had made it possible to choose genetically diverse parents for a hybridization programme. Multivariate analysis viz. Principal Component analysis, Principal Coordinate analysis, Cluster analysis and Canonical Vector analysis (CVA),

which quantify the differences among several quantitative traits, are efficient method of evaluating genetic diversity. These are as follows:

3.15.2.1 Principal Component analysis (PCA)

Principal Component analysis, one of the multivariate techniques, is used to examine the inter-relationships among several characters and can be done from the sum of squares and products matrix for the characters. Thus, PCA finds linear combinations of a set variant that maximize the variation contained within them, thereby displaying most of the original variability in a smaller number of dimensions. Therefore, Principles components were computed from the correlation matrix and genotypes scores obtained for first components (which has the property of accounting for maximum variance) and succeeding components with latent roots greater than unity. Contribution of the different morphological characters towards divergence is discussed from the latent vectors of the first two principal components.

3.15.2.2 Principal Coordinate analysis (PCO)

Principal Coordinate analysis is equivalent to PCA but it is used to calculate inter unit distances. Through the use of all dimension of p it gives the minimum distance between each pair of the n points using similarity matrix (Digby *et al.*, 1989).

3.15.2.3 Cluster analysis (CA)

Cluster analysis divides the genotypes of a data set into some number of mutually exclusive groups. Clustering was done using non-hierarchical classification. In Genstat, the algorithm is used to search for optimal values of chosen criterion proceeds as follows. Starting from some initial classification of the genotypes into required number of groups, the algorithm repeatedly transferred genotypes from one group to another so long as such transfer improved the value of the criterion. When no further transfer can be found to improve the criterion, the algorithm switches to a second stage which examines the effect of swooping two genotypes of different classes and so on.

3.15.2.4 Canonical Vector analysis (CVA)

Canonical vector analysis (CVA) finds linear combination of original variabilities that maximize the ratio of between group to within group variation, thereby giving functions of the original variables that can be used to discriminate between the groups. Thus, in this analysis a series of orthogonal transformations sequentially maximizing of the ratio of among groups to the within group variations. The canonical vector are based upon the roots and vectors of WB, where W is the pooled within groups covariance matrix and B is the among groups covariance matrix.

3.15.2.5 Calculation of D^2 values

The Mahalanobis's distance (D^2) values were calculated from transformed uncorrelated means of characters according to Rao (1952), and Singh and Chaudhury (1985). The D^2 values were estimated for all possible combinations between genotypes. In simpler form D^2 statistic is defined by the formula

$$D^2 = \sum_{i}^{x} d_i^2 = \sum_{i}^{x} (Y_i^j - Y_j^k)^2 \qquad (j \neq k)$$

Where,

Y = Uncorrelated variable (character) which varies from i = 1 ------to x

x = Number of characters.

Superscript j and k to Y = A pair of any two genotypes.

3.15.2.6 Computation of average intra-cluster distances

Average intra-cluster distances were calculated by the following formula as suggested by Singh and Chuadhury (1985).

$$\text{Average intra-cluster distance} = \frac{\sum D_i^2}{n}$$

Where,

D_i^2 = the sum of distances between all possible combinations (n) of genotypes included in a cluster.

n = Number of all possible combinations between the populations in cluster.

3.15.2.7 Computation of average inter-cluster distances

Average inter-cluster distances were calculated by the following formula as suggested by Singh and Chuadhury (1985).

$$\text{Average inter-cluster distance} = \frac{\sum D_{ij}^2}{n_i \times n_j}$$

Where,

$\sum D_{ij}^2$ = The sum of distances between all possible combinations of the populations in cluster i and j.

n_i = Number of populations in cluster i.

n_j = Number of populations in cluster j.

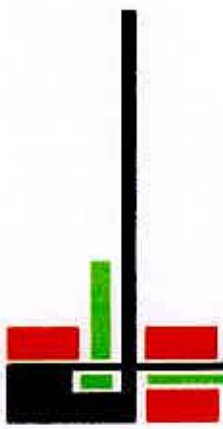
3.15.2.8 Cluster diagram

Using the values of intra and inter-cluster distances ($D = \sqrt{D^2}$), a cluster diagram was drawn as suggested by Singh and Chuadhury (1985). It gives a brief idea of the pattern of diversity among the genotypes included in a cluster.

3.15.2.9 Selection of genotypes for future hybridization programme

Divergence analysis is usually performed to identify the diverse genotypes for hybridization purposes. The genotypes grouped together are less divergent among themselves than those, which fall into different clusters. Clusters separated by largest statistical distance (D^2) express the maximum divergence among the genotypes included into these different clusters. Variety (s) or line(s) were selected for efficient hybridization programme according to Singh and Chaudhury (1985). According to them the following points should be considered while selecting genotypes for hybridization programme:

i. Choice of cluster from which genotypes are selected for use as parent (s)
ii. Selection of particular genotype(s) from the selected cluster(s)
iii. Relative contribution of the characters to the total divergence
iv. Other important characters of the genotypes performance.



Chapter 4

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the study are presented and discussed in this chapter. The data pertaining to thirty-one bottle gourd genotypes as well as yield and its contributing characters were computed and statistically analyzed and the results thus obtained are discussed below under the following heads:

1. Genetic parameters
2. Correlation co efficient
3. Path co-efficient analysis
4. Multivariate analysis

4.1 GENETIC PARAMETERS

The analysis of variances indicated that the existence of highly significant variation among the genotypes studied (Table 3). The mean sum of square, mean, range, variance components, genotypic and phenotypic coefficients of variations, heritability, genetic advance and genetic advance in percent of mean (GAPM) are presented in Table 3 and Table 4. The results are discussed character wise as follows:

4.1.1. Chracterization of country bean on the basis of yield and yield contributing characters

4.1.1.1 Days to first flowering

Significant differences was observed among all genotypes (95.395) studied for this character (Table 3). The mean performance of days to first flowering indicated that the maximum duration (64.00 days) to first flowering was produced by BD-8737 and that of minimum (40.00 days) by BD-8816 with mean value 50.04 days (Table 4)

4.1.1.2 Days to first fruiting

Significant differences was observed among all genotypes (195.715) studied for this character (Table 3). The mean performance of days to first fruiting indicated that the

Table 3 Mean Sum Square from the ANOVA of 26 genotypes of country bean

Characters		d.f.			MSS	
	Replication	Treatment	Error	Replication	Genotype	Error
Days to1st flowering	2	25	50	116.308	95.395**	6.308
Days to1st fruiting	2	25	50	137.577	195.715**	9.897
Inflorescences /plant	2	25	50	9.962	261.305**	7.402
Flower/ Inflorescence	2	25	50	2.000	25.315**	1.560
Pod/ Inflorescence	2	25	50	4.269	17.506**	1.189
Inflorescence len (cm)	2	25	50	21.023	208.689**	4.689
Pod len (cm)	2	25	50	1.315	16.744**	1.050
Pod width (cm)	2	25	50	0.138	4.679**	0.066
pod weight (g/pod)	2	25	50	1.148	6.129**	0.0493
Seed len (mm)	2	25	50	7.963	4.017**	0.0613
Seed width (mm)	2	25	50	1.403	1.508**	0.527
Pods/plant	2	25	50	316.654	2731.278**	360.414
Pod yield/plant	2	25	50	2566.937	179052.244**	6509.289

** indicates significant at 1% level of significance, MSS = Mean sum of squares due to genotypes

Table 4 : Mean performance of 26 Genotypes of country bean

Genotypes	Days to 1st flowering	Days to 1st fruiting	Number of Inflorescence / plant	No of Flower/ Inflorescence.	No. of Pod/ Inflorescence.	Inflorescene length (cm)	Pod length (cm)	Pod width (cm)	pod weight (g/pod)	Seed length (mm)	Seed width (mm)	No. Pods/ plant	Pod yield/plant(g)
BD-8737	64	69	35	8	5	27	12	1.5	6.19	13.33	8.27	135	835.65
BD-1816	45	49	40	8	6	17	12	3	6.33	13.13	8.03	153	969.25
BD-808	50	60	10	10	8	28	7	2.5	4.88	12.01	9.12	116	566.08
BD-8312	55	70	32	9	7	26	8	2	7.22	11.23	8.7	142	1025.24
BD-7978	48	55	35	10	8	20	6.5	2.3	5.2	10.52	8.8	120	624
BD-7985	55	65	40	11	9	22	7.2	8.23	4.62	10.13	8.23	154	711.48
BD-8832	40	48	51	10	7	22	8.5	1.5	7.87	11.13	9.39	161	1267.87
BD-1805	49	53	45	15	12	22	7	2.5	5.36	10.11	9.02	123	659.89
BD-7995	50	65	35	10	5	17	13	1.5	9.99	13.06	7.37	130	1299.35
BD-7977	55	65	17	9	4	13	9	2	8.54	12.72	8.15	116	991.22
BD-7998	52	62	24	16	10	18	7	2.5	5.64	12.4	9.75	183	1033.03
BD-113	55	69	30	10	6	25	7	2.8	6.38	12.9	9.37	123	784.74
BD-8034	45	60	38	10	8	12	8.5	2	5.64	11.09	7.74	250	1412.55
BD-130	50	65	26	8	5	13.4	11	2.5	6.67	12.76	7.88	120	801
BD-7999	53	68	30	10	8	38.6	9	2	6.39	13.13	9.96	158	1010.41
BD-8027	50	65	26	11	8	33	11	2.3	8.36	13.76	7.92	145	1212.2
BD-137	55	60	29	10	8	30	7	2	8.84	11.88	8.85	120	1061.4
BD-8001	60	78	27	10	5	24	6.5	2.7	4.96	13.27	9.33	130	645.45
BD-1830	49	55	30	10	6	30	7	2.6	5.5	11.55	8.2	118	649
BD-132	43	48	22	15	9	35	8	2.3	5.8	12.9	9.37	112	649.6
BD-1809	48	60	21	10	4	38	8.4	2.8	6.5	11.23	7.9	125	812.5
BD-8729	49	64	12	12	6	27	8	2.5	5.96	10.51	8.74	110	655.6
BD-8813	49	56	24	12	8	36	7	2	5.5	11.27	8.43	110	605
BD-7988	43	50	30	15	10	35	10	2.5	6.41	13.51	9.72	170	1090.55
BD-6	49	56	25	20	14	10	12.6	1.6	7.12	12.85	9.14	146	1039.52
BD-8816	40	46	28	8	5	30	15	3	9.17	13.76	9.39	121	1110.17
Mean	50.04	60.04	29.31	11.04	7.346	24.96	8.969	2.505	6.582	12.16	8.722	140	915.5
Maximum	64	78	51	20	14	38.60	15	8.23	9.997	13.76	9.960	300	1693.5
Minimum	40	46	10	8	4	10	6.5	1.5	4.620	10.11	7.370	110	566.1
%cv	5.02	5.25	9.28	11.31	14.84	8.67	11.43	10.23	10.67	6.44	8.33	13.76	8.92

maximum duration (78.00 days) to first fruiting was produced by BD-8001 and that of minimum (46.00 days) by BD-8816 with mean value 60.04 days (Table 4)

4.1.1.3 No. of inflorescence per plant

Mean sum of square for number of inflorescence per plant **was** significant (261.305) due to genotypes in country Bean (Table 3) indicating existence of considerable difference for this trait. The maximum number of inflorescence was found 51.00 in BD-8832 and the minimum was recorded 10.00 in BD-808 with mean value 29.31 (Table 4).

4.1.1.4 No. of flower per inflorescence

Mean sum of square for number of flower per inflorescence was significant (25.315) due to genotypes in country Bean (Table 3) indicating existence of considerable difference for this trait. The maximum number of flower per inflorescence was found 20.00 in BD-6 and the minimum was recorded 8.00 in BD-8737, BD-1816, BD-130 and BD-8816 with mean value 11.04 (Table 3).

4.1.1.5 No. of pod per inflorescence

Mean sum of square for number of pod per inflorescence was significant (17.506) due to genotypes in country Bean (Table 3) indicating existence of considerable difference for this trait. The maximum number of pod per inflorescence was found 14.00 in BD-6 and the minimum was recorded 4.00 in BD-7977 and BD-1809 with mean value 7.346 (Table 4).

4.1.1.6 Inflorescence length (cm)

Significant mean sum of square for inflorescence length (208.138) indicated considerable difference among the genotypes studied (Table 3). The maximum inflorescence length was found 38.60 in BD-7999 and the minimum was recorded 10.00 in BD-6 with mean value 24.96 (Table 4).

4.1.1.7 Pod length (cm)

Significant mean sum of square for fruit length (16.74) indicated considerable difference among the genotypes studied (Table 3). The maximum fruit length was

found 15.00 cm in BD-8816 and the minimum was recorded 6.50 cm in BD-8001 and BD-7978 with mean value 8.969 cm (Table 4).

4.1.1.8 Pod breadth (cm)

Mean sum of square fruit breadth was significant (4.679) due to genotypes in bottle gourd (Table 3) indicating existence of considerable variation for this trait. The maximum fruit breadth was found 8.23cm in BD-7985 and the minimum was recorded 1.50cm in BD-8737 with mean value 2.505cm (Table 4)

4.1.1.9 Pod weight (g/pod)

Mean sum of square for fruit weight was significant (6.13) in country bean (Table 3) indicating existence of considerable difference for this trait. The maximum weight per fruit was found 9.997 in BD-8816 and the minimum was recorded 4.620 in BD-7985 with mean value 6.582 (Table 4).

4.1.1.10 Seed length (mm)

Mean sum of square for seed length was significant (4.02) due to genotypes in country bean(Table 3) indicating existence of considerable difference for this trait. The maximum seed length was found 13.76 mm in BD-8816 and the minimum was recorded 10.11mm in BD-1805 with mean value 12.16 mm (Table 4).

4.1.1.11 Seed width (mm)

Mean sum of square for seed width was significant (1.51) due to genotypes in country bean(Table 3) indicating existence of considerable difference for this trait. The maximum seed width was found 9.96mm in BD- 7999 and the minimum was recorded 7.37mm in BD-7995 with mean value 8.722mm (Table 4).

4.1.1.12 Number of pod per plant

Genotype mean sum of square for number of fruit per plant was found significant (2731.28) as shown in (Table 3). The maximum number of fruit per plant was found 250.0 in BD-8034 and the minimum was recorded 110.0 in BD-8729 and BD-8813 with mean value 138.12 (Table 4).

4.1.1.13 Pod Yield per plant (g)

Significant mean sum of square for yield per plant (179052.24) indicated considerable difference among the genotypes studied (Table 3). The maximum yield per plant was found 1693.5 g in BD-8027 and the minimum was recorded 566.1g in BD-808 with mean value 915.5g (Table 4).

4.2 Variability of country bean on the basis of yield and yield contributing characters

4.2.1 Days to first flowering

Genotypic and phenotypic variance was observed 29.70 and 36.00 respectively for days to first flowering with large environmental influence and difference between the genotypic co-efficient of variation (10.89) and phenotypic co-efficient of variation (11.99) indicating existence of less variation among the genotypes (table-5). Heritability for this trait was estimated very high (82.48%) and genetic advance (10.19) and genetic advance in percent of mean (20.37) were found high, indicated that the possibility of predominance of additive gene effect for this characters is in agreement with the findings of earlier workers Singh *et al.* (1979), Mallareddy (1979), Pandita (1980), Kabir and Sen (1987) and Basavarajappa and Byre Gowda (2004). However, Muralidharan (1980) reported a high heritability coupled with low genetic advance for this trait. Phenotypic variation in flower among different genotypes is given in Plate 2a and 2b.

Table 5. Genetic parameters of thirteen vegetative and yield contributing characters of 26 country bean genotypes

Characters	σ2g	σ2p	σ2e	GCV	PCV	ECV	h^2b	GA(%) (5%)	GA in % of mean (5%)	CV%
Days to 1st flowering	29.70	36.00	6'31	10.89	11.99	5.02	82.48	10.19	20.37	5.02
Days to 1st fruiting	61.94	71.84	9.90	13.11	14.12	5.24	86.22	15.05	25.07	5.25
No. of Inflorescences /plant	84.63	92.04	7.40	31.39	32.73	9.28	91.96	18.17	62.01	9.28
No. of flower/Inflorescences	7.92	9.48	1.56	25.49	27.89	11.32	83.54	5.30	48.00	11.31
No. of pod/Inflorescences	5.44	6.63	1.19	31.75	35.05	14.84	82.06	4.35	59.24	14.84
Inflorescences length(cm)	67.82	72.51	4.69	32.99	34.11	8.67	93.53	16.41	65.73	8.67
Pod length (cm)	5.23	6.28	1.05	25.50	27.94	11.42	83.28	4.30	47.94	11.43
Pod width (cm)	1.54	1.60	0.07	49.50	50.55	10.26	95.88	2.50	99.85	10.23
Pod weight (g/pod)	1.88	2.37	0.49	20.82	23.40	10.67	79.21	2.51	38.18	10.67
Seed length (mm)	1.13	1.75	0.61	8.76	10.87	6.44	64.92	1.77	14.54	6.44
Seed width (mm)	0.33	0.85	0.53	6.56	10.60	8.32	38.29	0.73	8.36	8.33
Pods/plant	790.29	1150.70	360.41	20.35	24.56	13.75	68.68	47.99	34.75	13.76
Pod yield /plant	57514.32	64023.61	6509.29	26.51	27.97	8.92	89.83	468.24	51.76	8.92

CV = Co-efficient of Variation, σ^2e = Environmental variance, σ^2g = Genotypic variance, σ^2p = Phenotypic variance, GCV = Genotypic coefficient of variation, PCV = Phenotypic coefficient of variation, ECV= Environmental coefficient of variation, h^2_b = Heritability, GA = Genetic advance, GAPM= Genetic advance in percent of mean.

Plate 2a. Showing phenotypic variation in flower among different genotypes of country bean

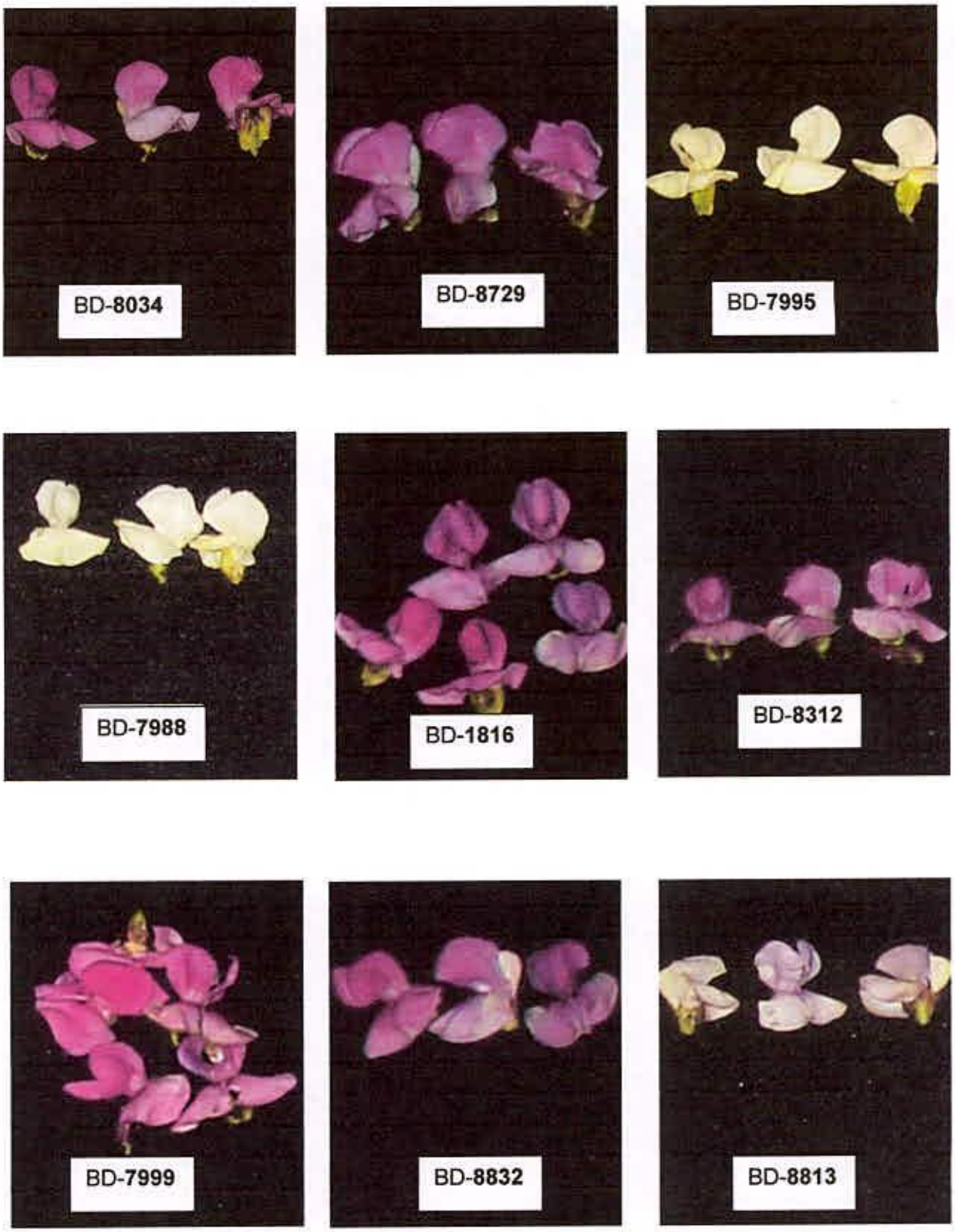


Plate 2b. Showing phenotypic variation in flower among different genotypes of country bean.

4.2.2 Days to first fruiting

Highest genotypic and phenotypic variance was observed 61.94 and 71.84 respectively for days to first fruiting with large environmental influence and difference between the genotypic co-efficient of variation (13.11) and phenotypic co-efficient of variation (14.12) indicating existence of less variation among the genotypes. Heritability for this trait was estimated very high (86.22%) and genetic advance (15.05) and genetic advance in percent of mean (25.07) were found high, indicated that the possibility of predominance of additive gene effect.Similar findings were recorded by Borah and Shadeque (1992), Basavarajappa and Byre Gowda (2004). In contrast, Mallareddy (1979) indicated higher heritability coupled with high genetic advance for this trait.

4.2.3. No. of inflorescence per plant

The differences in magnitudes in between genotypic (84.63) and phenotypic (92.04) variances was relatively high for this trait indicating large environmental influence on these characters. The genotypic co-efficient of variation and phenotypic co-efficient of variation were 31.39 and 32.73 respectively. Heritability (91.96%) estimates for this trait was high, genotypic advance (18.17) was moderately high and genotypic advance in percent of mean (62.01) was found high, indicate that apparent variation was due to genotypes so selection based on this trait could be effective. Muralidharan (1980) has got same result.

4.2.4 No. of flower per Inflorescence

The differences in magnitudes in between genotypic (7.92) and phenotypic (9.48) variances was relatively high for this trait indicating large environmental influence on these characters. The genotypic co-efficient of variation and phenotypic co-efficient of variation were 25.49 and 27.89 respectively. Heritability (83.54) estimates for this trait was high, genotypic advance (5.30) was moderately high and genotypic advance in percent of mean (48.00) was found high, revealed that the trait was controlled by additive gene agrees with the finding of Ali *et al.* (2005).

4.2.5 No. of pod per inflorescence

The differences in magnitudes in between genotypic (5.44) and phenotypic (6.63) variances was relatively high for this trait indicating large environmental influence on these characters. The genotypic co-efficient of variation and phenotypic co-efficient of variation were 31.75 and 35.05 respectively. Heritability (82.06) estimates for this trait was high, genotypic advance (4.35) was moderately high and genotypic advance in percent of mean (59.24) was found high, revealed that the trait was controlled by additive gene. This is in line with the findings of Ali *et al.* (2005).

4.2.6 Inflorescence length (cm)

The genotypic variance and phenotypic variance were 67.82 and 72.51 respectively. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this character. The genotypic co-efficient of variation (32.99) and phenotypic co-efficient of variation (34.11) were close to each other. Heritability (93.53%) estimates for this trait high, genotypic advance (16.41) and genotypic advance in percent of mean (65.73) were found moderately high, indicated that the trait was governed by additive gene and selection for this character would be effective. This finding is similar to that of Borah and Shadeque (1992) who recorded a high heritability value coupled with a high genetic advance for this character.

4.2.7 Pod length (cm)

The genotypic variance and phenotypic variance were 5.23 and 6.28 respectively. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this character. The genotypic co-efficient of variation (25.50) and phenotypic co-efficient of variation (27.94) were close to each other. Heritability (83.28%) estimates for this trait high, genotypic advance (4.30) and genotypic advance in percent of mean (47.94) were found moderately high, indicated that the trait was governed by additive gene and selection for this character would be effective Heritability estimate for this trait was high and agrees with the results obtained by Singh (1979), Pandita (1980), Borah and Shadeque (1992) and Ali *et al.* (2005). Low genetic advance as percent of mean

observed for this character is in line with Mallareddy (1979).Variation of fruit length among some genotypes of country bean in Plate 3a and 3b.

4.2.8 Pod breadth (cm)

The genotypic variance and phenotypic variance were 1.54 and 1.60 respectively. The genotypic co-efficient of variation and phenotypic co-efficient of variation were 49.50 and 50.55 respectively. Heritability (95.88%) estimates for this trait was high along with moderately high genetic advance (2.50) and genetic advance in percent of mean (99.85) indicated that this character was controlled by additive gene effects. Borah and Shadeque (1992) was reported similar result for these characters.

4.2.9 Pod weight (g)

The differences in magnitudes in between genotypic (1.88) and phenotypic (2.37) variances was relatively high for this trait indicating large environmental influence on these characters. The genotypic co-efficient of variation and phenotypic co-efficient of variation were 20.82 and 23.40 respectively for fruit weight which indicating that significant variation exists among different genotypes. Heritability (79.21%) estimates for this trait was high together with considerable high genetic advance (2.51) and genetic advance in percent of mean (38.18) indicated that selection for this character would be effective. Similar results were reported by Joshi Arunachala (1979), Baswana *et al.* (1980), Singh *et al.* (1985), Dahiya and Pandita (1989), Uddin and Newaz (1997) and Basavarajappa and Byre Gowda (2004).

4.2.10 Seed length (mm)

The genotypic variance (1.13) and phenotypic variances (1.75) were close to each other. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this character. The genotypic co-efficient of variation was 8.76 and phenotypic co-efficient of variation was 10.87. Heritability (64.92%) estimates for this trait was high, genotypic advance (1.77) and genotypic advance in percent of mean (14.54) were found moderately high, indicated that this trait was controlled by additive gene. Similar finding was reported by Kabir and Sen (1987).

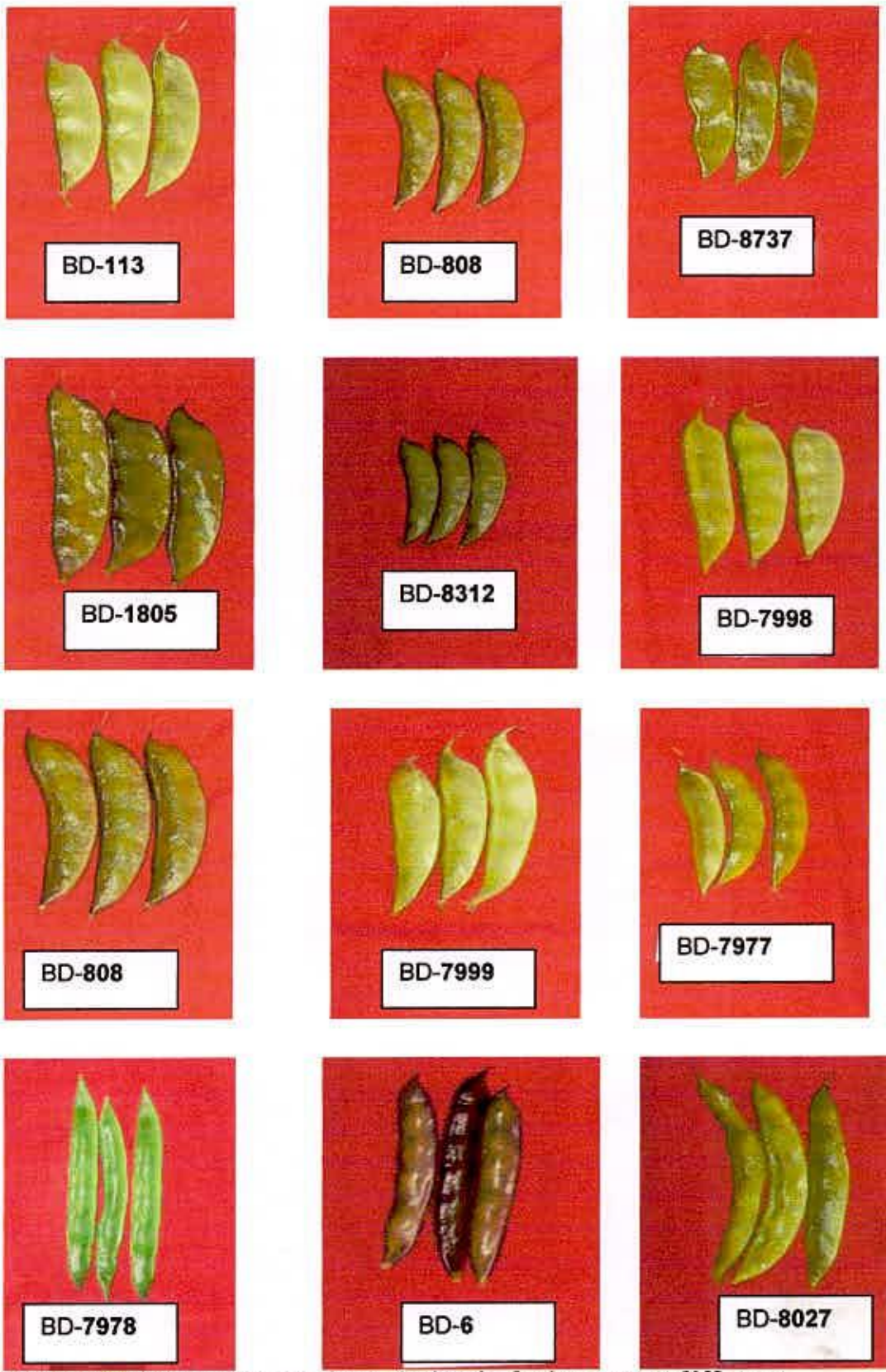


Plate 3a. Showing phenotypic variation in fruits among different genotypes of country bean.

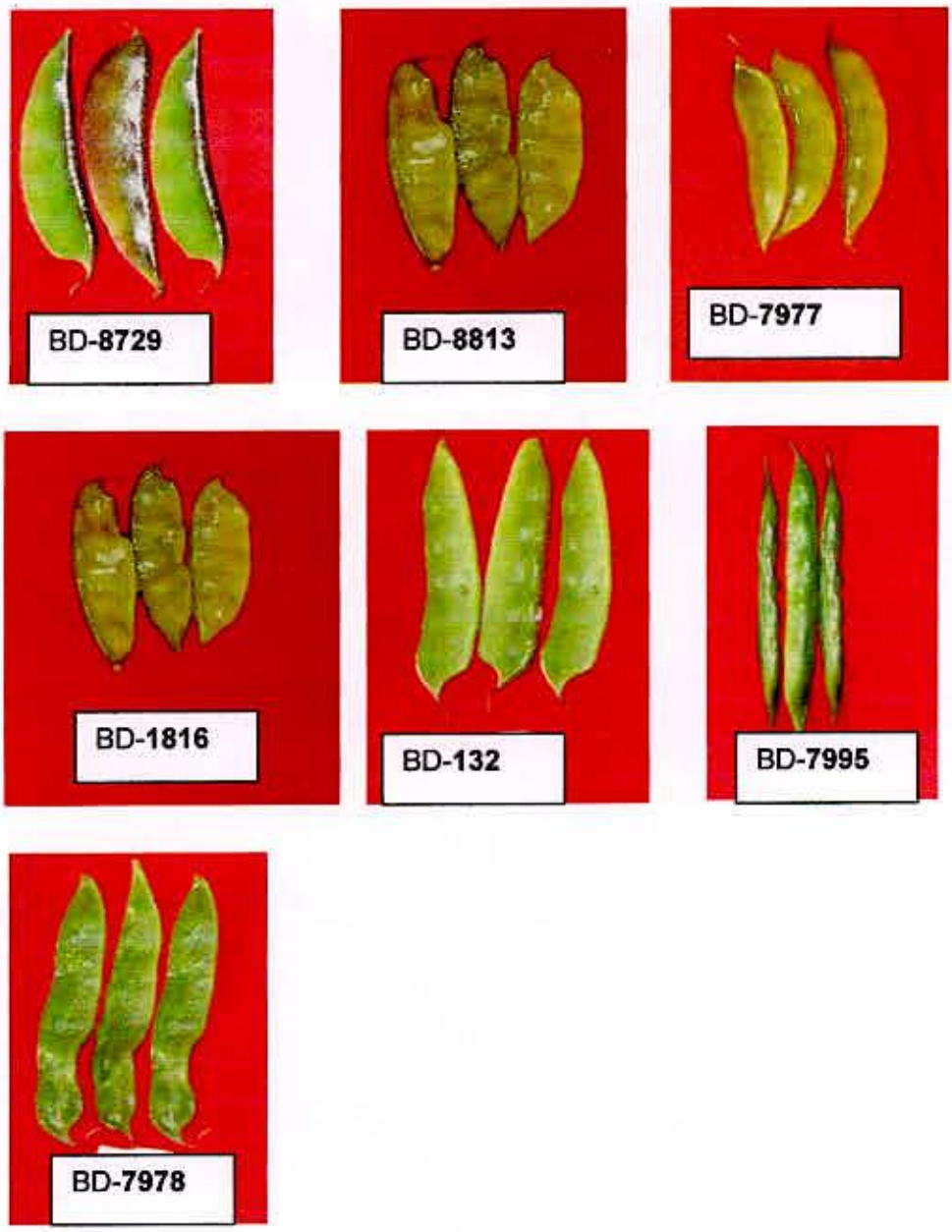


Plate 3b. Showing phenotypic variation in fruits among different genotypes of country bean

4.2.11 Seed width (mm)

The genotypic variance (0.33) and phenotypic variances (0.85) were close to each other. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this character. The genotypic co-efficient of variation was 6.56 and phenotypic co-efficient of variation was 10.60. Heritability (38.29%) estimates for this trait was high, genotypic advance (0.73) and genotypic advance in percent of mean (8.36) were found moderately high, indicated that this trait was controlled by additive gene. Similar finding was reported by Kabir and Sen (1987)

4.2.12 Number of pod per plant

The genotypic variance (790.29) and phenotypic variance (1150.70) for this trait were very low. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this character. The genotypic co-efficient of variation and phenotypic co-efficient of variation were 20.35 and 24.56 respectively which indicated presence of considerable variability among the genotypes. Heritability (68.68%) estimates for this trait was high, genetic advance (47.99) was found low and genetic advance in percent of mean (51.76) was found moderately high, indicated that the character was controlled by additive gene. Similar result was reported by Muralidharan (1980).

4.2.13 Pod yield per plant (g)

The differences in magnitudes in between genotypic (57514.32) and phenotypic (64023.61) variances was relatively high for this trait indicating large environmental influence on these characters. The genotypic co-efficient of variation and phenotypic co-efficient of variation were 26.51 and 27.97 respectively for yield per plant which indicating that significant variation exists among different genotypes. The heritability value (89.83%) as well as genetic advance (468.24) and genetic advance in percent of mean (51.76) were observed very high. The very high heritability with moderate genetic advance provided opportunity for selecting high valued genotypes for breeding programme. Nayar (1984) has got same results for this characters.

4.3 CORRELATION CO-EFFICIENT

Yield is a complex product being influenced by several interdependent quantitative characters. Selection for yield may not be effective unless the directly or indirectly influences of other yield components are taken into consideration. When selection pressure is exercised for improvement of any character highly associated with yield, it simultaneously affects a number of other correlated traits. Hence knowledge regarding association of character with yield and among themselves provides guideline to the plant breeder for making improvement through selection provide a clear understanding about the contribution in respect of establishing the association by genetic and non genetic factors. Higher genotypic correlations than phenotypic one might be due to modifying or masking effect of environment in the expression of the character under study (Nandpuri *et al.* 1973). Results of genotypic and phenotypic correlation co-efficient of sixteen yield and its contributing traits of country bean were estimated as vegetative character and reproductive character with yield and shown in Table 4 which discussed character wise as follows:

4.3.1 Days to first flowering

Significant positive relationships were found in days to first flowering at both genotypic and phenotypic levels (Table 6). Highly significant positive association between days to first flowering indicates that the traits are governed by same gene and simultaneous improvement would be effective. This character showed significant and positive correlation at both genotypic and phenotypic level between other traits like inflorescence per plant, flower per inflorescence, pod per inflorescence, pod length, pod weight, pod per plant and yield. Results indicated that the increasing the correlation of days to first flowering with other traits decreasing the yield in country bean. Basavarajappa and Byre Gowda (2004) also noticed this positive significant association of days to 50 per cent flowering with seed yield.

4.3.2 Days to first fruiting

Similar trends of correlation of days to first fruiting between other characters also observed. Here the character showed highly significant and negative correlation at genotypic (Table 6) between pods per inflorescence. This indicated that if day to first

Table 6. Genotypic and phenotypic correlation of nine yield contributing characters on yield of twenty six country bean Genotypes

Parameters		1st fruit	Inflorescence /plant	Flower/ Inflorescence	Pod/ Inflorescence	Pod len.(cm)	Pod width (cm)	Pod weight (g/pod)	Pods/ plant	Pod yield /plant
1st flowering	r_g	0.969**	-0.078	-0.195	-0.208	-0.262	0.108	-0.173	-0.256	-0.298
	r_p	0.841**	-0.052	-0.191	-0.194	-0.170	0.071	-0.126	-0.125	-0.218
1st fruit	r_g		-0.170	-0.275	-0.319*	-0.233	0.072	-0.115	-0.066	-0.066
	r_p		-0.150	-0.249	-0.293	-0.164	0.052	-0.049	-0.016	-0.080
Inflorescence /plant	r_g			-0.144	0.175	0.052	0.167	0.004	0.794	0.612**
	r_p			-0.105	0.169	0.092	0.187	-0.030	0.404**	0.307
Flower/ Inflorescence	r_g				0.982**	-0.100	-0.050	-0.536**	0.141	-0.353*
	r_p				0.774**	-0.109	-0.048	-0.150	0.077	-0.059
Pod/ Inflorescence	r_g					-0.136	0.049	-0.231	0.301	0.080
	r_p					-0.072	0.055	-0.229	0.250	0.055
Pod len (cm)	r_g						-0.216	0.667**	0.053	0.555**
	r_p						-0.140	0.533**	0.069	0.493
Pod width (cm)	r_g							-0.385*	0.029	-0.305*
	r_p							-0.346*	-0.007	-0.267
Pod weight (g/pod)	r_g								-0.104	0.654**
	r_p								-0.027	0.613
Pods/ plant	r_g									0.698**
	r_p									0.543

** indicates significant at 0.01 level of significance and * indicates significant at 0.05 level of significance

female fruiting is increased, then pod per inflorescence decreased. These results are in contaray with the findings of Mallareddy (1979), Pandey *et al.* (1980), Kabir and Sen (1987), Uddin and Newaz (1997), Basavarajappa, and Byre Gowda (2004).The character showed insignificant and negative correlation at both genotypic and phenotypic level between other traits like , like inflorescence per plant ,flower per inflorescence , pod length, pod weight, pod per plant and yield.. Insignificant association of these traits indicated that the association between these traits is largely influenced by environmental factors. But only positive correlation of days to first fruiting with pod width was observed. These results are in contaray with the findings of Mallareddy (1979), Pandey *et al.* (1980), Kabir and Sen (1987), Uddin and Newaz (1997), Basavarajappa, and Gowda (2004).

4.3.3 Number of inflorescence per plant

The character showed highly significant and positive relationship with pod yield per plant at both genotypic and phenotypic levels (Table 6) indicated that if inflorescence per plant is increased, then yield also increased. This is in line with the findings of Joshi (1971), Uddin and Newaz (1997), Basavarajappa and Byre Gowda (2004) and Ali *et al.* (2005). The character showed highly significant and positive relationship with pod per plant at phenotypic levels (Table 6) indicated that if inflorescence per plant is increased, then pod per plant also increased. This is in line with the findings of Joshi (1971), Uddin and Newaz (1997), Basavarajappa and Gowda (2004) and Ali *et al.* (2005). Negative and insignificant correlation between flowers per inflorescence .The character showed insignificant and positive relationship with pod per inflorescence, pod length, pod width, pods per plant at both genotypic and phenotypic level.

4.3.4 Number of flower per inflorescence

Flower per inflorescence showed positive and significant correlation with pod per inflorescence only at both genotypic and phenotypic level (Table 6). Baswana *et al.* (1980) agreed with this result But this character produced insignificant and negative correlation at both genotypic and phenotypic level with pod length and pod width indicated that the association among these traits is largely influenced by environmental factors. This character produced significant and negative correlation at

genotypic level with pod weight and pod yield indicated that the association among these traits is largely influenced by environmental factors.

4.3.5 No of pod per inflorescence

Pod per inflorescence showed insignificant and positive correlation with pod width, pod per plant and pod yield at both genotypic and phenotypic level (Table 6). Basavarajappa and Gowda (2004) was reported positive correlation with pod width, pod per plant and pod yield at both genotypic and phenotypic level. But this character produced insignificant and negative correlation at genotypic and phenotypic level with pod length; pod weight indicated that the association among these traits is largely influenced by environmental factors.

4.3.6 Pod length (cm)

Pod length showed significant and positive correlation with pod weight and pod yield at both genotypic and phenotypic level (Table 6) revealed that if the pod length is increased, then pod weight and pod yield also increased. Singh *et al.* (1979) and Ali *et al.* (2005) recorded positive significant association of pod length with seed yield per plant But this character produced insignificant and positive correlation at both genotypic and phenotypic level with pods per plant, negative and insignificant correlation with pod width.

4.3.7 Pod breadth (cm)

Pod width also showed significant and negative correlation with pod weight at both genotypic and phenotypic level (Table 6) indicated that if the pod breadth is increased, then pod weight decreased. On the other hand this character produced insignificant but positive correlation with pod per plant at genotypic level indicated that the association among these traits is largely influenced by environmental factors. Kabir and Sen (1987) reported that pod width was strongly correlated with pod number, pod length. Pod width also showed significant and negative correlation with pod yield per plant at genotypic level that indicated if pod breadth increase pod yield decreased.

4.3.8 Pod weight (g/pod)

The trait, pod weight showed highly significant and positive correlation with pod yield per plant at both genotypic and phenotypic level (Table 6) indicated that if the pod weight is increased, then the pod yield are also increased. Baswana *et al.* (1980) indicated positive association of grain yield with weight of pods, pod length, pod width and seeds per pod. The character also showed negative but insignificant correlation with pod per plant at both genotypic and phenotypic level.

4.3.9 Number of pod per plant

Yield highly significant and positively correlated with number of pod per plant at both genotypic and phenotypic level (Table 6) indicating that any increase in number of pod per plant should bring an enhanced in the yield. . In present research, the high and positive relations observed between the number of pods per plant and seed yield was similar to the results of Gopalan *et al.* (1982) and Singh *et al.* (1990).

4.4 PATH CO-EFFICIENT ANALYSIS

Partitioning of genotypic correlation of different genotype, yield and its contributing traits in country bean are shown in Table 6 and Table 7 and discussed character wise as follows:

4.4.1 Days to first flowering

Days to first flowering showed the positive direct effect (0.245) on yield (Table 7) and agrees with the findings of Basavarajappa and Gowda (2004).The character also showed the maximum positive indirect effect through pod per inflorescence (0.066) followed by pod length (0.031), pod width (0.005), inflorescence per plant (0.004). The negative indirect effect of this character on yield via flower per inflorescence (-0.064) was the highest followed by pod weight (-0.168), days to first fruiting (-0.175) and pods per plant (-0.243) which finally made insignificant negative correlation between days to first flowering and yield per plant (-0.2982).

Table 7. Path analysis of nine vegetative characters on yield of twenty six country bean genotypes.

	Days to 1st flowering	Days to 1st fruiting	No of Inflorescence per plant	No of Flower per Inflorescence	No. of Pod per Inflorescence	Pod length (cm)	Pod width (cm)	pod weight (g/pod)	No. of Pods per plant	Genotypic correlation with yield
Days to1st flowering	**0.245**	-0.175	0.004	-0.064	0.066	0.031	0.005	-0.168	-0.243	-0.2982
Days to1st fruiting	0.238	**-0.180**	0.009	-0.090	0.101	0.028	0.003	-0.112	-0.063	-0.0656
No.of Inflorescence per plant	-0.019	0.031	**-0.055**	-0.047	-0.055	-0.006	0.007	0.004	0.752	0.6123**
No. of flower per Inflorescence	-0.048	0.050	0.008	**0.326**	-0.310	0.012	-0.002	-0.522	0.134	-0.3532*
No.of Pod per inflorescence	-0.051	0.058	-0.010	0.320	**-0.316**	0.016	0.002	-0.225	0.285	0.0800
Pod length (cm)	-0.064	0.042	-0.003	-0.032	0.043	**-0.120**	-0.010	0.649	0.050	0.5551**
Pod width (cm)	0.026	-0.013	-0.009	-0.016	-0.015	0.026	**0.044**	-0.375	0.027	-0.3049*
pod weight (g/pod)	-0.042	0.021	0.000	-0.175	0.073	-0.080	-0.017	**0.973**	-0.099	0.6536**
No.of Pods/plant	-0.063	0.012	-0.043	0.046	-0.095	-0.006	0.001	-0.101	**0.948**	0.6982**

R= 0.132 ** indicates significant at 0.01 level of significance and * indicates significant at 0.05 level of significance.

4.4.2 Days to first fruiting

Days to first fruiting showed a negative direct effect (-0.180) on yield (Table 7). Basavarajappa and Gowda (2004) agreed with this result. This character, also showed the highest positive indirect effect through days to first flowering (0.238) followed by pod per inflorescence (0.101) and pod length (0.028),inflorescence per plant (0.009), pod width(0.003) on yield. The character also produced negative indirect effect on yield via pods per plant (-0.063), number of flower per inflorescence (-0.090), pod weight (-0.122). The cumulative effects of these characters produced a negative genotypic correlation on yield (-0.0656).

4.4.3 Number of inflorescence per plant

It was found that internodes distance showed the negative direct effect (-0.055) on yield (Table 7). The character also showed the maximum positive indirect effect through pods per plant (0.752) followed by days to first fruiting (0.031), pod width (0.007) and pod weight (0.004). The negative indirect effect of this character on yield via pod length (-0.006) was the highest followed by days to first flowering (-0.019), flower per inflorescence (-0.047) and pod per inflorescence (-0.055) which finally made significant positive correlation between number of inflorescence per plant and yield per plant (0.6123). Figure 1 showing Path diagram of yield and its contributing traits in twenty six genotypes of country bean.

4.4.4 Number of flower per Inflorescence

Number of flower per Inflorescence showed a positive direct effect (0.326) on yield (Table 7). A path coefficient analysis by Mallareddy (1979) also got the same result. This character also showed the highest positive indirect effect through pods per plant (0.134) followed by days to first fruiting (0.050), pod length (0.012), inflorescence per plant (0.008). The character also produced the negative indirect effect on yield via pod width (-0.002), days to first flowering (-0.048), pod per inflorescence (-0.310), pod weight (-0.522).The cumulative effects of these characters produced a significant and negative genotypic correlation on yield (-0.3532).

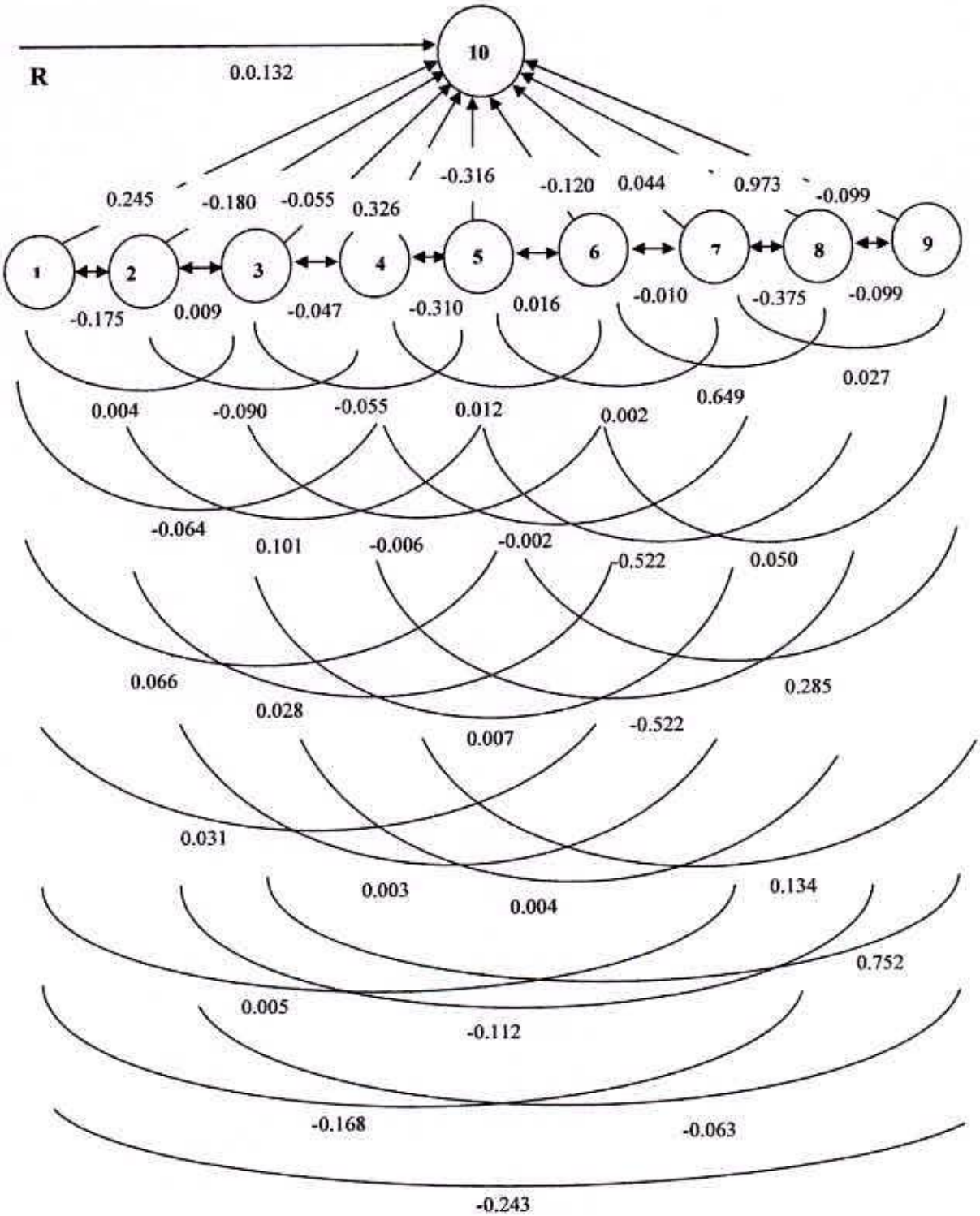


Fig. 1. Path diagram of nine yield and yield contributing characters of twenty six country bean genotypes.

1= 1st flower, 2= 1st fruit, 3= Inflorescence per plant, 4= Flower per Inflorescence, 5= Pod per inflorescence, 6= Pod len (cm), 7= Pod width (cm), 8= pod weight (g/pod), 9= Pods/plant and 10= pod yield/plant

4.4.5 Number of pod per Inflorescence

Number of pod per inflorescence showed the negative direct effect (-0.316) on yield (Table 7). A path coefficient analysis by Mallareddy (1979) also got the same result. This character also showed high positive and insignificant genotypic correlation with yield per plant (0.0800) due to moderately high indirect effect through flower per inflorescence (0.320) followed by pods per plant (0.285), days to first fruiting (0.058), pod length (0.016), pod width (0.002). Significant genotypic correlation coefficients between number of branches per vine and yield further strengthened their reliability in the process of selection for higher yield. But the negative indirect effect through inflorescence per plant (-0.010), days to first flowering (-0.051), pod weight (-0.225).

4.4.6 Pod length (cm)

Pod length showed negatively direct effect (-0.120) on yield (Table 7). However Kabir and Sen (1987) had got highest direct effect on yield. This character, however, showed positive indirect effect through pod weight (0.649), pods per plant (0.050), pod per inflorescence (0.043), days to first fruiting (0.042). The negative indirect effect via inflorescence per plant (-0.003) followed by pod width (-0.010) ,flower per inflorescence (-0.032),days to first flowering (-0.064)which were contributed to result insignificant positive genotypic correlation with yield per plant (0.5551).

4.4.7 Pod breadth (cm)

Pod breadth showed a positive direct effect (0.044) on yield (Table 7). This character, however, showed also positive indirect effect through pods per plant (0.027),pod length(0.026),days to first flowering (0.026). The negative indirect effects were also observed via inflorescence per plant (-0.009) followed by days to first fruiting (-0.013), pods per inflorescence (-0.015), flower per inflorescence (-0.016) and pod weight (-0.375) which were contributed to result significant negative genotypic correlation with yield per plant (-0.3049).

4.4.8 Pod weight (g/pod)

Pod weight showed a positive direct effect (0.973) on yield (Table 7). This character showed positive indirect effect pod per inflorescence (0.073) followed by days to first fruiting (0.021), inflorescence per plant (0.000). But the negative indirect effect through pod width (-0.017), days to first flowering (-0.042), pod length (-0.080), pods per plant (-0.099), flower per inflorescence (-0.175) which finally made significant positive correlation between pod weight and yield per plant (0.6536).

4.4.9 Number of Pods per plant

Number of pod per plant showed a positive direct effect (0.948) on yield (Table 7). This character, however, showed also positive indirect effect through flower per inflorescence (0.046), days to first fruiting (0.012). The negative indirect effects were also observed via days to first flowering (-0.063), inflorescence per plant (0.043), pod per inflorescence (0.095), pod length (-0.006),pod weight (0.101) which were contributed to result highly significant positive genotypic correlation with yield per plant (0.6982).

4.5 MULTIVARIATE ANALYSIS

4.5.1 Principal component analysis (PCA)

Principal component analysis was carried out with twenty-six genotypes of country bean. First three Eigen values for three principal coordination axes of genotypes accounted for 66.72% variation (Table 8). A two dimensional scattered diagram (Fig. 2) was developed on the basis of the principal component score; Z_1 and Z_2 score (Appendices 1V).

4.5.2 Principal coordinates analysis (PCO)

The results obtained from principal coordinate analysis showed that the highest inter genotypic distance was observed between genotypes G3 and G13 (2.108) followed by G13 and G22 (1.958) and the lowest distance was observed (0.387) between genotypes G12 and G18 followed by the distance (0.391) between genotypes G4 and

Table 8. Eigen values and percent contribution of 13 yield contributing characters of twenty six country bean genotype.

Characters	Eigen value	% contribution	Cumulative variation
Days to 1st flowering	5.340	31.02	31.02
Days to 1st fruiting	3.414	19.83	50.85
No. of inflorescence/plant	2.733	15.87	66.72
No. of flower /Inflorescence	2.204	12.80	79.52
No. of pod/Inflorescence	1.169	6.79	86.31
Inflorescence length (cm)	1.013	5.89	92.20
Pod length (cm)	0.502	2.92	95.12
Pod width (cm)	0.406	2.36	97.48
pod weight (g/pod)	0.231	1.34	98.82
Seed length (mm)	0.129	0.75	99.57
Seed width (mm)	0.047	0.27	99.84
No. of pods /plant	0.028	0.16	100.00
Pods yield/plant (g)	0.000	0.00	100.00

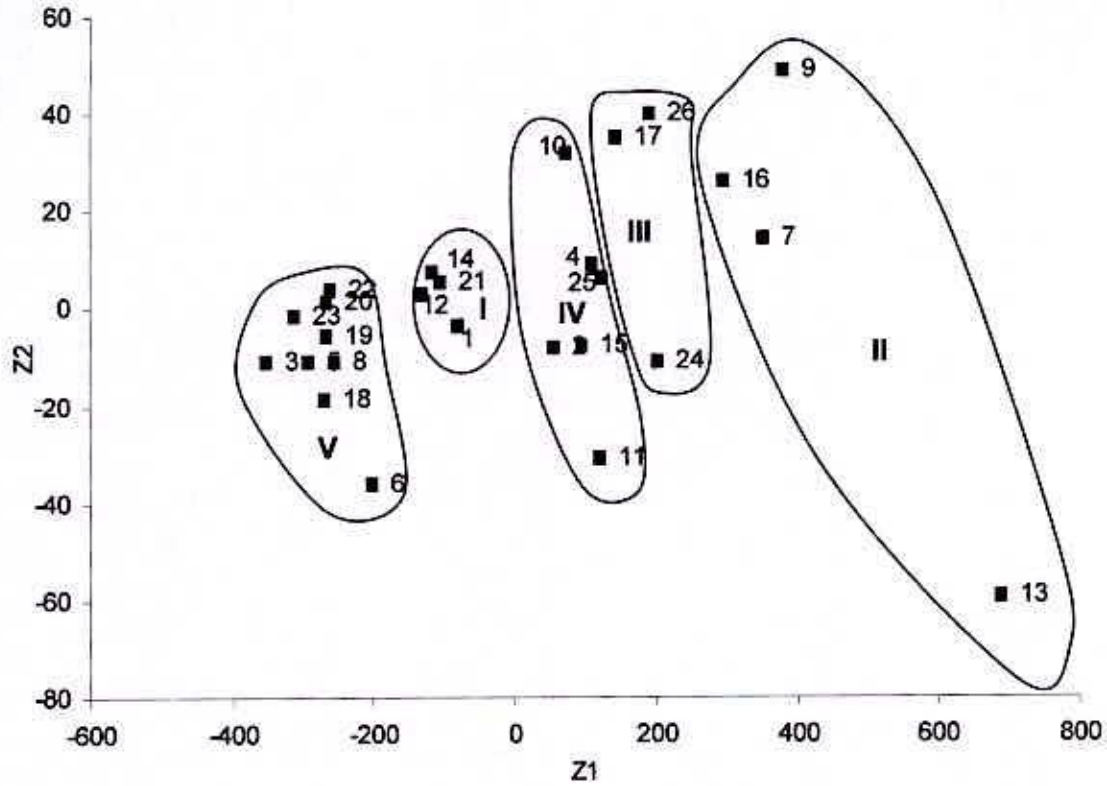


Fig. 2. Scattered diagram of twenty six genotypes of country bean superimpose Cluster

G17 (Table 9). The difference between the highest and the lowest inter genotypic distance indicated the moderate variability among the 26 genotypes of country bean. The highest intra-cluster distance was recorded in cluster IV (1.091) containing six genotypes BD-1816, BD-8312, BD-7977, BD-7998, BD-7999, BD-6. The lowest intra-cluster distance was observed in cluster I (0.85) having four genotypes viz. BD-8737 and BD-113, BD-130 and BD-1809. It favored to decide that intra-group diversity was the highest in cluster IV and the lowest in cluster I. Cluster II having four genotypes viz. BD-8832, BD-7995, BD-8034, BD- 8027 and had an intra-cluster distance 1.066. Cluster III having three genotypes viz. BD-137, BD-7988, BD-8816 and had an intra-cluster distance 0.945. The cluster V consisted nine genotypes viz. BD-808, BD-7978, BD-7985, BD-1805, BD-8001, BD-1830, BD-132, BD-8729, BD-8813 and had the intra-cluster distance 0.979 (Table 10).

4.4.3 Non-hierarchical clustering

The computations from covariance matrix gave non-hierarchical clustering among twenty six genotypes of country bean and grouped them into five clusters. The clustering pattern obtained coincided with the apparent grouping patterns performed by PCA. So the results obtained through PCA were confirmed by non-hierarchical clustering. Table 10 represents the clusters occupied by 26 genotypes of country bean. It explains that cluster V contained the highest number of genotypes nine, cluster IV constitute by six genotypes, cluster III constitute by three genotypes and cluster II constitute by four genotypes and cluster I having four genotypes. Cluster V was composed of BD-808, BD-7978, BD-7985, BD-1805, BD-8001, BD-1830, BD-132,BD-8729,BD-8813.The genotypes of cluster V are collected from Plant Genetic Resource Centre, BARI, Gazipur. Cluster mean for 13 traits are presented in (Table 11). From the Table -11, it was observed that the mean value of cluster V ranked first for pod width (3.07). Among 13 characters cluster III produced the maximum cluster mean for the five characters viz. inflorescence length (31.67), pod length (10.67), pod weight (8.15), seed length (13.05) and seed width (9.32). Similarly, cluster I ranked the first for days to first flowering (54.25), days to first fruiting (65.75). Cluster II had the highest cluster mean value was achieved for three characters viz. inflorescence per plant (37.50),pods per plant (171.50), pod yield per plant (1297.99).

Table 9. Ten highest and ten lowest inter genotypic distance among the twenty six country bean genotypes

Sl. No.	Genotypic combination	Distances
	A. 10 highest inter genotypic distance	
1	BD-8034 - BD-808 (G_{13} – G_3)	2.108
2	BD-8729 - BD-8034 (G_{22} – G_{13})	1.958
3	BD-6 - BD-1809 (G_{25} – G_{21})	1.914
4	BD-8832 - BD-808 (G_7 – G_3)	1.91
5	BD-6 - BD-7985 (G_{25} – G_6)	1.861
6	BD-132 - BD-8034 (G_{20} – G_{13})	1.859
7	BD-8813 - BD-8034 (G_{23} – G_{13})	1.849
8	BD-7995 - BD-808 (G_9 – G_3)	1.835
9	BD-6 - BD-808 (G_{25} – G_3)	1.806
10	BD-7977 - BD-7985 (G_{10} – G_6)	1.804
	B. 10 lowest inter genotypic distance	
1	BD-8001 - BD-113 (G_{18} – G_{12})	0.387
2	BD-137 - BD-8312 (G_{17} – G_4)	0.391
3	BD-8813 - BD-132 (G_{23} – G_{20})	0.395
4	BD-1830 - BD-113 (G_{19} – G_{12})	0.418
5	BD-8729 - BD-808 (G_{22} – G_3)	0.456
6	BD-8813 - BD-1830 (G_{23} – G_{19})	0.462
7	BD-113 - BD-8312 (G_{12} – G_4)	0.476
8	BD-8027 - BD-7999 (G_{16} – G_{15})	0.487
9	BD-7999 - BD-8312 (G_{15} – G_4)	0.495
10	BD-1830 - BD-7978 (G_{19} – G_5)	0.515

Table 10. Distribution of twenty six country bean genotypes in five clusters

Cluster	Members	No. of genotypes	Designation
1	4	1, 12, 14, 21	BD-8737, BD-113, BD-130, BD-1809
2	4	7, 9, 13, 16	BD-8832, BD-7995, BD-8034, BD-8027
3	3	17, 24, 26	BD-137, BD-7988, BD-8816
4	6	2, 4, 10, 11, 15, 25	BD-1816, BD-8312, BD-7977, BD-7998, BD-7999, BD-6
5	9	3, 5, 6, 8, 18, 19, 20, 22, 23	BD-808, BD-7978, BD-7985, BD-1805, BD-8001, BD-1830, BD-132, BD-8729, BD-8813

Table 11. Cluster mean of 13 characters of thirty six country bean genotypes

Character	I	II	III	IV	V
Days to first flowering	54.25	46.25	46.00	51.50	50.22
Days to first fruiting	65.75	59.50	52.00	61.67	59.33
No. of inflorescence/plant	28.00	37.50	29.00	28.00	27.22
No. of flower/Inflorescence	9.00	10.25	11.00	12.00	11.67
No. of pod/Inflorescence	5.00	7.00	7.67	8.17	7.89
Inflorescence length (cm)	25.85	21.00	31.67	20.43	27.11
Pod length (cm)	9.60	10.25	10.67	9.60	7.13
Pod width (cm)	2.40	1.83	2.50	2.18	3.07
pod weight (g/pod)	6.44	7.97	8.15	6.88	5.31
Seed length (mm)	12.56	12.26	13.05	12.58	11.36
Seed width (mm)	8.36	8.11	9.32	8.96	8.80
No. of pods/plant	125.75	171.50	137.00	149.67	121.44
Pod yield/plant (g)	808.47	1297.99	1087.38	1011.45	640.68

4.5.4 Canonical variate analysis

Canonical variate analysis was done to compute the inter-cluster Mahalanobis's D^2 values. Statistical distances represent the index of genetic diversity among the clusters. The highest inter-cluster distance was observed (Table 12 or Figure 4) between cluster II and cluster V (43.76) followed by between cluster I and cluster II (33.12) and between cluster III and cluster V (30.05). The higher inter-cluster distances between these clusters indicate to obtain wide spectrum of segregating population if parents chosen from these distant clusters are used for hybridization program. However, the highest inter-cluster distance was observed between clusters II and V indicated the genotypes in these clusters were far diverged than those of other clusters. Similarly, the lowest inter-cluster distance was observed between the cluster III and cluster IV (6.32).

Moderate or intermediate distance was found between cluster II and cluster IV (19.57). On the other, the highest intra-cluster distance was found in cluster IV (1.091) followed by cluster II (1.066). The lowest intra-cluster distance was observed between in cluster I (0.853). The inter cluster distances were found much higher than the intra cluster distances suggesting wider genetic diversity existed among the genotype of different groups . Result of different multivariate analysis were superimposed in figure 3 from which it may be concluded from the above results that different multivariate techniques supplemented and confirmed one another.

As per scatter diagram the genotypes were apparently distributed into five clusters. It was also revealed that the genotypes of cluster II were more diverse from the genotypes of cluster V. Islam *et al.* (2004) also observed the similar result. It is assumed that maximum amount of heterosis will be manifested in cross combination involving the genotypes belonging to most divergent clusters. However, for a practical plant breeding, the objective is not only high heterosis but also to achieved high-level production. In the present study the maximum distance existence between cluster II and cluster V. But considering the yield and duration crosses involving cluster II and V may be exhibit high heterosis for yield. Main and Bahl (1989) reported that the parents separated by D^2 values of moderate magnitude generally showed higher heterosis.

Table 12. Average intra and inter-cluster distances of 26 country bean genotypes

Cluster	I	II	III	IV	V
I	**0.853**				
II	33.12	**1.066**			
III	19.65	14.86	**0.945**		
IV	13.71	19.57	6.32	**1.091**	
V	10.64	43.76	30.05	24.29	**0.979**

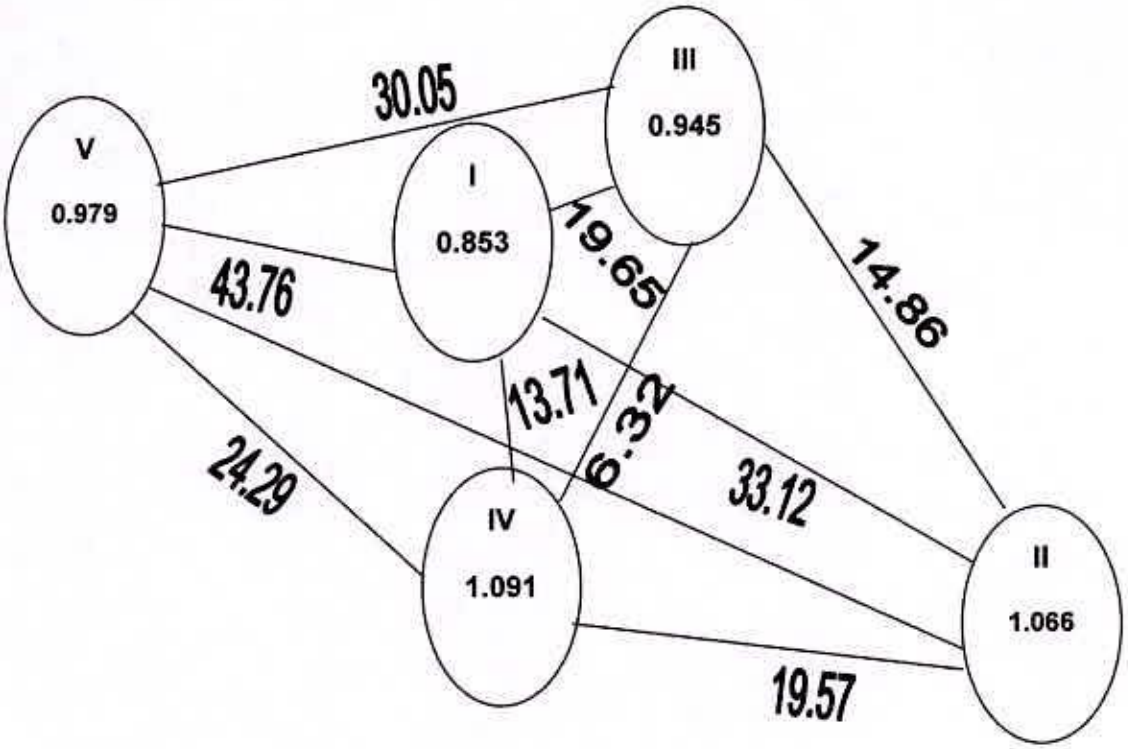


Fig. 3. Diagram showing intra- and inter-cluster distances of twenty six genotypes of country bean.

4.4.5 Contribution of characters towards divergence of the genotypes

The values of Vector I and Vector II are presented in Table 13. Vector I obtained from PCA expressed that days to first fruiting (0.1421), inflorescence per plant(0.1254),flower per inflorescence (0.6813),inflorescence length (0.0546),pod length(0.8505),pod weight (10.0842),seed width (0.8215),pod per plant(0.5248) were major characters that contribute to the genetic divergence. It was the reflection of first axis of differentiation. In vector II days to first fruiting (0.1708), inflorescence per plant (0.0513), flower per inflorescence (0.2241), pod yield per plant (0.0369) showed their important role toward genetic divergence. Negative values in both vectors for days to first flowering, pod per inflorescence, pod width and seed length had lower contribution towards the divergence.

4.5.6 Selection of genotypes as parent for future hybridization programme

Selection of genetically diverse parents is an important step for hybridization program. So the genotypes were to be selected on the basis of specific objectives. A high heterosis could be produced from the crosses between genetically distant parents (Falconer, 1960; Moll *et al.*, 1962; Ramanujam *et al.*, 1974; Ghaderi *et al.*, 1984).

Considering the magnitude of cluster mean and agronomic performance the genotype G_7 (BD-8832) for minimum days of first flowering from cluster II; G_{15} (BD-8816) for maximum fruit length and from cluster III; G_{13} (BD-8034) for maximum number of fruit per plant from cluster II and fruit breadth G_6 (BD-7985) from cluster V were found promising. Therefore considering group distance and other agronomic performance the inter genotypic crosses between G_7 (BD-8832) and G_{15} (BD-8816); G_6 (BD-7985) and G_7 (BD-8832); G_6 (BD-7985) and G_{15} (BD-8816) may be suggested for future hybridization program.

Table 13. Latent vectors for 13 principal component characters of twenty six country bean genotypes

Character	Vector I	Vector II
Days to first flowering	-0.0562	-0.1693
Days to first fruiting	0.1421	0.1708
No. of inflorescence /plant	0.1254	0.0513
No. of flower/ inflorescence	0.6813	0.2241
No. of pod/ inflorescence	-0.6249	-0.2648
Inflorescence length (cm)	0.0546	-0.0446
Pod length (cm)	0.8505	-0.1008
Pod width (cm)	-0.3666	-0.1802
pod weight (g/pod)	10.0842	-5.2361
Seed length (mm)	-1.4017	-0.0122
Seed width (mm)	0.8215	-1.5218
No. of pods/plant	0.5248	-0.2204
Pods yield/plant (g)	-0.1505	0.0369

Chapter 5

Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The present experiment was carried out in the Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh to evaluate the field performance, variability, character association and genetic divergence of twenty six genotypes of Country Bean using morphological characters.

The field experiment was laid out in Randomized Complete Block Design (RCBD) with three (3) replications. Data on different characters were recorded and analyzed statistically. The analysis of variance of all the traits was computed and significant differences were found among the accessions in respect of different characters studied. The maximum value in respect of days to first flowering (64.00 days) was observed in G_1 (BD-8737) and the minimum days (40days) to first flowering was recorded in G_7 (BD-8832) and G_{16} (8816). Genotype number G_{18} (BD-8001) recorded the maximum value (78 days) days to first fruiting and the lowest days to first fruiting (46 days) was recorded in G_{26} (BD-8816). In respect of number of inflorescence per plant, genotype no. G_7 (BD-8832) recorded the highest value (51) and genotype G_3 (BD-808) counted the lowest value (10). Genotype G_{25} (BD-6) had the highest flower per inflorescence (20.00) and genotype G_1 (BD-8737), G_2 (BD-1816), G_{14} (BD-130), G_{26} (BD-8816) produced the lowest number of flower per inflorescence (8.00). In case of number of pod per inflorescence, the highest value (14.00) was recorded in G_{25} (BD-6) and the lowest value was (4.00) found in G_{10} (BD-7977) and G_{21} (BD-1809). In respect of inflorescence length, the highest value (38.60 cm) was observed in G_{15} (BD-7999) and the genotype no. G_{25} (BD-6) had the smallest inflorescence length (10.00 cm). In case pod length, the highest value (15.00 cm) was observed in G_{26} (BD-8816) and the lowest value (5.6 cm) was observed in G_5 (BD-7978) and G_{18} (BD-8001). Genotype G_6 (BD-7985) was the highest pod width (8.23 cm) and genotype G_1 (BD-8737) and G_9 (BD-7995) was the lowest pod width (1.5 cm). Genotype G_9 (BD-7995) was the highest pod weight (9.997 cm) and genotype G6 (BD-7985) showed the lowest pod weight (4.62 cm). In case of no. of seed length, the highest value (13.76mm) was observed in G_{16} (BD-8027) and G_{26} (BD-8816) and the lowest value (10.11mm) was observed in G_8 (BD-1805). In case of seed width, the

highest value (9.96 mm) was observed in G_{15} (BD-7999) and the lowest value (7.37) was observed in G_9 (BD-7995). In case of pod per plant, the highest value (300.00) was observed in G_{13} (BD-8034) and the lowest value (110) was observed in G_{22} (BD-8729) and G_{23} (BD-8813). Genotype G_{13} (BD-8034) yielded the highest no. of pod yield (1693gm) and genotype G_3 (BD-808) had the lowest no. of pod yield per plant (566.01gm).

The phenotypic variance was higher than the corresponding genotypic variance in all the characters, indicating greater influence of environment on the expression of these characters. The maximum differences between genotypic and phenotypic coefficient of variation were 20.35 7% and 24.56% respectively which indicated that the no. of fruit per plant mostly depended on environmental effect. The highest estimated heritability among thirteen yield contributing characters, 95.88%, 93.53%, 91.96% and 89.83% was in pod width, inflorescence length, inflorescence per plant, pod yield per plant respectively. The lowest heritability was 64.92% in seed length.

The maximum genetic advance was observed in pod yield per plant (468.24) and followed by maximum value was 47.99 in respect of genetic advance for pods per plant among thirteen characters of Country bean genotypes. The maximum genetic advance in percent of mean (GAMP) was obtained for pod width (99.85%) and the lowest was for seed width (8.36%).

Multivariate analysis was carried out through principal component analysis (PCA), principal coordinate analysis (PCO), cluster analysis, and canonical vector analysis (CVA) using Genstat 5.13 software programme. The first three principal characters with Eigen values were contributed 66.72% variation toward divergence. As per as PCA, D^2 and cluster analysis using the genotypes were grouped into five different clusters. Cluster I, II, III, IV and V comprised four, four, three, six and nine genotypes, respectively.

The maximum inter-cluster distance was observed between cluster II and V (43.76) followed by the distance between clusters I and II (33.12), III and V (30.05), IV and V (24.29). The lowest inter-cluster distance was observed between cluster III and IV (6.32) followed by I and V (10.64).

The highest intra-cluster distance was identified in cluster IV (1.091) and the lowest intra-cluster distance was observed in cluster I (0.853). Genotypes included in cluster V were suitable for fruit diameter (3.07 cm) and no. of fruit per plant (171.50) included in cluster II. Cluster I had the highest mean for days to first flowering (54.25 days) and days to first fruiting (65.75 days).

Findings of the present study indicated significant variation among the genotypes for all the character studied. Considering diversity pattern and other field performances, genotypes G_7 (BD-8832) from cluster II; G_6 (BD-7985) from cluster V; G_{13} (BD-8034) plant from cluster II; G_{15} (BD-8816) from cluster III could be the best choice as suitable parents for efficient hybridization programme.

The result of the present study revealed that a wide variability exists among the collected country bean genotypes. In addition, there was also genotypic variability of different yield contributing characters with yield of country bean. From the findings of the present study, the following conclusions could be drawn:

i. Wide range of genetic diversity existed among the country bean genotypes. That variability could be used for future breeding programme of country bean in Bangladesh.

ii. Selection procedure would be applied for desired characters such as days to first flowering , days to first fruiting, number of inflorescence per plant, number of flower per inflorescence, number of pod per inflorescence, pod length, pod breadth, number of fruits per plant to develop high yielding varieties.

Further collection of country bean germplasm would be continued for getting more variability and desired traits in country bean.

Chapter 6

References

CHAPTER VI

REFERENCES

Abdullah, M.M.F. (1974). Potentialities of breeding field beans . *Vicia faba* L. *Egyptian J. of Genet. And cytology* **3** (2): *298.*

Ahmed, K. U. (1976). Gardener's book of production and nutrition. **vol. 1**. pp. 133-134

Ali, F., Sikdar, B., Roy, A. K. And Joarder, O. I. (2005). Correlation and genetic variation of twenty different genotypes of lablab bean, *Lablab purpureus* (L.) Sweet. *Bangladesh J. Bot.*, **34** (2): 125-128.

Anonymous, (1991). Basat Bari Sabzi Utpadan (in Bengali). Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. pp.239

Anonymous, (1998). Year Book of Agricultural Statistics of Bangladesh .(1997). Bangladesh Bureau of Statistics, Ministry of Planning, Govt. of the People's Republic of Bangladesh. Dhaka.

Anonymous, (2003). Year Book of Agricultural Statistics of Bangladesh (2000). Bangladesh Bureau of Statistics, Ministry of Planning, Govt. of the people's Republic of Bangladesh. Dhaka. pp.36-39.

Arunachala, A. S.(1979), Genetic variability and correlation studies in field bean (*Dolichos lablab* L.). *Mysore J. Agril. Sci.*, **8** (3). pp 369.

Asgari, A. and P. Vojdani (1994). study of genetic diversity of the Iranian common bean landraces in relation to geographical and climatical classification. Seed and Plant. **10**. pp 1-11.

Aung, L.H. (1976). Effect of photoperiod and temperature on vegetative and reproductive responses of *lycopersicon esculentum Mill. J. Amer. soc. Hrt. Sci.* **101**: 358-360.

Badwaj, C. L, S. C. Nayital, S. Verma and N. R. Kalia. (1994). Effect of sowing date,variety and management of angular leaf spot on yield of French bean (*Pbaseorus vulgaris* L.) *Indian J.Agril. Sci.* **64** (5): 336-333.

Basavarajappa, P. S. and Byre Gowda, M. (2000), Genetic divergence among field bean (*Lablab purpureus* (L.) Sweet) cultivars of Southern Karnataka. *Indian J. Pl. Genet. Res.,* **13** (2) : 134-137.

Basavarajappa, P. S. and Byre Gowda, M.(2004). Assessment of field bean germplasm of southern Karnataka and Isolation of elite genotypes. *Mysore J. Agric. Sci.,* **38** (4) : 474-479.

Baswana, K. S., Pandita, M. L., Dhankhar, B. S. and Partap, B. S.(1980). Correlation and path coefficient analysis of Indian bean (*Dolichos lablab* var. Lignosus L.). *Haryana Agril. Uni. J. Res.,* **10** (4) : 485-489.

Baswana, K. S., Pandita, M. L., Dhankhar, B. S. and Partap, B. S.(1980) Genetic variability and heritability studies on Indian bean (*Dolichos lablab* var. Lignosus L.). *Haryana J. Horti. Sci.,* **9** (1-2) : 52-55.

Baswana, K. S., Pandita, M. L., Partap, P. S. and Dhankhar, B. S.(1980). Genetic divergence for yield and its components in Indian bean (*Dolichos lablab* var. Lignosus L.). *Haryana J. Horti. Sci.,* **9** (3-4) : 184-187.

BBS. (2004). Year Book of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, p. 106.

Birari, S. P. And Ghanekar (1992). Genetic diversity in Lablab bean. J. of Maharastra Agricultural University. **17** (2): 257 -260.

Borah, P. and Shadeque, A.(1992) Studies on genetic variability of common Dolichos bean. *Indian J. Hortic.*, **49** : 270-273.

Bose,T. K and Som, M.G. (1986). Vegetable crops in India, Naya Prokash, Calcutta, India. pp: 91-164.

Burton, G. W. (1952). Quantitative inheritance in grass pea. Proc. 6th grassl. Cong. **1:** 277-283.

Cameron, D G. (1988) Tropical and subtropical pasture legumes. *Queensland Agricultural Journal*. March-April: 110-113.

Carrasco, H.V.F. Fivivarov, R.M.Garcia and T.Romero.(1979).Bean production from early sowing .*Ciencias de la agricultura* , no. 4: 167-171. [Cited from Field Abst.**34**(1),item no.350.1981].

Chakravarty .A.K. (1985). Dolichos bean .In: vegetable crops in India.T.K.Boss and M.G.Som(ed.). Naya Prokas, Calcata ,India . pp. 524-528.

Charles, W.B.and R.E.Harris.1972.Tomato fruit set and low temperature .*Can.J.Plant Sci.* **52**: 497-506

Chatterjee B.N., K. K. Bhattacharyya and A. A. Miah. (1987). Growth analysis of bean. Food Legume Improvement for Asian Farming Systems.ACIR Proceeding No.**18**.Canberra, Australia.

Choudhury,A.R., M.Ali, M.A.Quadir and M.H.Talukder.(1989). Floral biology of hyacinth bean (*lablab purpureus* L.Sweet).*Thai J.Agric.Sci.* 22-67.

Chowdhury, A.R.and M.Ali. (1987). Development of early fruiting/year round varieties of country bean .Abstracts of papers presented in the Research Review Meeting ,Institute of post Graduate Studies in Agriculture Salna, Gazipur.

Comstock, R. E. and Robinson, H. F. (1952). Genetic parameters their estimation and significance. Proc. of 6th Int. Grassland Cong. **1**:128-291.

Dahiya, M. S. and Pandita, M. L., (1989). Variability studies in Indian bean (*Dolichos lablab* L.). *Haryana J. Agron.*, **5** (1) : 5-8.

Dahiya, M. S., Pandita, M. L. and Vashistha, R. N. (1991). Correlation and path analysis studies in sem (*Dolichos lablab* var. Lignosus L.). *Haryana J. Hortic. Sci.*,**20** (1-2) : 134-138.

Das, A. K., Hazra, P. And Som, M. G. (1987).Genetic variability and heritability studies in Dolichos bean (*Dolichos lablab* Roxb L.). *Veg. Sci.*, **14** (2) : 169-173.

Davis, F.F. (1945). The effect of some environmental factors on the set of pods and yield of white pea beans.*J.Agric.Res.***70**: 237-249.

Deka R K and Sarkar C R (1990). Nutrient composition and anti-nutritional factors of *Dolichos lablab* L seeds. Food Chemistry. 38: 239-246

Upadhyay,D. and N. Mehta. (2010). Biometrical Studies in Dolichos Bean (*Dolichos lablab* L.) for Chhattisgarh Plains. *Research Journal of Agricultural Sciences* 2010, **1**(4): 441-447.

Dewey, D. R. and Lu, K. N. (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.*, **51** : 515-518.

Diaz, M.,Z.F.Mayor ,E.M. Isai and J.A Sanchez.(1986). Flower and pod abscission and seed abortion in bean (*phaseolus vulgaris*). Ciencian-de-la Agricultura.28: 143-144.

Digby, P.,N.Galway and P.Lane. (1989).GENSTATS, A second course , Oxford science publications,Oxford. pp. 103-108.

Dora, D. K., (2001). Genetic divergence in hyacinth bean (*lablab purpureus* L.Sweet)). *Veg. Sci.*, **28**(2): 170-171.

Duarte, R. A. and Adams, M. W. (1972). Path coefficient analysis of same yield component inter-relations in field neam (*Phaseobus vulgaris*). *Crop Sci.*, **12** (5) : 579-582.

Dubetz, S. and Welis, S. A. (1968). Relation of barley varieties to nitrogen fertilizers. *J. Agril. Sci.*, Cambridge, **70** : 253-256.

Duke, J.A, A. E .Krestschmer ; C.F. Red and J.K.P. Weder. (1981). (*Lablab purpureus* L.Sweet).In: Handbook of Legumes of World Economic Importance ,Duke,J.A.(ed.).Plenum Press, NewYork, USA. pp. 102-106.

English, B.H. (1999). *Lablab purpurious* in Australia .In:Forage seed production **vol 2**: Tropical and subtropical species, D. S. Loch & J.E. Ferguson (eds.),CAB International ,Wallingford ,UK. PP. 395-399.

Falconer, D. S. (1960). Introduction of quantitative genetics. Oliver and Boud. London. p. 304.

Fakir, M.S.A., M.A. Hossain, A.K.M.Z. Hossain , A.K.M.A.Prodhan and S.M.Afraruzzaman .A study of flower production and abscission in country bean(2000). Bangladesh *J.Agric. Sci.* **27** (2).

Fisher, N.M. (1980). The effect of time of planting of four beans (*phaseolus vulgaris*) genotypes in Kenya. *J.Agril.Sci.Camb.* **59**(20) : 401-408.

Fuji, T. (1948). Studies on the flower dropping of fruit and vegetables. Bull. Chiba Coll.Hrt.**6**: 1-84.

Gangadharappa, K. R. (1979). Genetic studies in *Dolichos lablab* (L.) var. Typicus F2 breeding behaviour for green pod yield. *M. Sc. (Agri.) Thesis*, Uni. Agri. Sci., Bangalore (India).

Ghaderi, A., Adams, M. W. and Nassib, A. M. (1984). Relationship between genetic distance and heterosis for yield and morphological traits in dry edible bean and febabean. *Crop Sci.* **24**: 37-42.

Gopalan, C. V., B. Y. Ramasastri and S. C. Balasubramarium. (1982). Nutritive values of Indian food. National Institute of Nutrition, ICMR , Hydra bad. Pp. 75.

Haider, J., T. Marumoto and A. K. Azad. (1991). Estimation of microbial biomas. Carbon and nitrogen in Bangladesh soils. Soil Sci. Tech. **20**: 643-653.

Halim, G. M. A. and S. Ahmed. (1992). Study of morphogenetic divergence in country bean. Bangladesh Hort. **20** (2): 103-107.

Hendricksen, R. E. and D. J. Minson. (1985). *Lablab purpureus* - A Review. Herbage Abstracts **55**: 215-227.

Hiremath, S. R., Shivashankar, G. and Shashidhar, H. E. (1979) A unique strain of vegetable field bean (*Lablab purpureus* L. Sweet). *Curr. Res.*, **8** : 58.

Islam MS, Satter MA, Rahman MM, Quyum MA, Alam SMN, Alam MS, Mustafi RA. 2004. Handbook of Agro-technology (3rd ed.). Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.

Islam MT, Haque MM, Rahman MM. (2002). Catalogue on Hyacinth bean (*Dolichos lablab* (L.)). Plant Genetic Resources Centre, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.

Ismunadji, M. and Arsyad, D. M., (1990). Lablab bean : An unexploited potential food legume. *Paper Presented to Training/workshop.* Improvement of unexploited

and potential food legumes in Asia, 27th Oct. To 3rd Nov. (1990), Bogor, Indonesia.

Jacob (1981) Genetic architecture of yield and its components in field bean (*Lablab purpureus* (L.) Sweet). *Ph. D. Thesis*, Uni. Agril. Sci., Bangalore (India).

Jager, M . I., D. Garethojones and E. Griffith. (1983). Component of partial resistance of wheat seedlings to septoria nodorum. Euphytica. **32**: 575-584.

Johnson, H. W., Robinson, H. F. and Comstock, R. I. (1955). Estimates of genetic and environmental variabilaity in soybean. *Agron J.*, **47**(2): 314-318.

Joshi S, Sreekantaradhya R, Shambulingappa KBG, Shivashankar G, Jagannath DP. (1995). Genetic variation in pod characteristics in fieldbean (*Lablab purpureus* (L.) Sweet) and its relation to classification as subspecies. Crop Research (India) 9(1): 78–80.

Joshi, S. N. (1971). Studies on genetic variability for yield and its components in Indian bean (*Dolichos lablab* var. Lignosus). *Madras Agril. J.*, **58** (5) : 367-371.

Kabir, J. and Sen, S. (1987). Studies on genetic variability and heritability in Dolichos bean. *Ann. Agri. Res.*, **8** (1): 141-144.

Katyal, S. K. and K. L. Chadha. (1985). Vegetable growing in India. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi. Pp. 60-61.

Khurana and Singh, G. R. (1987) Performance of different seem (*Dolichos lablab* L.) cultivars under Hissar conditions. *Res. Develop Rep.*, **4** (2) : 230-232.

Konsens, I. , M. Ofir and J. Kigel. (1991). The effect of temperature on the production and abscission of flowers and pods in snap bean (*Phaseolul vulgaris* L.). Annals of Botany. **67**: 391-399.

Krarup, A. H. (1983). Dates of sowing and nitrogen application on yield of faba beans (Yecia faba L.). *Agro Sur.* **11**(2): 105-109.

Kumar, R. U. and P. Chandrasekharan. (1991). Genetic divergence in fodder lablab. Indian Genet. **51**(l): 28-29.

Liu CJ. (1996). Genetic diversity and relationship among *Lablab purpureus* genotypes evaluated using RAPD as markers. Euphytica **90**: 115–119.

Lush, J. L. (1943). Animal Breeding Plans. Iowa State Press, Ames, Iowa, p. 437.

Maass B. L., K. K. Ayisi, P. M. Bopape, M. Usongo and B. c. pengelly. (2003). Appropriate germplasm facilities new interest in integrated Crops- in the case of *Lablab purpureus* in the Limpopo Provina, South Africa. International Workshop on Underutilized Plant Species. 6-8 May (2003). Leipzin, Germany.

Maass BL, Jamnadass RH, Hanson J, Pengelly BC. (2005). Determining sources of diversity in cultivated and wild *Lablab purpureus* related to provenance of germplasm by using amplified fragment length polymorphism. Genetic Resources and Crop Evolution **52**: 683–695.

Maass, B. L. (2006). Changes in seed morphology, dormancy and germination from wild to cultivated hyacinth bean.

Mallareddy, S. (1979) Genetic variability studies and formulation of selection indices in field bean (*Lablab purpureus* (L.) Sweet). *M. Sc. (Agri.) Thesis*, Uni. Agril. Sci., Bangalore (India).

Mannan, M. A. (2000). Plant biodiversity in the homesteads of Bangladesh and its utilization in crops improvement. Ph. D. Thesis. Dept. of genetics and plant Breeding, BSMRAU, Gazipur : 214.

Marcellos, H. and G. A. Constable. (1986). Effect of plant density and sowing date on grain yield of faba beans (*Vicas faba* L.) in Northern New South Wales. *Aus. J. Agric.* **26** (4): 493-496.

Matias, C., M . Esperance and V. Ruz. (1990). The effect of sowing dates and spacing on the seed yield of *lablab purpureus* cv. Rongai. Pastos -y-forages. **13**: 149-146.

Main, M. A. K. and Bahl, P. N. (1989). Genetic divergence and hybrid performance in chickpea. *Indian J. Genet.* **49**: 119-124.

Mauk, C. S., P. J- Breen and H. J. Mack. (1987). Flower and pod abscission in snap bean as influenced by inflorescence potion, raceme node, irrigation and plant density.*Canadian J. Plant Sci.* (**4**): 1193-1202.

Mohan, N. and Aghora, T. S. (2006). Collection and evaluation of Dolichos bean (*lablab purpureus* (L.) Sweet) Germplasm in Tamil Nadu, India, *Paper Presented in First International Conference on Indigenous Vegetables and legumes*, ICRISAT, Patancheru, AP, India.

Mollah, M. S., S. R. Saha and M. S. Islam. (1995). Effect of method of support on the yield performance of some advanced lines of hyacinth bean. *Bangladesh J. Crop Sci.*,**6**(r&2): 37-40.

Moll, R. H., Salhawana, W. S. and Robinson, H. F. (1962). Heterosis and genetic diversity in soybean. *J. Oilseed Res.* **4**(1): 103-107.

Mozumder, M. A., M. A. Rouf, M. s. Mullah and M. A. Rashid. (1996). collection and evaluation of bush bean germplasms. Research report on vegetable crops, HRC.RARS, Hathazai. pp. 35-39.

Muralidharan, K. (1980). Studies on genetic divergence and breeding behaviour of few inter varietal crosses in field bean. *M. Sc. (Agri.) Thesis*, Uni. Agril. Sci., Bangalore.

Nandi, A. P. Tripathy and D. Lenka. (1997). Correlation, co-heritability and path analysis studies in Dolichos bean. ACIAR Food Legume News. **25**: 1-2.

Nandi, A., Tripathi, P. and Lenka, D. (2000). Genetic divergence in hyacinth bean (*Dolichos lablab*). *Indian J. Agril. Sci.*, **70** (7) : 450-451.

NAS. (1979). Lablab bean. In: NAS. Tropical Legumes: Resources for the future, National Academy of Sciences (NAS), Washington DC, USA. pp. 59-67.

Nasir, U. M. (1999). Yield and quality of jack bean (*Canavalia ensiformis* L.) influenced by nitrogen and phosphorous. MS thesis. Banghabandhu Sheik Majibur Rahman Agricultural University (BSMRAU), Salna, Gazipur. pp. 87.

Nayar, K. M. D. (1984) Studies on genetic divergence and breeding behaviour of few inter varietal crosses in field bean (*Lablab purpureus* (L.) Sweet). *Mysore J. Agril. Sci.*, **16** (4): 486.

Nayer, K. M. D. (1980). Studies on genetic divergence and breeding behavior of few intervarietal crosses in field bean *[lablab purpureus* (L.) Sweet l. Ph. D. thesis, University of Agricultural Sciences, Banglalore, India.

Newaz, M. A. . and Uddin, M. S (1991). Genetic parameters and the association among flower and pod characteristics of hyacinth bean (*Lablab purpureus* L.). *Legume Res.*, **20** (2): 82-86.

Pandey, R. P. and Dubey, K. G. (1972). Studies on variability in *Dolichos lablab*. *JNKVV Res. J.*, **6** (2):145-148.

Pandey, R. P., Assawa, B. M. and Assawa, R. K. (1980). Correlation and path coefficient analysis in *Dolichos lablab* L. *Indian J. Agril. Sci.*, **50** (6) : 481-484.

Pandey, R. P., Assawa, B. M. and Tiwari, J. P. (1983). Genetic divergence in *Dolichos lablab*, *JNKVV Res. J.*, **17** (1 and 2): 66-70.

Pandita, M.L., Pandey,S.C., Sidhu ,A. S. and Arora, S.K. (1980). Studies on genetic variability and correlation in Indian bean (*Dolichos lablab* L.) *Haryana J. Hortic. Sci.*, **9** (3- 4): 154-159.

Pengelly, B. C. and B. L. Maass. (2001). *Lablab purpureus* L. Sweet-diversity, potential use and determination of a core collection of this multi-purpose tropical legume. Genetic Resources and crop Evolution, **48**: 261-272.

Pilbeam, C. J., P. D. Hebblethwaite and H. E. Rickets. (1989). The response of determinate and semideterminate faba bean varieties to different sowing dates in spring. Ann. Applied biology : 377-390.

Pleskov, B. P. (1976). Practical work on plant biochemistry. Moscov kolos. pp. 236-238. podded pea. Ann. Inter. Rev. Rice Fanning system Division. pp. 7-8, 19-20.

Porch. T. G. (2006). Application of Stress Indices for Heat Tolerance Screening of Common Bean. Journal of agronomy and crop science *Zeitschrift fur Acker und Pflanzenbau. J* **92**(5): 390-394.

Pujari, I. (2000). Elucidation of genetic variability in country bean with conventional and molecular strategies. *M. Sc. (Agri.) Thesis*, O.U.A.T., Bhubaneshwar.

Purseglove, J. W. (1977). Tropical crops In: Dicotyledons. Longman, London. pp. 273-276.

Rahman, A. F. M. H. (1988). Vegetables and flowers. Production, marketing and use (in Bengali). Mrs Amina Khatoon, 3/D, Zikatola Dhaka-1209. pp. 296-298.

Rahman, M. H. and A. M. M. Hoque. (1992). Study on the effect of varying plant population and support materials on growth and yield of Hyacinth bean cultivars. Paper presented in the 17th Annual Conference of Bangladesh Association for Advancement of Science. Abst. Section 1. P. 88.

Rahman, M. J. (2002). Performance, nutritive value and post harvest loss in sweet pepper (*Capsicum annum* L.) M. S. Thesis. Department of Horticulture. Banghabandhu Sheik Mujubur Rahman Agricultural University. pp. 66-73.

Rahman, M. M., M. S. Ahmed and K. R. Haque. (1985). A study on the morphological characters of twenty local collections of country bean. Bangladesh Hort. **13** (1 &2). pp. 1-94.

Rajashekaraiah (1979). Studies on genetic inheritance of six quantitative characters in a cross between Hebbal avare-1 US-8 Lablab niger (*Dolichos lablab* L.). M.Sc (Agric.Thesis, UAS, Bangalore).

Ramanujam, S., Tiwary, A. S. and Mehra, R. B. (1974). Genetic divergence and hybrid performance in mungbean. *Theor. Appl. Genet.* **44**(5): 211-214.

Rao, C. R. (1960) Multivariate analysis: An indispensable tool in statistical and in applied research: *Sankya*, **22**: 317-338.

Rathnaiah, T. R. (1986). The study of variability and formulation of selection indices for vegetable yield in field bean (*Lablab purpureus* L. Sweet). *M. Sc. (Agri.) Thesis*, Uni. Agril. Sci., Bangalore (India).

Reddy, M., Vishanath, S. R., Satyan, B. A. and Wali, M. C. (1992), Genetic variability heritability and genetic advance for yield and yield attributing characters in field bean (*Lablab purpureus* L. Sweet). *Mysore J. Agril. Sci.*, **26** (1) : 15-20.

Rekhi, S. S. (1997). Vegetable improvement and seed production. Paper presented in the National Seminar on vegetable improvement and seed production held at BARI during March 3-4. Gazipur, Bangladesh.

Rowland, F. G. (1960). Fertility studies in the field beans (*Vicia faba*.L.). l. Cross and self fertility. Heredity, **15**: 16l-173.

Rowland,G. G., D. A. Bond and M. L. Parker. (1983). Estimates of the frequency of fertilization in field beans (*Vicia faba* L.). *L.Agric. sci., camb.* **100**: 25-30.

Sarkar, S. K., Marity, T. K. and Som, N. G. (1999). Correlation, co-heritability and path analysis studies in Dolichos bean.pp.no. **56**(3): 252-255.

Shivashankar, G. and R. S. Kulkarni. (1992). *Lablab purpureus* (L.) sweet. In: plant resources of South- East Asia No. l. Pulse, Van der Maesen, L. G. R. and S. Sommtnadja (eds.). Wageningen. pp. 48-50.

Singh, A. K., Gautham, N. C. and Kirti Singh (1985). Genetic variability and correlation studies in sem (*Lablab purpureus* (L.) Sweet). *Indian J. Hortic.*, **42**: 252-257.

Singh, R. K- And B. D. Choudhury. (1985). Biometrical methods in quantitative genetic analysis. Kalyani publishers, New Denhi. pp. 102-138.

Singh, S. P, J. A. Gutierrez., A. Molina., C. Urrea and P. Gepts. (1991). Genetic diversity in cultivated common bean: II. Marker-based Analysis of Morphological and Agronomic traits. *Crop Sci.* **31** : 23-29.

Singh, S. P. (1991). Genetic divergence and canonical analysis in hyacinth bean (*Dolichos lablab*). *J. Genet. Breed.*, **45** (1) : 7-11.

Singh, S. P., Singh, H. N., Singh, N. P. and Srivastava, J. P. (1979). Genetic studies on yield components in field bean. *Indian J. Agril. Sci.*, **49** (8) : 579-582.

Smartt, J. (1985). Evolution of grain legume, II. Old and New world pulses of lesser economic importance. *Experimental Agriculture* **21** : 1-18.

Smith, F. L. and H. Pryor. (1962). Effects of maximum temperature and age on flowering and seed production in three bean varieties. *Hilgaedia* **33**: 669-688.

Somogy, M. 1952. Notes on sugar determination. *J. Bil. chem.* **195**: 19-23.

Steel, R. C. D. and J. H. Torrie. (1980). Principles and procedures of statistic. Mc Graw Hill Book Co. Inc., New york. pp. 107-109.

Subhadrabandhu, S., M. W. Adams and D. A. Reicosky (1978). Abscission of flowers and fruits in *phaseolus vulgaris* L. I. Cultivar differences in flowering pattern and abscission. Crop Sci. **18:** 893-896.

Sultana N. (2001). Genetic variation of morphology and its application to breeding in Lablab bean (*Lablab purpureus* L. sweet). A Ph. D. thesis, Kyushu University, Fukuoka" Japan: 143.

Togum A. O. and T. O. Tayo (1990). Flowering, pod and seed development in pigeon pea (*Cajanus cajan*). *J. Agric. Sci.* (Camb), **115**: 327-335.

Uddin, M. (2003). Studies on flower & Cropping problems in lablab bean (*Lablab purpureus* L. Sweet). Ph.D. Thesis, Department of Horticulture. Bangabandhu Sheikh Mujibur Rahman Agricultural University. 118 p.

Uddin, M. S. (2003). Yield nutritive value and post harvest loss of ascorbic acid in photosensitive lablab bean (*Lablab purpureus* L. sweet). M. S. Thesis,

Department of Horticulture "Bangabandhu Sheijk Mujibur Rabman Agricultural University: 118

Uddin, M. S. and Newaz, M. A. (1997). Genetic parameters and the association among flower and pod characteristics of hyacinth bean (*Lablab purpureus* L.). *Legume Res.*, **20** (2): 82-86.

Venkatesha S.C, Gowda MB, Mahadevu P, Rao AM, Kim D-J, Ellis THN, Knox MR. (2007). Genetic diversity within *Lablab purpureus*and the application of gene-specific markers from a range of legume species. Plant Genetic Resources: Characterization and Utilization **5**(3): 154–171.

Wang ML, Gillaspie AG, Newman ML, Dean RE, Pittman RN, Morris JB, Pederson GA. (2004). Transfer of simple sequence repeat (SSR) markers across the legume family for germplasm characterization and evaluation. Plant Genetic Resources: Characterization and Utilization **2**(2): 107–119.

Wang ML, Morris JB, Barkley NA, Dean RE, Jenkins TM, Pederson GA. (2007). Evaluation of genetic diversity of the USDA *Lablab purpureus* germplasm collection using simple sequence repeat (SSR) markers. *Journal of Horticultural Science and Biotechnology* **82** (4): 571–578.

Weis, K. G. and B. D. Webster. (1990). Flower and fruit development in Tepary bean. *Hort. Sci.* **25** (l): 119-120.

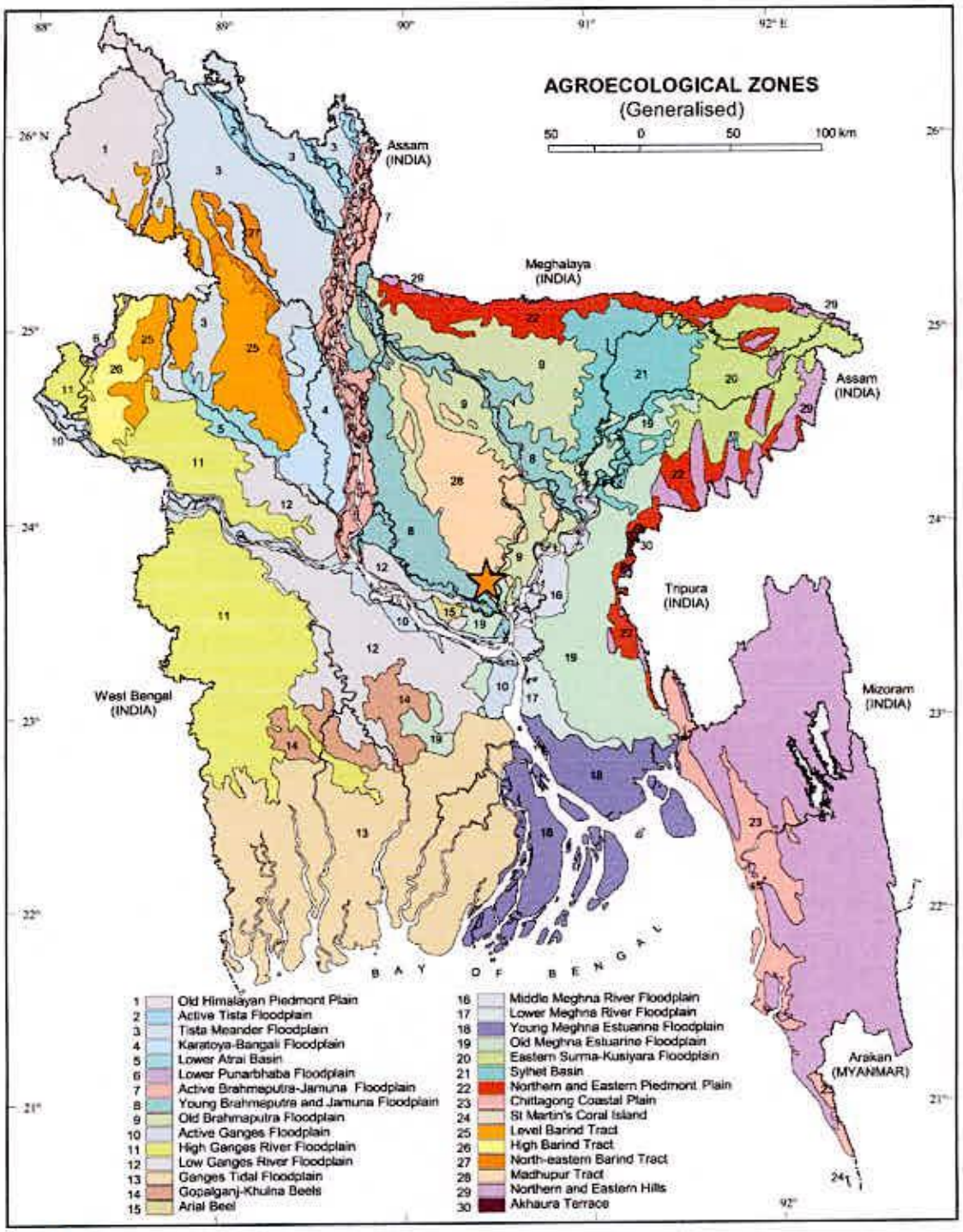
Wright, S. (1921), Correlation of caustion. *J. Agril. Res.*, **20**: 202-209.

Zhong-cheng T., Shu-yao W, Wen-long W, Liu L. (2005). Study of the diversity of germplasm resources of *Dolichos lablab* L. Natural Science *Journal of Hainan University* **23**: 53–60.


Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



The experimental site under study

Appendix II. Monthly average Temperature, Relative Humidity and Total Rainfall of the experimental site during the period from October, 2009 to March, 2010

Month	Air temperature (°c)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
October, 2009	34.8	18.0	77	227	5.8
November, 2009	32.3	16.3	69	0	7.9
December, 2009	29.0	13.0	79	0	3.9
January, 2010	28.1	11.1	72	1	5.7
February, 2010	33.9	12.2	55	1	8.7
March, 2010	34.6	16.5	67	45	7.3
April, 2010	35.8	20.3	65	88	8.3

Source: Bangladesh Metrological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Morphological, physical and chemical characteristics of initial soil (0-15 cm depth) of the experimental site

A. Physical composition of the soil

Soil separates	%	Methods employed
Sand	36.90	Hydrometer method (Day,1915)
Silt	26.40	Do
Clay	36.66	Do
Texture class	Clay loam	Do

B. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N (kg/ha)	1790.00	Bremner and Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner, 1965
6	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7	Exchangeable K (kg/ha)	89.50	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	pH (1 : 2.5 soil to water)	5.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Source: Soil Resource and Development Institute (SRDI), Dhaka.

Appendix IV. Principal component score twenty six genotypes of country bean.

SL NO.	Z1	Z2
1	-80.0	-3.6
2	55.0	-7.9
3	-350.3	-11.0
4	109.3	9.0
5	-291.9	-11.0
6	-201.4	-36.2
7	353.0	14.5
8	-255.8	-10.9
9	380.9	49.0
10	72.7	31.8
11	121.3	-30.7
12	-131.9	3.0
13	690.4	-59.1
14	-115.9	7.7
15	96.1	-7.5
16	295.5	26.4
17	142.9	35.1
18	-269.8	-18.4
19	-267.4	-5.4
20	-267.5	1.4
21	-104.2	5.6
22	-261.8	4.0
23	-312.1	-1.5
24	177.1	-10.9
25	124.0	6.3
26	191.7	40.1