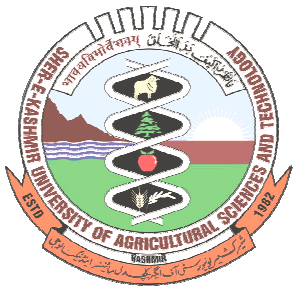
Variability and Divergence studies in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]

Vaidya Aashish Vivek
(2010-A-848-M)



Division of Vegetable Science

Faculty of Post-graduate Studies

Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir

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Variability and Divergence studies in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]

Vaidya Aashish Vivek
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Thesis

Submitted to

The Faculty of Post-graduate Studies
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Master of Science in Horticulture
(Vegetable Science)

2012

Dedicated to my beloved Father and little Brother

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Division of Vegetable Science, Shalimar Campus, Srinagar
191121

Certificate – I

This is to certify that the thesis entitled, **"Variability and Divergence studies in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Horticulture (Vegetable Science)**, to the **Faculty of Post-graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Vaidya Aashish Vivek (Regd. No. 2010-A-848-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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Certificate – II

We, the members of the Advisory Committee of **Mr. Vaidya Aashish Vivek (Regd. No. 2010-A-848-M),** a candidate for the degree of **Master of Science in Horticulture (Vegetable Science)** have gone through the manuscript of the thesis entitled, **"Variability and Divergence studies in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]"** and recommend that it may be submitted by the student in partial fulfillment of the requirements for the award of the degree.

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Certificate – III

This is to certify that the thesis entitled, **"Variability and Divergence studies in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]"** submitted by **Mr. Vaidya Aashish Vivek (Regd. No. 2010-A-848-M)** to the **Faculty of Post-graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** in partial fulfillment of the requirements for the award of the degree of **Master of Science in Horticulture (Vegetable Science)** was examined and approved by the Advisory Committee and External Examiner on ……...

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ABSTRACT

Genetic variability and divergence was studied in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.] to elicit information on the magnitude of variability and divergence. Forty two genotypes along with two checks were evaluated in RBD with 3 replications during kharif 2011 at Experimental Farm of Division of Vegetable Science, Shalimar. Observations were recorded on growth, yield, yield component and quality traits. Significant variations among genotypes were observed for all traits indicating presence of high level of genetic variability and divergence. High heritability (b.s.) was demonstrated by all the traits with maximum genetic gain (per cent of mean) for total fruit yield plant^{-1}(kg), dry matter yield 100^{-1} (g), number of secondary branches, number of fruits plant^{-1} and average fruit weight.Total fruit yield plant^{-1}(kg) was positively correlated with number of fruits plants^{-1}, fruit length (cm), fruit girth (cm), average fruit weight (kg), total chlorophyll content (%) and dry matter yield 100^{-1} (g). The total fruit yield plant^{-1} was result of direct effect of average fruit weight (kg), fruit length (cm) and dry matter yield 100^{-1}(g). Analysis for divergence, using D^2 statistics revealed highly significant differences for traits indicating diversity among the genotypes, grouping the 42 genotypes into 4 clusters. Cluster I had maximum number of genotypes (29) followed by cluster II (9). Maximum inter-cluster distance was observed in cluster II and cluster III (658.09),

whileas, the maximum intra cluster distance was observed in cluster III (167.00) and cluster II (95.64). Highest percent contribution to divergence came from total fruit yield plant^{-1} (kg) and number of fruits plant^{-1}.

Key words: Clusters, Divergence, Genetic gain, Heritability, *Lagenaria siceraria* and Variability.

Signature of Student
Dated: _____

Signature of Major Advisor
Dated: _____

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"Too many people spend money they haven't earned, to buy things they don't want, to impress people they don't like."

(Will Smith)

In the name of God, the most Beneficent and Merciful, Billions of Peace and Blessings be upon Holy Prophet (SAW). I bow in reverence to Almighty for giving me enough courage, patience and success in this venture.

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Vaidya Aashish Vivek

Place : Shalimar, Srinagar

Dated : ……

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Chapter - 1

INTRODUCTION

Bottle gourd [*Lagenaria siceraria* (Molina) Standl.] is one of the most popular vegetables of the family Cucurbitaceae, with a chromosome number 2n=14. It is a highly cross pollinated crop due to its monoecious and andromonecious nature (Swiander and Maccollum, 1994). It can be grown in both summer and rainy season, but it can't tolerate cold. (Rastogi, 1998). The names "lagenaria" and "siceraria" are derived from Latin words "lagena" for bottle and "sicera" for drinking utensil. Cucurbitaceous family is economically most significant family, supplying edible and nutritious fruits to humanity (Bisognin, 2002). Plants of this family, whilst possessing similar characteristics of the sprouting segments, are characterised by great genetic diversity in fruit shape, fruit length and texture of fruit, resulting in variability and wide range of diversity.

Bottle gourd originated in Africa (Singh, 1990) and from there by floating on the seas, it travelled to India, where it has evolved into numerous local varieties, and has spread to China, Indonesia and far to New Zealand.

In areas with mild climate, it can be grown throughout the year. In India the exact figures on area and production are not available but it is commercially grown in most of the states like U.P, Bihar, West Bengal, Assam, Punjab and Gujarat. The total area under cultivation in the country is approximately 1, 19,940 hectares with annual production of 18, 28,296 tones (NHB, 2009). However in Jammu and Kashmir it is grown over an area of 500 hectares with a production of 7500 tones (Anonymous, 2010). Productivity of bottle gourd is still low in India; hence, enhancement of crop yield is still an important goal for bottle gourd breeders in India. In spite of the extensive cultivation and consumption, bottle gourd has not been taken up for systematic research work in order to understand the genetic architecture and

endeavour in an improvement programme. Many important features of cultivated crops are not associated with discrete Mendelian traits, but are of a continuous or quantitative nature. Yielding ability is a prime example of such a trait and is of obvious importance.

Although bottle gourd is a modest source of nutrients, it is very popular among a large section of people. It is easily digestible and is used extensively as vegetable. Fruits are used in sweets, pickles (especially on hills), kofta, petha, halwa, kopoorkand, paratha and rayata. It is digestible easily, therefore, it is recommended during convalescence. The young shoots and leaves of a few cultivars are occasionally used as a pot herb. Dry hard shells of the fruits have been used for making a wide range of articles of common use, including bowls, bottles, containers, floats for fishing nets, pipes and musical instruments. In addition, the seeds and seed oil are also edible. Immature fruits are consumed in a number of ways. Bottle gourd has got cooling effect, so in the eastern countries; fruits are often used as cooling vegetable. Fruit pulp is used as purgative and is very useful in coughs. It is an antidote to certain poisons. The cut surface of small size fruit is rubbed on the underside of the feet and hands to reduce the effect of heat. The fruit ash with honey is useful to eyes for night blindness. It is ideal for people suffering from jaundice and allied diseases and also very much useful in preventing constipation. Seeds contain oil, which is helpful for brain development and body smoothness. Hence, it is being used in Ayurvedic preparations (Robinson and Decker-Walter, 1999). Besides this, the whole fruit is used in cosmetic and soap industries.

The fruits contain 96.3% moisture; Vitamin C (11m.g), Thiamine (0.044m.g), Riboflavin (0.023m.g), Niacin (0.33m.g), Mineral matters (0.05%), Carbohydrates (2.9%), Fats (0.5%) and Protein (0.2%) and its different parts possess large number of medicinal properties (Desai and Musmade, 1998).

The basic problem in bottle gourd is concerning the low marketable yield. The reduced marketability of the fruits is due to the misshapening of the fruits. The causes for such misshaped fruits have not been clearly documented. Any stress factor during the crop growth could result in misshaped fruits. Apart from stress factors, genetic background could also be a factor determining the misshapening of the fruits. Bottle gourd fruits may be long, oblong or round depending upon the variety. Bottle gourd shows large variation for various economic traits of which the most interesting variation is found for size, shape and color of fruits. On the basis of fruit shape, the cultivars of bottle gourd are broadly classified into two group's viz.; long fruited and round fruited. Bottle gourd is characterised by differently shaped fruits that can be used as utensils or decorative ornaments, whilst younger juicy fruits are edible and nutritious. Prasad and Prasad (1979) have created unique bottle gourd varieties in India, primarily for human consumption. It has been used in varied and specific ways in cultures of different nations. Scientists believe that, of all currently known plants, bottle gourd is the only species that had been used worldwide in prehistoric times.

The variation in bottle gourds is sometimes spectacular. The background colour is either light green or dark green. The dark green can be distributed as a solid colour, as regular or irregular stripes, and as an irregular blotch. The size of the fruit varies from 2-12 inches in diameter and from 4-40 inches in length. The fruit can have a sterile (seedless) neck that varies from a few to 15 inches in length and from 1-2 inches in width. Wider necks usually contain seeds, and the neck may have a seed-containing bulge. The seed-containing portion of the fruit varies from flat to round, cylindrical, club-shaped, or long and narrow. The long and narrow forms are best for vegetables.

The essential prerequisite for launching a breeding programme in any crop is the extent of genetic variability and genetic divergence in the breeding material. Wide differences between morphological traits such as size, color, resistance to pest and

diseases and yield are of immense importance to the breeders since number of cultivars could be developed to suit various requirements.

Bottle gourd is a monoecious and cross pollinated crop in which large amount of variation has been observed for many economically important traits. Precise information regarding the extent of genetic divergence in the breeding lines is crucial in heterosis breeding programme. The available diversity within the species for desired fruit enables a breeder in choosing the most suitable combinations to use for exploitation of hybrid vigor in a given crop.

The genetic parameters such as heritability, genetic advance, genotypic and phenotypic coefficient of variability provide an effective tool in the hands of a breeder to select a genotype having the most desirable traits for yield.

Many of the quantitative traits such as number of fruits plant $^{-1}$ and yield plant $^{-1}$ are highly influenced by location, cultivar and environmental conditions portioning the overall variability into heritable and non-heritable components which will be of immense help in any planned breeding programme.

Mahalanobis (1936) set the ground rules for study of variability in a population when he proposed the D^2 statistic. This invariably strengthened the concept of breeding for superior genotypes by defining the levels of exploitable variability and by predicting the results of a breeding programme. D^2 analysis permits precise comparison among all possible pairs of populations before effecting actual cross in modeling the cultivars in a desired genetic architecture.

Though bottle gourd is extensively cultivated in India no systematic studies have so far been reported on the extent of genetic variability and divergence in this fairly popular vegetable. There is hardly any information available on the various genetic parameters like heritability, genetic advance, gene action and genetic architecture of bottle gourd.

Therefore, the present investigation entitled “Variability and Divergence studies in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]” was initiated with the following objectives:-

1. To characterize the magnitude of variability for important economic traits.
2. To study the cause and effect relationship.
3. To study the genetic divergence and to identify diverse lines for future improvement programme.

Chapter - 2

REVIEW OF LITERATURE

Bottle gourd is one of the most important and popular vegetable crops grown in India and abroad. It has been looked upon by many early workers. The relevant literature related to evaluation of varieties for different characters genetic variability and association of characters is reviewed under different suitable headings.

Variability studies in bottle gourd

The crop improvement depends on the magnitude of genetic variability and the extents to which the desirable characters are heritable. The part played by environment in expression of economic characters also needs to be taken into account. No doubt that the efficiency of selection depends mainly on the extent of genetic variability present in population. However, Burton (1952) suggested that great co-efficient of variability together with heritability estimate will give the good picture of amount of advance to be expected from selection. Similarly, Thakur and Choudhary (1965) reported high heritability estimates in conjugation with high genetic advance together with genotypic coefficient of variability leads to high genetic gain. Such estimate of high heritability and genetic advance may be ascribed to the action of additive genes as reported by Brar and Sidhu (1977) in Watermelon, Abusaheha and Dutta (1990) in ridge gourd and Chaudhari *et al.* (1991) in bitter gourd.

Prasad and Prasad (1979) studied 40 genotypically diverse lines of bottle gourd and reported high estimates of heritability for vine length, fruit length and fruit diameter. Number of fruits plant^{-1}, girth of fruit and length of fruit showed high heritability values accompanied by high genetic gain which may be attributed to

considerable additive gene effects. Yield was also found to have significant association with the characters having high heritability estimates.

Pal and vani (1988) observed thirty seven bottle gourd lines for variability and reported that fruit number and size were highly correlated with yield. High narrow sense heritability for days to first male flower and days to first female flower opening, fruit length, fruit girth, number of fruits vine^{-1} and fruit weight

Sharma and Dhankar (1990) evaluated thirty five genotypes of bottle gourd during summer season for two years under Hissar conditions for studying the variability. Hissar local-3, a round genotype was earliest and highest yielder. PSPL, Hissar Sel-1 and Hissar Sel-2 were most promising for earliness and higher yield among long types. High heritability along with high genetic advance was recorded for male to female flower, vine length, total number of branches and fruits plants^{-1}.

Prasad *et al.* (1993) observed thirty genotypes for their variability, the studies revealed highest genotypic and phenotypic coefficient of variability for fruit yield plant^{-1} followed by number of male flowers on primary laterals and fruits vine^{-1}. Heritability estimates were higher for all the characters while genetic advance was maximum for fruit yield plant^{-1}. The genotypic differences for all the characters were highly significant. The magnitude of PCV was higher than GCV for all characters suggesting the effect of environment. GCV and PCV were high for fruit yield plant^{-1} and fruit length. A very high broad sense heritability (>90 %) was recorded for length of main vine, number of primary branches plant^{-1}, number of nodes of first male flower, number of nodes of first female flower, fruit length, fruit weight, number of fruit plant^{-1}, fruit yield plant^{-1}. High genetic advance (percent of mean) was recorded for sex ratio, fruit length and fruit yield plant^{-1}. The sex ratio, fruit length and fruit yield plant^{-1} showed high heritability (> 80%) coupled with high genetic advance.

Narayan *et al.* (1996) studied the genetic variability, heritability, genetic advance, correlation and path coefficient analysis in 25 diverse population of bottle gourd. Wide zone of variation was observed in most of the characters. The high value of GCV and heritability estimates associated with greater genetic advance observed for number of primary branches plant^{-1} and yield vine^{-1} indicated that these two characters had additive gene effect and therefore they are more reliable for effective selection. Correlation coefficients revealed that fruit yield plant^{-1} can be successfully improved by making selection for higher fruit number, fruit weight, Path coefficient analysis revealed that maximum weightage should be given primarily to day to the first harvest followed by average weight of edible fruit, fruit number plant^{-1} and day to anthesis to first female flower while formulating selection indices for improvement of yield in bottle gourd. A wide zone of variability was recorded for most of the characters. Heritability in the broad sense was very high for all the 8 characters, number of male flowers, number of female flowers and fruit yield plant^{-1} exhibited high heritability coupled with high genetic advance.

Singh *et al.* (2002) studied genotypic and phenotypic coefficients of variation, heritability and genetic advance for 14 characters of bottle gourd (*Lagenaria siceraria*) in 10 lines, 2 testers and 20 F_1's. The phenotypic coefficient of variation was higher than genotypic coefficient of variation for fruit yield plant^{-1}, fruit diameter, fruit length, fruit height, number of nodes to first male flower and vine length which were also characterized by high genetic variation. High estimate of heritability in broad sense was recorded for fruit yield plant^{-1}, vine length, number of days to first harvest, number of nodes to first male and female flowers, number of primary branches plant^{-1} and fruit length, weight and diameter. High heritability and high genetic advance were recorded for fruit yield plant^{-1}, vine length, fruit diameter, fruit length, fruit weight, number of nodes to first male and female flowers and number of primary branches plant^{-1}.

Munshi *et al.* (2005) evaluated the performance of 12 bottle gourd (*Lagenaria siceraria*) cultivars. High genotypic and phenotypic coefficient of variation were observed for vine length, number of primary branches vine^{-1} number of nodes on the main axis, peduncle length, sex ratio number of fruits plant^{-1}, fruit length, girth and weight, crop yield^{-1}. Fruit length, number of days to first fruit harvest and number of days to first female flower anthesis exhibited moderate to high heritability with moderate genetic advance. Considerable diversity within and between clusters were observed. Total yield plant^{-1}, fruit length, fruit weight, number of primary branches vine^{-1}, days to first male and female flower appearance, sex ratio and harvesting date were potent factors in differentiating bottle gourd germplasm.

Yadav *et al.* (2008) studied 18 bottle gourd (*L. siceraria*) strains / cultivars based on nine characters namely days to first male flowering, days to first female flowering, number of nodes of first male flowering, number of nodes of first female flowering. Days to edible fruit, fruit length, fruit width, number of fruits plant^{-1} and yield plant^{-1}. All the characters showed considerable amount of variability. The fruit width had the highest coefficient of genotypic and phenotypic variability. High heritability coupled with high genetic advance were observed for fruit length, fruit width, days to first female flowering days to first male flowering and yield plant^{-1}.

Singh *et al.* (2008) studied genetic variability in bottle gourd, the analysis of variance revealed significant differences among the parents and their F_1 hybrids in both summer and rainy seasons for all the characters studied. The highest genotypic and phenotypic coefficients of variation were recorded for yield vine^{-1}. All the characters under study were highly heritable excepting number of days for bearing first male and female flowers. High heritability coupled with high genetic advance and genetic coefficient of variation were recorded for number of female flowers vine^{-1}, number of primary branches vine^{-1} and yield vine^{-1} which indicate that these characters are more reliable for effective selection.

Pandit *et al.* (2009) evaluated fifteen genotypes of bottle gourd (*Lagenaria siceraria*) during autumn-winter season of 2003-2004 to study genetic variability, heritability and potential for screening suitable genotypes for future improvement programmers'. There was considerable variability in all traits except fruits plant^{-1}.

Heritability and genetic advance

Phenotype of an individual is determined by genotype and environment in which it grows. Success of a breeder in changing and improving the heredity of character depends upon the degree of correspondence between phenotypic and genotypic value. Heritability is a measure that provides this information (Dabholkar, 1992). Heritability in broad sense or degree of genetic determination is proportion of total heredity variance to phenotypic variance. The more useful estimate i.e. narrow sense heritability or degree of resemblance between relatives is ratio of additive genetic variance to phenotypic variance (Falconer, 1989). The most important function of heritability in the genetic studies of metric characteristics is if predictive role in expressing the reliability of phenotypic value as a guide to breeding value (Falconer, 1989). Genetic advance means improvement in the performance of selected lines over original population.

A brief summary work done for estimating heritability and genetic advance of yield and yield contributing characters in presented below.

Panwar *et al.* (1977) observed high estimates of heritability along with high genetic advance in sponge gourd for fruit length and days to flower while as characters like numbers of fruits plant^{-1} and fruit diameter showed lower value of the estimates.

Prasad and Prasad (1979) studied 40 genotypically diverse lines of bottle gourd and reported high estimates of heritability for vine length, fruit length and fruit diameter.

Gopalkrishnan *et al.* (1981) reported significant variability for fruit yield, vine length, fruit height and their respective components in 18 diverse genotypes of pumpkin (*Cucurbita moschata*). The length of the main vine and fruit weight had the maximum direct effect on yield.

Sharma *et al.* (1983) conducted genetical studies on bottle gourd and reported high heritability estimates for days to opening of first male and female flower and marketable maturity. Low heritability was recorded for fruit weight, number of fruits and total yield. The characters having high heritability failed to express high genetic advance.

Reddy and Rao (1984) found that the magnitude of heritability estimates in the broad sense varied among the different characters in ridge gourd. Lowest heritability was recorded for days to first harvest while the attribute fruit diameter showed moderate value. Highest heritability estimate was in the case of individual fruit height, fruit yield plant^{-1}. Fruit size and fruit number plant^{-1} showed high heritability in broad some. Fruit yield, fruit weight and fruit number recorded high genetic advance.

Kadam and Kale (1985) studied genetic variability in ridge gourd and found that days to flowering had the highest heritability (94.82) and high genotypic coefficient of variation (16.48) attributed to high genetic advance (13.70). Similar results were obtained for nodal position of female flower, fruit volume and percent intensity of powdery mildew. High heritability were observed for branches vine^{-1} (77.76), Percent of female flowers (51.51), yield (43.87), deformed fruit vine^{-1} (43.33) and fruit diameter (42.71) and the genetic advance was considerably low.

Chaudhari *et al.* (1991) studied fifty five F_1 progenies involving 11 true breeding bitter gourd lines. High genetic advance was observed for weight of fruit

(21.32). The high heritability and genetic gain was recorded in Percent of yield plant^{-1}, weight of fruit and number of fruits plant^{-1}.

Krishna Prasad and Singh (1993) estimated genetic variation and heritability for growth, flowering and yield component characters in cucumber. The heritability estimates ranged from 0.20 to 48 Percent for number of fruits plot^{-1} and fruit length respectively. Low heritability for number of fruits and yield plot^{-1} suggested that environmental effects contributed a major portion of the total phenotypic variation. High heritability coupled with high genetic advance for fruit length, fruit breadth and fruit weight might be due to additive gene action and selection could be applied for these characters.

Singh *et al.* (1992) estimated heritability in broad sense and expected genetic advance of fruit yield and nine other characters were studied in 36 genotypes of pointed gourd. High heritability coupled with high genetic advance was observed for yield and number of fruits plant^{-1}.

Singh *et al.* (1996) evaluated genetic variability and correlation studies in bottle gourd and reported that most of characters under study should have high magnitudes of heritability. However, from selection point of view only that part of heritability is desirable which is due to additive gene effects. High heritability with high genetic advance is considered more useful than heritability estimated alone in predicting resultant effect in the selection programme inference traits like node at which first female flower appeared, fruits plant^{-1}, yield plant^{-1} could be more responsive to selection in bottle gourd.

Arunkumar *et al*., (2000) studied 45 F_1 hybrids in bottle gourd and reported low narrow range of heritability for all the nutritional characters.

Dora *et al.* (2002) observed for characters like node at which first female flower appears, vine length and number of fruits plant^{-1} high heritability estimates and high genetic advance in pointed gourd.

Karuppaiah *et al.* (2002) studied 12 genotypes of ridge gourd to assess mean, variability, heritability and genetic advance. High heritability was observed for number of female flowers plant^{-1}, yield plant^{-1}, number of female flower plant^{-1} and flesh thickness. When heritability and genetic advance as Percent over mean were considered together, number of female flowers plant^{-1}, yield plant^{-1}, number of fruits plant^{-1} recorded highest values.

Krishna Prasad *et al.* (2002) conducted an experiment on adaptive response and diversity in watermelon and reported high heritability coupled with high genetic advance for yield plot^{-1}, number of nodes, days to female flowers appeared and number of fruits plant^{-1}.

Pandey *et al.* (2002) reported high estimates of heritability and genetic advance for yield plant^{-1} in pumpkin.

Singh *et al.* (2002) studied variability, heritability and genetic advance in ash gourd (*Benincasa hispida*) and reported high estimates of heritability for characters like fruit length, fruit diameter, average fruit weight, total yield and number of fruits. This shows that the characters were least affected by environment. Higher value of genetic advance (72%) was observed for fruit diameter and total fruit yield.

Literature concerned with other cucurbitaceous crops

Prasad *et al* (1988) reported high phenotypic and genotypic coefficient of variation for number of fruits vine^{-1}, average fruit weight, seeds fruit^{-1}, hundred seed weight and fruit yield vine^{-1} in germplasm of watermelon.

Prasad and Singh (1990) reported high phenotypic and genotypic coefficient of variation for fruit length, yield plant^{-1} and vine length. The number of fruits and fruit width showed moderately high estimates of PCV and GCV in ridge gourd.

Lawande (1991) reported high estimates of variability for fruit yield vine^{-1}, fruit weight, fruit length, fruit diameter and number of fruits vine^{-1} in eleven cultivars of bitter gourd.

Rajput *et al* (1996) reported high PCV and GCV for seeds fruit^{-1} and yield vine^{-1} in bitter gourd. Mishra *et al.* (1998) studied variability in bitter gourd and reported there was a frequent occurrence of dominant alleles and both additive and non-additive gene action was involved in character expression.

Mathew and Khader (1999) reported high PCV and GCV for average fruit weight, seeds fruit^{-1}, fruit yield plant^{-1} and fruit length in 34 genotypes of snake gourd.

In ridge gourd, Chowdhury and Sharma (2002) found very high GCV and PCV for vine length and fruit weight. The magnitude of phenotypic coefficient of variation (PCV) was greater than the corresponding genotypic coefficient of variation (GCV) for all traits under study.

Dora *et al*. (2002) reported high GCV for node at which first female flower appeared followed by number of nodes plant^{-1}, weight of fruit, number of fruits plant^{-1} and number of branches plant^{-1} in pointed gourd.

Owens *et al.* (2002) recorded high PCV with equally high GCV in yield vine^{-1}, fruits vine^{-1}, fruits branch^{-1} and node of first male flower, indicating maximum variability in the genotypes for these characters in ridge gourd.

In ridge gourd, Karuppaiah *et al.* (2002) reported high GCV for yield plant^{-1} and number of fruits plants^{-1} . Singh *et al.* (2002) recorded higher genotypic coefficient of variation for total yield, average fruit weight and dry weight of fruit in ash gourd.

Tiwari (2003) reported higher PCV than GCV for all characters in muskmelon. The highest phenotypic as well as genotypic coefficient of variation was observed for economically important characters such as average weight of fruit, fruit cavity and number of fruits vine^{-1}.

Rai *et al.* (2005) studied variability in chow chow and reported the phenotypic coefficients of variation (PCV) were higher than the genotypic coefficients of variation (GCV) indicating presence of environmental influence. Yadav *et al.* (2007) studied variability in chow chow and reported variability in terms of fruit shape, size, colour and presence of spines was observed in different genotypes.

Correlation Studies

Prasad *et al.* (1993) observed thirty genotypes for their correlation studies revealed highly significant and positive association of fruit yield and with number of fruits vine^{-1}, average weight of fruit and number of female flowers vine^{-1}.

Sharma and Dhankar (1993) studied correlation in 35 genotypes of bottle gourd and observed the positive correlation between yield and number of fruits was mainly due to highest direct effect of number of fruits. Days to first female flowering node showed negative association with vine length.

Narayan *et al.* (1996) reported that yield was positively and significantly correlated with number of fruits plant^{-1} and average weight of fruit. Negative and significant correlation between yield and days to anthesis of first male flower was observed.

Badade *et al.* (2001) reported that the yield was significantly and positively correlated with number of branches vine^{-1}, percentage of female flower and number of fruits vine^{-1} in bottle gourd, while significantly and negatively correlated with days to first male and female flower appearance at both phenotypic and genotypic levels. At genotypic level, vine length, diameter of fruit, number of seeds fruit^{-1} and 100 seed weight showed significant and negative correlation, where as percentage of powdery mildew intensity showed positive correlation with fruit yield plant^{-1}. Fruit length showed positive but non-significant correlation with fruit yield plant^{-1}.

Kumar *et al.* (2007) observed that the value of correlation at genotypic level was higher than the phenotypic correlations, indicating that there is strong inherent association between the various characters studied. The fruit yield vine^{-1} showed positive and significant correlation with number of branches vine^{-1}, vine length, node number of first female flower, length of edible fruits, number of fruits vine^{-1}, number of seeds fruit^{-1} and 100 seed weight at genotypic and phenotypic levels. This

indicated that fruit yield can be improved by making selection on the basis of number of branches vine^{-1}, vine length, nodes number of first female flower, length of edible fruit and number of fruit vine^{-1}.

Yadav *et al.* (2007) while studying 18 strains of bottle gourd revealed that yield plant^{-1} was positively and significantly associated with the number of fruits plant^{-1}, but has a negatively significant correlation with days to first female flowering at both genotypic and phenotypic levels.

Pandit *et al.* (2009) while evaluating 15 genotypes of bottle gourd revealed that the correlation between both genotypes and phenotypes indicated the over-riding importance of fruit length and fruit width in determining the average fruit weight, which in turn adequately described the increase in fruit yield plant^{-1}.

Literature concerned with other cucurbitaceous crops

Solanki *et al.* (1980) observed all the characters were positively and genotypically correlated with fruit yield^{-1}. Only the number of secondary branches plant^{-1} showed a negative significant environmental correlation with fruit yield plant^{-1}. Number of primary branches plant^{-1} had the significant genotypic and phenotypic correlation coefficient with fruit yield and yield contributing characters which indicates that this character had a significant effect on total fruit yield plant^{-1}.

Doijode (1984) examined phenotypic and genotypic correlations between eight quantitative characters in pumpkin. Fruit weight showed positive correlation with vine length, days to fruit maturity, fruit size and cavity size indices and flesh thickness. Vine length was positively correlated with number of laterals, days to female flowering, days to fruit maturity and flesh thickness. Fruit size also showed positive correlation with flesh thickness.

Choudhary *et al.* (1987) evaluated thirty diverse genotypes of cucumber and revealed that yield vine^{-1} expressed high positive correlation with number of female flowers vine^{-1}, number of fruits vine^{-1}, fruit length and fruit weight at both genotypic and phenotypic levels.

Sharma and Bhutani (2001) in bitter gourd, recorded significant positive correlations of total yield plant^{-1} to fruits plant^{-1} and average fruit weight. Significant positive correlation was also observed between first female flowering node with fruit length and fruit diameter with average fruit weight.

Singh *et al.* (2002) studied character association in cucumber and reported that the fruit weight, fruit girth and length of fruit had higher correlation with fruit yield plant^{-1}. Genotypic correlation coefficients were higher than phenotypic, which indicated strong association among these traits.

Dora *et al*. (2002) observed that yield plant^{-1} was significantly and positively correlated with number of fruits plant^{-1}, fruit set, and fruit retention at both phenotypic and genotypic levels in pointed gourd.

Choudhary *et al.* (2003) observed that yield plant^{-1} had a significant positive correlation with fruit weight, fruits plant^{-1}, and number of vines plant^{-1}, harvest duration, rind thickness, shelf life and vine length in muskmelon.

Rolonia *et al* (2003) reported that fruit yield was positively correlated with main vine length, number of primary branches plant^{-1}, number of nodes plant^{-1}, number of female flowers plant^{-1}, number of fruits plant^{-1} and harvest duration in watermelon.

Rao *et al*. (2004) reported that yield was positively correlated with fruit weight, fruit length and flesh thickness at both genotypic and phenotypic levels in cucumber.

Narayankutty *et al.* (2006) revealed that yield was strongly correlated with fruit weight, fruits plant^{-1}, fruit girth, days to first harvest, flesh thickness and days to first female flower opening in snake gourd.

It is thus, seen that there is considerable genetic diversity and vast range of variation in different characters in different cucurbits in general and bottle gourd in particular which would be utilized or breeding purpose. Thorough and critical information obtained through various parameters will be of immense help to launch a coherent improvement programme.

Concept of divergence

Murthy and Arunachalam (1965) hypothesized that Mahalanobis; generalised distance, a measure of metric distance between population centroids, could be a useful multivariate statistical tool for effective discrimination among parents on the basis of genetic diversity. Precisely information about genetic divergence is critical for a productive breeding programme, as genetically diverse plants are known to produce high heterotic effects consequently yield desirable segregants.

The D^2 statistics give a result based on the magnitude of divergence independent of the sample size. The technique has been extensively used by numerous workers in classifactory problems (Rao, 1952) in understanding the nature of genetic divergence and for selecting diverse parents for successful hybridization in outbreeding population, such as, self incompatible Brassica (Murthy and Arunachalam, 1965) and in self pollinated crops, such as, Wheat (Jatasra and Paroda, 1978).

Studies in number of crop species with different breeding systems by means of D^2 statistics suggested that genetic diversity need not to be directly related to the geographic diversity (Murthy and Arunachalam, 1965).

Murthy and Arunachalam (1965) examined the nature of genetic divergence as measured through D^2 statistic and its relationship to components of genetic variation in some out breeding populations, self fertilizing crops and crops showing variable degree of out crossing. It was observed that in general plant weight, days to flowering, grains plant^{-1} and grain weight was contributing significantly to total genetic diversity in most of the crops studied.

Genetic diversity in bottle gourd

A successful breeding programme is associated with diversity of the parents within a reasonable range. More the diversity, better are the chances of improving economic characters under consideration in the resulting progenies. It also helps to know the relative distance between these strains for the characters under study.

It is thus, seen that these is considerable genetic diversity and vast range of variation in different characters in different cucurbits in general and bottle gourd in particular which would be utilized or breeding purpose. Thorough and critical information obtained through various parameters will be help to launch a viable improvement programme.

Badade *et al.* (2001) studied genetic divergence using Mahalanobis D^2 statistics for seven quantitative characters including yield $vine^{-1}$ in a collection of twenty diverse cultivars of bottle gourd. The cultivars differed significantly for almost all the characters and were grouped into 10 clusters based on the similarities of D^2 value. Considerable diversity within and between was noted and it was observed for the characters viz., vine length, number of branches, percentage of female flowers, fruits $vine^{-1}$, length and diameter of fruit and yield $vine^{-1}$. There were factors responsible for genetic divergence which may be useful for heterosis breeding in bottle gourd.

Mathew *et al.* (2001) assessed twenty eight accessions of bottle gourd for their genetic divergence using Mahalanobis D^2 statistics. Based on D^2 values of 17 yield related characters, accessions were grouped into eight clusters. Clustering pattern indicated that there was no association between geographical distribution of accessions and genetic divergence. The characters like number of fruits $plant^{-1}$,

number of seeds fruit^{-1}, length of fruit, average fruit weight, vine length and fruit set percentage contributed maximum to genetic divergence.

Islam *et al.* (2004) studied divergence in bottle gourd and reported that there was no clear relationship observed between geographic origin and genetic diversity.

Munshi *et al.* (2005) evaluated the performance of 12 bottle gourd (*Lagenaria siceraria*) cultivars and reported considerable diversity within and between them. Total yield plant^{-1}, fruit length, fruit weight, number of primary branches vine^{-1}, earliness to male and female flowers appearance, sex ratio and harvesting date were potential factors in differentiating bottle gourd germplasm.

Singh *et al.* (2007) studied divergence in bottle gourd and reported that there was no parallelism between the clustering pattern and geographic origin and maximum genetic diversity was obtained between cluster III and XII.

Literature concerned with other cucurbitaceous crops

Singh and Lal (2002) studied fifty one genotypes of muskmelon to assess genetic divergence using D^2 statistics. The genotypes were grouped in to 13 clusters. The intra cluster distance was maximum in cluster VIII and minimum in clusters IX, X, XI, XII, and XIII. The inter cluster distance was maximum between cluster VII and XII and minimum between cluster I and II. Maximum divergence was provided by the node at which first female flower appeared and minimum by fruit yield vine^{-1}.

Rao *et al.* (2003) studied thirty one genotypes to assess genetic divergence by using Mahalanobis D^2 statistics. The genotypes got grouped into 16 clusters based on similarities at D^2 values. Genotypes from different regions were distributed in to various clusters at random, demonstrating that geographical isolation may not be one of the factors for causing biological or genetic diversity.

Veralakshmi *et al.* (2003) studied thirteen quantitative characters in twenty one diverse ridge gourd genotypes using Mahalanobis D^2 statistics. The genotypes were grouped into 10 clusters. The maximum genetic divergence was observed between clusters III and VI. The characters namely number of days to first female flower, vine length; number of first female flowering node, fruit weight, number of seeds $fruit^{-1}$, number of fruits $vine^{-1}$ and 100 seed weight contributed maximum to divergence.

Dey *et al.* (2006) studied diversity in bitter gourd and reported the clustering pattern based on yield related traits and molecular variation was different.

Dey *et al.* (2007) studied divergence in bitter gourd and reported no parallelism between geographic and genetic diversity.

Haribabu (2007) studied eighteen genotypes of cucumber to assess genetic divergence using D^2 statistics. On the basis of D^2 analysis eighteen genotypes were grouped in eight clusters with substantial genetic divergence between them. The clusters A, B, and E had 5, 5 and 3 strains respectively and remaining clusters C, D, F, G and H had one strain each. The maximum inter cluster distance was observed between F and H (11.24) and minimum inter cluster distance was observed between C and F (5.33). The cluster pattern revealed that the genetic diversity was not parallel to the geographical distribution of the genotypes.

Chapter - 3

MATERIAL AND METHODS

The present investigation entitled Variability and Divergence in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.] was conducted in the Experimental field of the Division of Olericulture, Sher-e-Kashmir University of Agriculture Sciences and Technology of Kashmir during summer, 2011.

The details of material used, methods adopted and statistical analysis followed during the course of this investigation are described below.

3.1 Experimental Material

The material under investigation consisted of Forty two genotypes, collected from local areas coded and maintained at the Division of Olericulture, Sher-e-Kashmir University of Agriculture Sciences and Technology of Kashmir. The genotypes were studied for different diverse characters.

The detail of germplasm of bottle gourd their sources are given in Appendix - 1.

3.2 Layout of the experiment

Seeds of 42 genotypes of Bottle gourd were directly sown during summer season, 2011 in Randomized Block Design with 3 replications to study the genetic variability. Sowing of seeds of each genotype was done on the top of broad beds. Planting geometry was 1.20 m × 0.60 m. All cultural practices i.e. manuring irrigation plant protection weeding etc. were carried out as per the prescribed package of practices recommended by the division.

3.3 Observations recorded

Plate – 1: Field view of Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]

The observations for morphological quantitative and qualitative characters were recorded on randomly selected 3 plants of each genotype in each replication.

3.3.1 Quantitative characters

3.3.1.1 Days to appearance of first male flower

The number of days required for the appearance of first male flower after sowing were recorded.

3.3.1.2 Days to appearance of first female flower

The number of days required for the appearance of first female flower after sowing were recorded.

3.3.1.3 Node number of first female flower

The node at which the first female flower appeared was recorded.

3.3.1.4 Days to first harvest

Days to first harvest was recorded on the basis of number of days required for the first harvest of tender fruit from the date of sowing.

3.3.1.5 Ratio of female to male flower

The actual amount of male and female flowers on each observational plant was recorded and the percentage of female flowers was calculated.

3.3.1.6 Number of secondary branches plant $^{-1}$

The numbers of secondary branches on main stem of each observational plant was recorded and form the mean, number of branches plant^{-1} was carried out.

3.3.1.7 Fruit length (cm)

The length of five randomly selected fruits from the observations plants from each replication was measured in cm from the blossom end to the distal end of the fruit.

3.3.1.8 Fruit girth (cm)

Diameter of five randomly selected fruits from observational plant in each replication was measured at the centre of the fruit using Vernier Caliper and mean diameter was calculated.

3.3.1.9 Average fruit weight (kg)

Average weight of fruit was calculated by dividing the total weight of all the fruits harvested to the total number of fruits.

13.3.1.0 Number of fruits plant^{-1}

The total number of fruits harvested at all the harvestings of each observational plant was recorded and the average number of fruit plant^{-1} was worked out.

3.3.1.11 Total fruit yield plant^{-1} (kg)

The yield of fruit at each harvesting from five observational plants were recorded from the first to last harvesting and mean yield of fruits plant^{-1} was calculated.

3.3.2 Qualitative characters

3.3.2.1 Total chlorophyll content (%)

The green fruit at the edible stage was assessed by estimating the total chlorophyll and was expressed in mg 100 g^{-1}.

Principal: Chlorophyll is extracted in 80 Percent acetone and the absorption at 663 and 645 nm are read in a spectrophotometer using the absorption coefficients and the amount of chlorophyll is calculated following A.O.AC. (1980).

Reagent: Acetone (80%)

Method of chlorophyll extraction: 1 gram composite sample of green fruits of each treatment was weighed and taken into a clean mortar. The sample was grounded to fine pulp with the addition of 20 ml, 80 Percent acetone and filtered into a volumetric flask. The procedure was repeated till the residue was colorless. The filter paper, pestle and mortar were washed with 80 Percent acetone. The final volume was made to 100 ml with acetone. The absorbance of the solution was read at 645 nm and 663 nm.

Total chlorophyll was calculated by the formulae:

$$\text{Total chlorophyll (mg 100 g -1)} = 20.2\ (A\ 645nm) + 8.02\ (A663nm) \times \frac{V}{1000 \times w} \times 100$$

Were,

A= Absorbance at specific wave length,

V= Volume of chlorophyll extract in 80% acetone and

W= Fresh weight of tissue extracted

3.3.2.2 Dry matter content (%)

A 100g of sample of fresh fruit was taken and sun dried. The sun dried sample was put in an oven and dried until the entire moisture in the sample was lost. Then dry matter content (%) was calculated as:

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight of sample}}{\text{Fresh weight of sample}} \times 100$$

3.4 Statistical procedures

The data recorded was subjected to following statistical and biometrical analysis.

3.4.1 Analysis of variance

The analysis of variance for all characters was carried as per the procedure suggested by Panse and Sukhatme (1985).

The analysis was based on following mathematical model :

$Y_{ik} = \mu + g_i + r_k + l_{ik}$

Where,

Y_{ik} = Observation of i^{th} genotype (g = I to *i*) in k^{th} replication

μ = general mean

g_i = effect of the i^{th} genotype

r_k = effect of k^{th} replication, and

l_{ik} = random error associated with i^{kth} observation

3.4.1.1 Expectation of mean squares

Expectation of mean squares based on the model given above. The expectations of various mean squares were dried as follows :

Source of variation	d.f.	Expected mean squares	M.S
Replications	(r-l)	$\hat{\sigma}^2_e + g\hat{\sigma}^2_r$	MSR
Genotypes	(g-l)	$\hat{\sigma}^2_e + r\hat{\sigma}^2_g$	MSG (M_2)
Error	(g-l) (r-l)	$\hat{\sigma}^2_e$	ME (M_1)

3.4.1.2 Standard error of mean

$$SEm = \pm\sqrt{\frac{MSE}{r}}$$

3.4.1.3 Critical difference

$$CD\,at\,5\% = \sqrt{\frac{2MSE}{r}}\,x\,t$$

Where,

r = Number of replications,

MSE = Error mean sum of squares

t = Tabulated value at 5% or 1% level of significance for the error d.f.

3.4.2 Estimation of components of variance co-efficient of variation and heritability

3.4.2.1 Genotypic variance

Genotypic variance was calculated using the formula :

$$\hat{\sigma}^2_g = \frac{MSG - MSE}{r}$$

Where,

$\hat{\sigma}^2_g$ = Genotypic variance,

MSG = mean sum of squares due to genotypes,

MSE = mean sum of squares due to error, and

r = number of replications.

3.4.2.2 Phenotypic variance

Phenotypic variance was calculated as per the procedure given by Allard (1960).

$$\hat{\sigma}^2 p = \hat{\sigma}^2 g + \hat{\sigma}^2 e$$

Where,

$\hat{\sigma}^2 p$ = Phenotypic variance

$\hat{\sigma}^2 g$ = genotypic variance, and

$\hat{\sigma}^2 e$ = error variance

3.4.2.3 Phenotypic co-efficient of variation (PCV)

The magnitude of phenotypic variation existing in a trait was worked out by the formula given Burton (1952) :

$$PCV = \frac{\sqrt{\hat{\sigma}^2 p}}{\overline{x}} \times 100$$

Where,

$\hat{\sigma}^2 p$ = Phenotypic variance, and

$\overline{x}$ = grand mean of the trait studied

3.4.2.4 Genotypic co-efficient of variation (GCV)

The magnitude of genotypic co-efficient of variation existing in a trait was worked out by the formula given by Allard (1960) :

$$GCV = \frac{\sqrt{\hat{\sigma}^2 g}}{\bar{x}} \times 100$$

Where,

$\hat{\sigma}^2 g$ = Genotypic variance, and

$\bar{x}$ = grand mean of the trait studied

3.4.2.5 Heritability

Heritability in broad sense, which is the ratio of genotypic variance to the phenotypic variance was calculated by the method given by Allard (1960) using the formula :

$$h^2 (b.s) = \frac{\hat{\sigma}^2 g}{\hat{\sigma}^2 p}$$

Where,

$\hat{\sigma}^2 g$ = Genotypic variance

$\hat{\sigma}^2 p$ = phenotypic variance, and

h^2 = heritability in broad sense

3.4.3 Estimation of genotypic and phenotypic covariances and correlation coefficient

Covariance analysis followed the same pattern as the variance analysis. The genotypic and phenotypic covariances between two characters were obtained in the same fashion as corresponding variances. Estimate of genotypic and phenotypic variances and covariances were substituted in the following formula suggested by

Panse and Sukatme (1985), calculate correlation co-efficient between all possible pairs of characters.

3.4.3.1 Genotypic correlation co-efficient

$$r_{xy}\ (g) = \frac{\hat{\sigma}^2{}_{xy}\ (g)}{\sqrt{\hat{\sigma}^2{}_x\,(g)\ \hat{\sigma}^2{}_y\,(g)}}$$

3.4.3.2 Phenotypic correlation coefficient

$$r_{xy}\ (p) = \frac{\hat{\sigma}^2{}_{xy}\ (p)}{\sqrt{\hat{\sigma}^2{}_x\,(p)\ \hat{\sigma}^2{}_y\,(p)}}$$

Where,

$r_{xy}(g), r_{xy}(p)$	=	Genotypic and phenotypic correlation coefficients, respectively, between a pair of characters x and y
$\hat{\sigma}^2 xy(g), \hat{\sigma}^2 xy(p)$	=	Genotypic and phenotypic covariances, respectively, for a pair of characters x and y
$\hat{\sigma}^2 x(g), \hat{\sigma}^2 y(g)$	=	Genotypic variance for characters x and y, respectively, and
$\hat{\sigma}^2 x(p), \hat{\sigma}^2 y(p)$	=	Phenotypic variance for character x and y, respectively.

3.4.3.3 Test of significance

The significance of a correlation co-efficient was tested by the following formula :

$$t = \frac{r(n-2)^{0.5}}{(1-r^2)^{0.5}}$$

Where,

r = Correlation coefficient and

n = number of observations

Any value (±) exceeding the table value of t at n-2 d.f is significant.

3.4.3.4 Genetic advance

Genetic advance was predicted by using the formula :

$R = i. h^2. \hat{\sigma}_p$ (Allard, 1960)

Where,

R = Genetic advance at a particular selection intensity,

i = standardized selection differential values at a particular selection intensity,

h^2 = heritability (b.s) of the trait, and

$\hat{\sigma}_p$ = phenotypic standard deviation.

3.4.3.5 Genetic gain (Percent of mean)

$$\text{Genetic gain} = \frac{\text{Genetic advance (R)}}{\overline{X}} \text{ X } 100$$

Where,

$\overline{X}$ = Mean of the trait

3.4.3.6 Path coefficient analysis

The partitioning of the correlation coefficient into direct of indirect effects on grain yield of different traits was done following Dewey and Lu (1959) as under :

$P_{y1} + P_{y2}\ r_{12} + P_{y3}\ r_{13}$ + ……. $P_{yn}\ r_{1n} = r_{y1.}$

$P_{y1} + r_{12}$ + $P_{y2} + P_{y3}\ r_{23}$ + ……. $P_{yn}\ r_{2n} = r_{y2.}$

$P_{y1}\ r_{1n} + P_{y2}\ r_{2n} + P_{y3}\ r_{3n}$ + ……. + $P_{yn} = r_{yn.}$

Where,

P_{y1}, P_{y2}, P_{y3}, ……. Pny are the direct path effect of 1, 2, 3 ……. n variable on the dependent variable y;

r_{12}, r_{13}, …….r_{1n} ……. r (n-1)n are the possible coefficients of correlation between various independent variables and r_{y1}, r_{y2} ……. r_{yn} are the coefficients of correlation of independent variables with the dependent variable y.

The residual factor (i.e. the variation in yield unaccounted for those associations) was calculated from the following formula :

Residual factor (x) = $1-R^2$

$R^2 = P_{y1}\ r_{y1} + P_{y2}\ r_{y2}$ + ……. + $P_{yn}\ r_{yn}$

R^2 is the squared multiple correlation co-efficient and is the amount of variation in yield that can be accounted for by the yield component character.

3.5 Estimates of genetic divergence

The genetic divergence was computed using the procedure as described by Rao (1952) and Singh and Choudhary (1985). The details of analysis are described under the following heads:

1) Test of Wilk's criterion,

2) Transformation of correlated variables,

3) Computation of D^2 values,

4) Relative contribution of individual characters towards total divergence, and

5) Group constellation.

3.5.1 Test of Wilk's criterion

Variances and covariances were obtained from analysis of variance and covariance tables and the following analysis of dispersion table was constructed:

Analysis of dispersion

Dispersion due to	d.f.	Matrix due to			
		Sum of squares		Sum of products	
		X^2_1	X^2_2……	$X_1 X_2$	$X_1 X_3$…….
Replications	r-1	a	b	C	d…...
Between treatments (Q)	Q	a′	b′	c′	d′…..
Within treatments (W)	By subtraction	A-(a+a′)	B-(b+b′)	C-(c+c′)	D-(d+d′)….
Total	**N**	**A**	**B**	**C**	**D…..**

The determination of error and error + variety variance-covariance matrix were calculated by pivotal condensation method of using 'V' statistics which, in turn, utilizes Wilk's criteria. A simultaneous test of differences between mean values of characters from all the genotypes in the present study was performed, as per the details given below:

The Wilk's test is :

V = -mlog eA

Where,

$$\lambda = \frac{W}{W + Q}$$

$$= \frac{\text{Determinant of error matrix}}{\text{Determinant of error + variety matrix}}$$

and,

$$m = n - \frac{q + k + 1}{2}$$

Where,

n = Total number of observations minus one,

q = number of variable minus one, and

k = number of characters under study.

'V' Statistics so obtained was compared with the tabulated value of χ^2 for 2qk degrees of freedom.

3.5.2 Transformation of correlated variables

Plot means of the varieties corresponding to the characters studied were transformed to uncorrelated variables by Pivotal Condensation Method, which rendered the computation of D^2 values between any combinations of two varieties to simple summation of squares of differences in transformed values for various characters. The skeleton procedure of obtaining transformed variables by Pivotal Condensation Method is described below:

Let dispersion matrix of original variables x_1, x_2 …… x_p be

λ_{11} λ_{12} …… λ_{1p}

λ_{21} λ_{22} …… λ_{2p}

•	•	……	•
•	•	……	•
•	•	……	•
•	•	……	•
•	•	……	•
λ_{p1}	λ_{p2}	……	λ_{pp}

and consider the extended matrix

λ_{11}	λ_{12}	……	$\lambda_{1p\ x\ 1}$
λ_{21}	λ_{22}	……	$\lambda_{2p\ x\ 2}$
•	•	……	•
•	•	……	•
•	•	……	•
•	•	……	•
•	•	……	•
λ_{p1}	λ_{p2}	……	$\lambda_{pp\ x\ p}$

taking λ_{11} as the first pivotal element, the first row is replaced by

$$1 \quad \frac{\lambda_{12}}{\lambda_{11}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \frac{\lambda_{1p}}{\lambda_{11}} \quad \frac{x\ 1}{\lambda_{11}}$$

Sweeping out first column and using the first pivotal row, following reduced matrix is obtained

$$\begin{pmatrix} \lambda_{22'} & \cdots\cdots\cdots\cdots & \lambda_{2p'} \\ \bullet & & \bullet \\ \bullet & & \bullet \\ \bullet & & \bullet \\ \bullet & & \bullet \\ \lambda_{p2'} & \cdots\cdots\cdots\cdots & \lambda_{pp'} \end{pmatrix} \begin{pmatrix} X_{2'} \\ \bullet \\ \bullet \\ \bullet \\ \bullet \\ x_{p'} \end{pmatrix}$$

where,

$$\lambda_{ij} = - \frac{\lambda_{ij}}{\lambda_{11}} \lambda_{ij} x_i$$

$$x_i = - \frac{\lambda_{il}}{\lambda_{ll}} X_1$$

$$\text{Now, } = V_{(xi)} = V_{(xi)} - \frac{2\lambda_{il}}{\lambda_{ll}} \text{Cov.}(x_i x_1) + \frac{2\lambda_{il}}{\lambda_{ll}} V(X_1)$$

$$= \lambda_{ii} - \frac{\lambda_{il}^2}{\lambda_{ll}} X_{1i}$$

$$\text{Now, } V_{(xi')} = + \frac{\lambda_{il}}{\lambda_{ii}} V(xl)$$

Similarly, Cov. $(x'_{i1}\, x'j) = \lambda_{ij}'$

Similarly, Cov. $(x'_i{}'\, x'j') = \lambda_{ij}'$

also, cov. (x 1 x′i) = cov. (xlxi) - λil v(xi)

$$\lambda ll$$

$$= \lambda il - \lambda il = 0$$

So the new variables are uncorrelated.

Considering the second pivotal row

$$\frac{\lambda 23}{\lambda 22'} \qquad \frac{\lambda 2p'}{\lambda 22'} \qquad \frac{x2'}{22'}$$

the further reduced matrix is

$$\left| \begin{matrix} \lambda 33'' & \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. & \lambda 3p'' \\ \bullet & & \bullet \\ \bullet & & \bullet \\ \bullet & & \bullet \\ \lambda p3'' & & \lambda pp'' \end{matrix} \right| \left| \begin{matrix} \lambda x3'' \\ \bullet \\ \bullet \\ \bullet \\ xp'' \end{matrix} \right|$$

resulting into variables

x1′ x 2′ x 3″ ………………………………… with variance

x11′ x λ22′ λ33″ ………………………..

They are all mutually uncorrelated as shown above and further x'_2, depends on x_1 and x_2', and x_3 on x_1', x_2 and x_3 only.

3.5.3 Computation of D^2 values

For each pair-wise combination of the varieties the differences in transformed values for various characters were computed and D^2-values were calculated according to the following formula:

$$D^2 = \sum_{i-1}^{p} (\overline{Y}_{ij} - Y_{ik})^2$$

Where,

P = number of characters studied, and

Y_{ij} and Y_{ik} = are two transformed variables of the i^{th} character for two genotypes

3.5.4 Relative contribution of individual characters towards total divergences

The ranking of differences in uncorrelated means between all the characters for all pair-wise combinations of varieties was carried out, with first rank being assigned to the highest differences. Finally relative contribution of a character towards total divergence was estimated by calculating the percentage of first rank in that character.

3.5.5 Group constellation

Tocher's method was used for assigning various varieties to different clusters. The two varieties having smallest distance from each other were considered first to which a third variety having smallest average D^2 value from the first two varieties was added. Next come the nearest fourth variety and the process continued till the average D^2 value increased. The remaining varieties were then considered for the next cluster and the process was continued till all varieties were included in various clusters.

The spatial distances between clusters were arrived at by taking square root of average intra and inter cluster D^2 values.

For each combination (pair of genotypes) the mean deviation (d^2i) i.e. Y_1-Y_1 with I = 1, 2, 3 …….. p was computed and D^2 values were calculated as sum of

these deviations i.e. (y_i^1-y_i^2), where, y_i is the transformed variable from the original variable xi. Accordingly D^2 values for all combinations were calculated. The D^2 values so obtained for each pair of population were treated as x^2 and were tested against the tabulated values of λ^2 for p degrees of freedom, where p is the number of traits considered.

In all combinations each character was ranked on the basis of $d_i = y_{ij} - y_{ik}$ values. Rank I was given to the highest mean difference and rank p to the lowest mean difference, where p is the total number of characters. In this manner contribution of each character to the total divergence was computed.

Tocher method for grouping of varieties into various clusters was adopted. This method is detailed in a simplified way by Rao (1952) and Singh and Choudhary (1985).

All the above computations were carried out using the software Windostat at Computer Section of the Division of Plant Breeding and Genetics, SKUAST-Kashmir, Shalimar.

Chapter - 4

EXPERIMENTAL FINDINGS

The results of present investigation entitled, "Variability and Divergence in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]" was carried out to study the magnitude of variability for maturity, quality and yield and yield attributing characters and analyse cause and effect relationship so as to identify the most important component traits contributing to fruit yield. The experimental material comprised genotypes mostly suited to mountain regions, with two checks SKBG-12 and Shalimar Improved. The list of genotypes used in the study is presented in Appendix-1. Data was recorded on thirteen maturity, yield component and quality traits viz., days to first male flower, days to first female flower, node number at which first female flower appeared, ratio of female to male flower, number of secondary branches plant^{-1}, days to first fruit harvest, number of fruits plant^{-1}, fruit length (cm), fruit girth (cm), average fruit weight (kg), total fruit yield plant^{-1} (kg), total chlorophyll content (%) and total dry matter content (%).

4.1 Analysis of variance

Analysis of variance indicated substantial variation among the genotypes for all the thirteen characters under study as shown in Table-1.

4.2 Range of variability

The experimental material exhibited wide variation for characters under study (Table 2).

A wide range of variation was observed for days to appearance of first male flower from 57.00 (ABGS-99) to 40.33 (PBOG-8). The days to appearance of first female flower ranged from 67.66 (Shalimar Improved) to 50.00 (PBOG-8) and node

Table-1: Analysis of variance with respect to M.S.S for different traits in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]

Source of variation	d.f.	Mean sum of squares					
		Days to first male flower	Days to first female flower	Node number at which first female flower appeared	Ratio of female to male flower	Number of secondary branches	Days to first fruit harvest
Replications	2	0.857	2.126	0.603	0.156	1.500	71.166
Genotypes	41	49.033**	48.344**	8.693**	0.826**	8.463**	54.506**
Error	82	0.653	0.728	4.237	0.051	1.833	19.028

** - Significant at 1% level of significance

Cont…

Table 1 Cont…

Source of variation	d.f.	Mean sum of squares						
		Number of fruits plant^{-1}	**Fruit length (cm)**	**Fruit girth (cm)**	**Average fruit weight (kg)**	**Total fruit yield plant^{-1} (kg)**	**Chlorophyll content (%)**	**Dry matter content (%)**
Replications	2	6.103	137.225	61.612	0.059	1.143	7.309	1.799
Genotypes	41	8.793**	143.318**	79.461**	0.365**	5.606**	12.392**	17.950**
Error	82	2.306	42.317	29.326	0.079	0.279	3.374	2.795

** - Significant at 1% level of significance

Table-2: Estimates of variability parameters for different characters in Bottle gourd [*Lagenaria siceraria* (molina) Standl.]

S. No.	Character	Mean	Range	Coefficient of variability (%)		Broad sense heritability (bs)	Genetic advance (% of mean)
				Phenotypic	Genotypic		
1.	Days to first male flower	47.38	57.00-40.33	8.64	8.47	0.961	17.11
2.	Days to first female flower	57.29	67.66-50.00	7.11	6.95	0.956	14.00
3.	Node number at which first female flower appeared	5.44	2.00-9.33	43.93	22.38	0.260	23.49
4.	Ratio of female to male flower	0.65	0.34-1.16	42.15	24.21	0.330	28.64
5.	Number of secondary branches	3.86	3.00-7.00	61.64	45.57	0.547	69.41
6.	Days to first fruit harvest	87.52	98.00-79.00	6.34	3.92	0.383	5.01
7.	Number of fruits plant^{-1}	4.07	3.66-8.33	52.43	36.47	0.484	52.26
8.	Fruit length (cm)	28.82	15.53-41.53	30.24	20.12	0.443	27.60
9.	Fruit girth (cm)	24.20	14.20-39.53	28.03	16.89	0.363	20.96
10.	Average fruit weight (kg)	0.85	0.72-2.01	53.45	39.43	0.544	59.92
11.	Total fruit yield plant^{-1} (kg)	3.15	2.61-8.22	54.79	50.92	0.864	97.51
12.	Chlorophyll content (%)	6.19	2.33-12.33	40.80	28.00	0.471	39.60
13.	Dry matter content (%)	6.34	3.00-15.33	44.11	35.39	0.644	58.51

number of first female flower appeared ranged between 2.00 (AJBG-9) to 9.33 (NDBG-601). Ratio of female to male flower ranged between 0.34 (Pusa Naveen) to 1.16 (NDBG- Round-2). Number of secondary branches ranged from 3.00 (PBOG-7) to 7.00 (AJBG-4002).

Days to first fruit harvest ranged from 98.33 (ABGS-99) to 79.00 (Guttka) and number of fruits plant^{-1} ranged from 3.66 (NDBG-619) to 8.33 (Pusa Naveen).

Length of fruit ranges from 15.53 cm (NDBG- Round-2) to 41.53 (Shalimar Improved) and fruit girth ranged from 14.20 cm (F-S-1) to 39.53 cm (Narendra Madhuri). Average weight of fruit ranges between 0.72 kg (PBOG-2) to 2.01 kg (Pusa Naveen). The range of total fruit yield plant^{-1} was between 2.61 kg (NDBG-Round-2) to 8.22 (SKBG-12).

The range of Percent Chlorophyll content was between 2.33 (VRBG-2) to 12.33 (SKBG-12) and dry matter content ranged between 3.00 % (NDBG-133) to 15.33 % (SKBG-12).

Variation among different genotypes is shown in Appendix- 2.

4.3 Estimates of Genotypic and phenotypic coefficient of variation

The estimates of genotypic coefficient of variation were low as compared to phenotypic coefficient of variation (Table 2) for all the characters under study. The genotypic coefficient of variation was lowest for days to first harvest (3.92) and highest for total fruit yield plant^{-1} (50.92). The phenotypic coefficient of variation was lowest for the character days to first fruit harvest (6.34) and highest for number of secondary branches (61.64). Both the coefficients of variation for rest of the characters ranged in between those for above characters.

4.4 Estimates of Heritability and genetic advance

Lowest heritability was recorded for node number at which first female flower appeared (26.0%), followed by ratio of female to male flower (33.0%), fruit girth (36.3%) and days to first fruit harvest (38.3). However, the character days to first male flower recorded highest heritability (96.1%), followed by days to first female flower (95.6), total fruit yield plant^{-1} (86.4%), dry matter content (64.4) and number of secondary branches (54.7%), Whereas remaining characters like number of fruits plant^{-1}, fruit length and chlorophyll content showed medium heritability (44.3-48.4).

The genetic advance expressed as percent of mean, however, ranged from 5.01 for days to first fruit harvest to 97.51 for total fruit yield plant^{-1}.

4.5 Estimates of phenotypic and genotypic correlation coefficients

The magnitude of genotypic correlation coefficients in general was higher than the phenotypic correlation coefficients (Table 3).

The days to appearance of first male flower exhibited significant and positive correlation with days to appearance of first female flower and days to first fruit harvest at both genotypic and phenotypic levels, for number fruits plant^{-1} only at genotypic level. It was significantly and negatively correlated with number of secondary branches plant^{-1}, average fruit weight, total fruit yield plant^{-1}, total chlorophyll content and dry matter content at genotypic and phenotypic levels; for fruit length, fruit girth only at genotypic level; for number fruits plant^{-1} only at phenotypic level. It was non-significantly and positively correlated with node number at which first female flower appeared at genotypic and phenotypic levels. It was non-significantly and negatively correlated with ratio of female to male flower at genotypic and phenotypic levels, for fruit length and fruit girth only at phenotypic levels.

Table-3: Genotypic (Upper Value) and Phenotypic (Lower Value) Correlation coefficients between various pairs of characters in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]

S. No.	Character	Days to first male flower	Days to first female flower	Node number at which first female flower appeared	Ratio of female to male flower	No. of secondary branches plant^{-1}	Days to first fruit harvest	No. of fruits plant^{-1}	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (kg)	Total fruit yield plant^{-1} (kg)	Total chlorop-hyll content (%)	Dry matter content (%)
1.	Days to first male flower	--	0.5427**	0.0388	-0.1930	-0.4388**	1.1526	0.4011**	-0.2300*	-0.3086**	-0.3150**	-0.3017**	-0.3380**	-0.3311**
			0.5109**	0.0201	-0.0873	-0.3260**	0.6560	-0.2666*	-0.1492	-0.1785	-0.2441*	-0.2852**	-0.2486*	-0.2806**
2.	Days to first female flower		--	-0.1817	-0.1996	-0.3231**	0.6521**	-0.4336**	0.1967	-0.2323*	-0.2085*	-0.0948	-0.1164	-0.2865**
				-0.0736	-0.0934	-0.2186*	0.4020**	-0.3036**	0.1245	-0.1503	-0.1688	-0.0939	-0.0857	-0.2263*
3.	Node no. at which 1st female flower appeared			--	1.1146	-0.1946	0.0637	-0.3093**	0.1514	0.0340	-0.0570	-0.0524	-0.0904	-0.0286
					0.2529	0.0486	0.1067	-0.1462	0.0140	-0.0535	0.0301	-0.0895	0.0928	-0.0332
4.	Ratio of female to male flower				--	-0.2681**	-0.0896	0.0781	-0.1776	0.2390*	-0.0481	0.0930	0.4027**	0.3175**
						-0.0540	-0.1130	0.0053	-0.0458	0.1681	0.0044	0.0633	0.0659	0.1465
5.	No. of secondary branches plant^{-1}					--	-0.4437**	0.2793*	0.3029**	0.0142	0.2337*	0.1160	0.5040**	0.3486**
							-0.1658	0.1619	0.1151	-0.1173	0.0874	0.0208	0.2794*	0.2178*
6.	Days to first fruit harvest						--	-0.4906**	-0.3457**	-0.5241**	-0.2875**	-0.3278**	-0.3854**	-0.4225**
								-0.2153	-0.0334	-0.0831	-0.1648	-0.1684	-0.1126	-0.1823
7.	No. of fruits plant^{-1}							--	0.1790	0.2404*	0.3912**	0.5533**	0.4782**	0.7038**
									0.2621*	0.0984	0.1989	0.3498**	0.2509*	0.4045**
8.	Fruit length (cm)								--	-0.0441	0.1807	0.3863**	0.2447*	0.1856
										0.2301*	0.2626*	0.3177**	0.0608	0.1920
9.	Fruit girth (cm)									--	0.4454**	0.4354**	0.1293	0.1388
											0.3567**	0.3601**	0.0368	0.0788
10.	Average fruit weight (kg)										--	0.7596**	0.2818**	0.3227**
												0.6140**	0.1553	0.1684
11.	Total fruit yield plant^{-1} (kg)											--	0.6547**	0.6485**
													0.4086**	0.4861**
12.	Total chlorophyll content (%)												--	0.7857**
														0.4259**
13.	Dry matter content (%)													--

*,** Significant at 5% and 1% level of significance, respectively.

The Days to appearance of first female flower was significantly and negatively correlated with number of secondary branches plant^{-1}, dry matter content at both genotypic and phenotypic levels and for fruit girth and average fruit weight only at genotypic level. It was significantly and positively correlated with days to first fruit harvest at both genotypic as well as phenotypic levels. It was non-significantly and negatively correlated with node number at which first female flower appeared, ratio of female to male flower, total fruit yield plant^{-1}, total chlorophyll content at both genotypic as well as phenotypic levels and for fruit girth, average fruit weight only at phenotypic level. It was non-significantly and positively correlated with fruit length at both genotypic as well as phenotypic levels.

Nodal position of first female flower showed a non-significant and negative correlation with number of fruits, total fruit yield plant^{-1} at both genotypic as well as phenotypic levels and for number of secondary branches plant^{-1}, average fruit weight plant^{-1}, total chlorophyll content showed only at genotypic level and for fruit girth only at phenotypic level. It showed non-significant, positive correlation with days to first fruit harvest, fruit length at both genotypic as well as phenotypic levels and for number of secondary branches plant^{-1}, average fruit weight plant^{-1}, chlorophyll content showed only at phenotypic level and for fruit girth showed only at genotypic level. It showed a significant and positive association with ratio of female to male flower only at phenotypic level.

Ratio of female to male flower showed a non-significant and negative correlation with days to first fruit harvest, fruit length at both genotypic as well as phenotypic levels and for number of secondary branches plant^{-1} only at phenotypic level and for average fruit weight only at genotypic level. It also showed non-significant, positive correlation with number of fruits plant^{-1}, total fruit yield plant^{-1} at both genotypic as well as phenotypic levels and for fruit girth, average fruit weight, chlorophyll content, and dry matter content showed only at phenotypic level. It

showed significant and positive correlation with fruit girth, chlorophyll content, and dry matter content only at genotypic level. It also showed a significant and negative correlation with number of secondary branches plant^{-1} only at genotypic level.

Number of secondary branches plant^{-1} showed a significant and positive correlation with average fruit weight plant^{-1}, fruit length, number fruits plant^{-1} at only genotypic level, and for chlorophyll content, dry matter content at both genotypic as well as phenotypic levels. It showed significant negative association with days to first fruit harvest at only genotypic level. It showed a non-significant and negative correlation with days to first fruit harvest, fruit girth only at phenotypic level. It showed non-significant and positive correlation with total fruit yield plant^{-1} at both levels genotypic as well as phenotypic levels, for fruit girth only at genotypic level, for number of fruits plant^{-1}, fruit length, and average fruit weight only at phenotypic level.

Days to first fruit harvest showed a significant and negative association with number of fruits plant^{-1} at genotypic as well as phenotypic levels and fruit girth, fruit length, average fruit weight, total fruit yield, chlorophyll content, dry matter content only at genotypic level. It showed a non-significant negative correlation with fruit girth, fruit length, average fruit weight, total fruit yield, chlorophyll content and dry matter content only at phenotypic level.

Number of fruits plant^{-1} showed a significant and positive correlation with total fruit yield, chlorophyll content and dry matter content at genotypic as well as phenotypic levels and for fruit girth, average fruit weight only at genotypic level and for fruit length only at phenotypic level. It showed a non-significant positive correlation with average fruit weight, fruit girth only at phenotypic level and for fruit length only at genotypic level.

Fruit length showed a non-significant negative correlation with fruit girth only at genotypic level. It also showed a non-significant positive correlation with fruit girth and chlorophyll content at phenotypic level and for average fruit weight plant^{-1} at genotypic level and for dry matter content at genotypic as well as phenotypic levels. It showed a significant positive correlation with total fruit yield plant^{-1} at genotypic as well as phenotypic levels and for average fruit weight at only phenotypic level and for chlorophyll content only at genotypic levels.

Fruit girth showed a significant positive correlation with average fruit weight plant^{-1} and total fruit yield plant^{-1} at genotypic as well as phenotypic levels. It also showed a non-significant positive correlation with chlorophyll content and dry matter content at genotypic as well as phenotypic levels.

Average fruit weight plant^{-1} showed a significant positive correlation with total fruit yield plant^{-1} at genotypic as well as phenotypic levels and for chlorophyll content and dry matter content only at genotypic level. It showed a non-significant positive correlation with chlorophyll content and dry matter content only at phenotypic level.

Total fruit yield plant^{-1} showed a significant and positive correlation with chlorophyll content and dry matter content at genotypic as well as phenotypic levels.

Chlorophyll content showed a significant positive correlation with dry matter content at genotypic as well as phenotypic levels.

4.6 Cause and effect relationship (path coefficient analysis)

Direct and indirect contributions of twelve different yield attributing traits were estimated through partitioning of their genotypic correlation coefficients by path analysis. The results are presented in Table-4 and depicted in

Table-4: Path Coefficient Analysis of direct (diagonal) and indirect (above diagonal) effects of component traits in Bottle gourd [*Lagenaria siceraria* (Mol.) Standl]

S. No.	Character	Days to first flower	Days to first female flower	Node number at which first female flower appeared	Ratio of female to male flower	No. of secondary branches plant^{-1}	Days to first fruit harvest	No. of fruits plant^{-1}	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (kg)	Total chlorophyll content (%)	Dry matter content (%)	Genotypic correlation with yield (g plant^{-1})
I.	Days to first flower	**0.3009**	-0.1177	-0.0084	-0.0027	0.2152	-0.2017	0.0540	-0.0864	-0.0260	-0.1898	-0.1881	-0.0510	-0.3017**
II.	Days to first female flower	0.1633	**-0.2170**	0.0392	-0.0028	0.1584	-0.1141	0.0584	0.0739	-0.0196	-0.1256	-0.0648	-0.0441	-0.0948
III.	Node number at which first female flower appeared	0.0117	0.0394	**-0.2157**	0.0156	0.0954	-0.0111	0.0416	0.0569	0.0029	-0.0344	-0.0503	-0.0044	-0.0524
IV.	Ratio of female to male flower	-0.0581	0.0433	-0.2404	**0.0140**	0.1315	0.0157	-0.0105	-0.0667	0.0202	-0.0290	0.2241	0.0489	0.0930
V.	No. of secondary branches plant^{-1}	-0.1320	0.0701	0.0420	-0.0038	**-0.4904**	0.0776	-0.0376	0.1138	0.0012	0.1408	0.1805	0.0537	0.1160
VI.	Days to first fruit harvest	0.3468	-0.1415	-0.0137	-0.0013	0.2176	**-0.1750**	0.0660	-0.1299	-0.0442	-0.1732	-0.2145	-0.0651	-0.3278**
VII.	No. of fruits plant^{-1}	-0.1207	0.0941	0.0667	0.0011	-0.1369	0.0858	**-0.1346**	0.0672	0.0203	0.3357	0.2662	0.1084	0.5533**
VIII.	Fruit length (cm)	0.0692	-0.0427	-0.0327	-0.0025	-0.1485	0.0605	-0.0241	**0.3756**	-0.0037	0.1089	0.1362	0.0286	0.3863**
IX.	Fruit girth (cm)	-0.0929	0.0504	-0.0073	0.0033	-0.0069	0.0917	-0.0324	-0.0166	**0.0843**	0.2684	0.0720	0.0214	0.4354**
X.	Average fruit weight (kg)	-0.0948	0.0452	0.0123	-0.0007	-0.1146	0.0503	-0.0527	0.0679	0.0376	**0.6025**	0.1568	0.0497	0.7596**
XI.	Total chlorophyll content (%)	-0.1017	0.0252	0.0195	0.0056	-0.2471	0.0674	-0.0644	0.4919	0.0109	0.1698	**0.1565**	0.1210	0.6547**
XII.	Dray matter content (%)	-0.0996	0.0622	0.0062	0.0044	-0.1709	0.0739	-0.0947	0.0697	0.1117	0.1945	0.1372	**0.3540**	0.6485**

Residual effect = 0.1669 * ,** Significant at 5% and 1%, respectively.

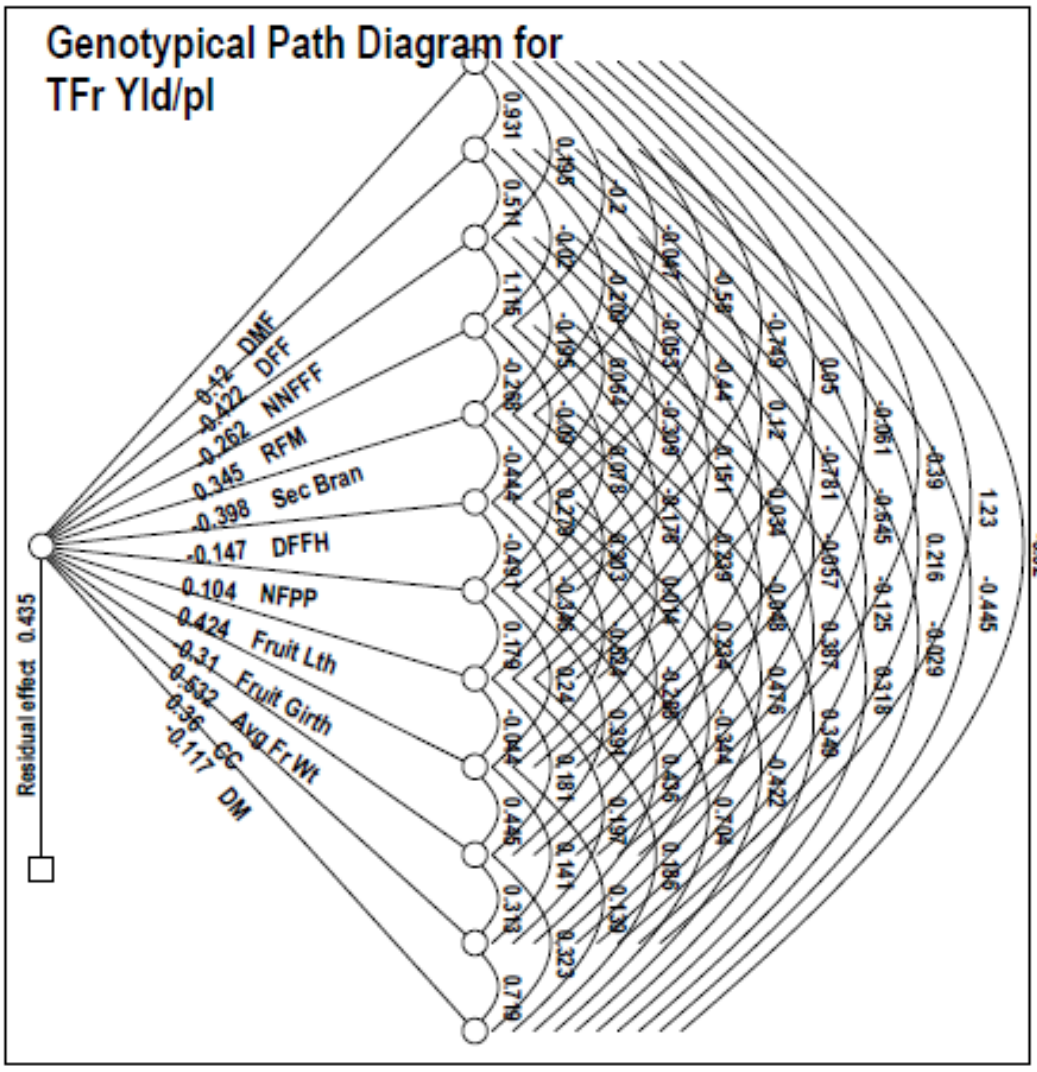

Fig-1. Path Coefficient Analysis (cause and effect relationship) for Total fruit Yield Plant^{-1}

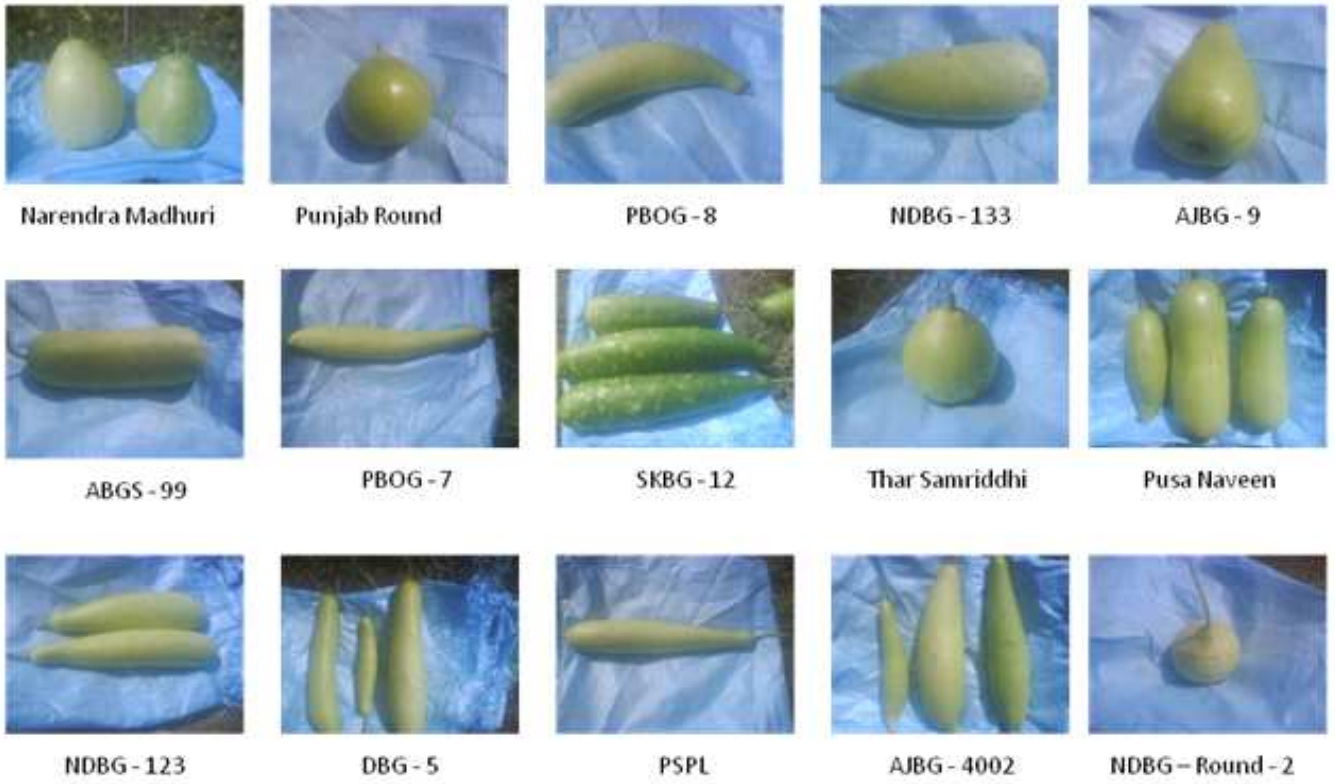

Plate – 2: Variability observed among different Bottle gourd Genotypes [*Lagenaria siceraria* (Mol.) Standl.]

Figure-1. Average fruit weight recorded highest positive direct effect (0.6025) on total fruit yield plant^{-1} followed by fruit length (0.3756), dry matter content (0.3540) and days to first male flower (0.3009). Total chlorophyll content (0.1565), fruit girth (0.0843) and ratio of female to male flower (0.0140) revealed weak positive effect.

Highly significant and positive genotypic correlation of number of fruits plant^{-1} with total fruit yield plant was observed mainly due to indirect effect of this trait via average fruit weight (0.3357), total chlorophyll content (0.2662). Significant genotypic correlation of fruit girth with dependant variable, at genotypic level was observed to be mainly due to strong positive indirect effect via average fruit weight (0.2684) and total chlorophyll content (0.0720).

Average fruit weight exhibited a strong positive direct effect on total fruit yield plant^{-1}. However, the highly significant negative correlation of this trait with total fruit yield plant^{-1} was supported by strong indirect negative effect via number of secondary branches plant^{-1}. Dry matter showed a strong direct effect on total fruit yield plant^{-1}, however strong correlation of dry matter with total fruit yield plant^{-1} was due to weak indirect positive effect via average fruit weight and total chlorophyll content. Total chlorophyll showed a weak positive direct effect on total fruit yield plant^{-1}, however strong correlation of total chlorophyll content with total fruit yield plant^{-1} was due to strong indirect positive effect via fruit girth and average fruit weight.

The study of direct and indirect effects clearly indicated that average fruit weight and fruit length were the most important traits that influenced the dependant variable through direct effect. Path analysis revealed a residual variance of 0.16 indicating thereby that percent accounted for by the path analysis.

4.7 Estimation of genetic divergence

Analysis of variance for dispersion (Table-5) revealed that the genotypes tested expressed significant variability for all quantitative and quality characters. The 'V' statistics which is a Wilk's criterion was significant and its value was 0.005812. Genetic divergence was estimated for forty two genotypes of Bottle gourd.

Based on the performance of the genotypes, forty two genotypes (including checks) got grouped into 4 clusters (Table-6) as per Mahalanobis D^2 analysis employing Tocher's method (Rao, 1952). Cluster I comprised of maximum cultivars (29) followed by cluster II (9), cluster III (3) and cluster IV (1). Cluster I grouped Punjab Round, Local long green and NDBG round-2 whereas SKBG-12 got grouped in cluster II alongwith PSPL, NDBG-123, Pusa Naveen and PBOG-89. The single genotype Shalimar Improved got clubbed in cluster IV, whereas PBOG-7, ABGS-99 and Bhagirathi go grouped in cluster III .

The mean intra and inter cluster distance (D^2) value (Table-7) revealed that cluster III had the highest intra cluster distance (D^2) value of 167.00 followed by cluster I (96.92) and cluster II (95.64). The inter cluster distance (D^2) value was highest between cluster II and III (658.09) followed by cluster III and IV (475.36), cluster II and IV (414.76), cluster I and III (265.21). The minimum inter cluster distance was observed between cluster I and IV (255.75) and cluster I and II (227.84).

Cluster means for different traits (Table-8) revealed that the magnitude of differences among the mean of traits for different traits was significant. The range of variation in cluster means for days to first female flower was 42.00 in cluster IV to 55.33 in cluster III. Minimum mean of days to first fruit harvest was recorded in cluster IV (81.00) and maximum in cluster III (95.78). The range of variation in cluster means for number fruits plant^{-1} was 3.49 in cluster I to 5.89 in cluster II. Cluster mean for fruit length ranges from 26.21 in cluster III to 41.53 in cluster IV.

Table - 5: ANOVA for dispersion in various genotypes of Bottle gourd

Source of Variations	df	Mean Squares
Varieties	41	4.79**
Error	81	1.62
Total	122	5.47

****, Significant at 1% level of significance**

` **Wilk's Creiterion** = 0.005812

V statistics = 2880.00

Table-6: Distribution of different Bottle gourd genotypes into clusters based on D^2 statistics

Cluster	Number of genotypes in cluster	Name of the genotypes
I	29	NDBG – 622, Narendra rashmi, PBOG- 4, PBOG- 6, Narendra madhuri, NDBG – 140, NDBG- 5006, NDBG round- 2, NDBG – 133, NDBG - 613 – 4, NDBG – 619, F -G – 2, NDBG – 104, NDBG – 129, F - S – 10, F - S – 1, Thar samriddhi, Local long green, DBG – 5, JBOGL - 03 – 1, Punjab round, Guttka, DBG – 6, AJBG – 9, AJBG - 99 -1, VRBG – 2, PBOG – 92, DARL - 28
II	9	PSPL, PBOG- 8, NDBG – 123, SKBG – 12, NDBG – 601, Narendra dharidhar, Ajbg – 4002, Pusa Naveen, PBOG - 89
III	3	PBOG- 7, ABGS – 99, Bhagirathi
IV	1	Shalimar improved

Table-7: Average inter cluster (above diagonal) and intra cluster (diagonal) D^2 values among different Bottle gourd genotypes

Cluster	I	II	III	IV
I	**96.92**	227.84	265.21	255.75
II		**95.64**	658.09	414.76
III			**167.00**	475.36
IV				**0.000**

Table-8: Cluster means for morphological, maturity, yield and yield component traits in different clusters of Bottle gourd genotypes

Clusters	Days to first male flower	Days to first female flower	Node number at which first female flower appeared	Ratio of Female to male flower	Number of secondary branches plant^{-1}	Days to first fruit harvest	Number of fruits plant^{-1}	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (kg)	Total fruit yield plant^{-1} (kg)	Total chlorophyll content (%)	Dry matter content (%)
I	48.17	58.03	5.48	0.66	2.93	88.26	3.49	27.18	24.58	0.73	2.30	5.86	5.56
II	42.78	52.78	**5.74**	**0.70**	4.07	83.11	**5.89**	33.59	24.37	0.96	3.56	7.26	**8.37**
III	**55.33**	60.22	4.89	0.50	3.11	**95.78**	3.67	26.21	18.69	0.65	2.19	5.78	7.33
IV	42.00	**67.67**	3.33	0.45	**6.00**	81.00	4.00	**41.53**	**28.30**	**2.24**	**4.47**	**7.33**	8.00

Cluster mean of fruit girth ranges from 18.69 in cluster III to 28.30 in cluster IV. The range of variation in cluster means for average fruit weight was from 0.65 in cluster III to 2.24 in cluster IV. The cluster mean total fruit yield plant^{-1} ranges from 2.19 in cluster III to 4.47 in cluster IV. The mean total chlorophyll content ranges from 5.78 in cluster III to 7.33 in cluster IV. The mean dry matter content ranges from 5.56 in cluster I to 8.37 in cluster II.

The percent contribution of the traits towards total genetic divergence (Table-9) revealed that total fruit yield plant^{-1} was the main factor contributing towards divergence (47.96 percent) followed by number of fruits plant^{-1} (17.77 percent), days to first female flower (13.01 percent), days to first male flower (10.10 percent), average fruit weight (2.56 percent), number of secondary branches plant^{-1} (2.09 percent), fruit length (1.97 percent) and dry matter content (1.28 percent). The minimum contribution towards divergence was from ratio of female to male flower, fruit girth and total chlorophyll content (0.93 percent), node number at which first female flower appeared (0.35 percent) and days to first fruit harvest (0.12 percent).

Table-9: Percent contribution of individual traits towards total genetic divergence in Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]

Traits	Times Ranked 1st	Contribution %
Days to first male flower	87	**10.10%**
Days to first female flower	112	**13.01%**
Node number at which first female flower appeared	3	**0.35%**
Ratio of Female to male flower	8	**0.93%**
Number of secondary branches plant^{-1}	18	**2.09%**
Days to first fruit harvest	1	**0.12%**
Number of fruits plant^{-1}	153	**17.77%**
Fruit length (cm)	17	**1.97%**
Fruit girth (cm)	8	**0.93%**
Average fruit weight (kg)	22	**2.56%**
Total fruit yield plant^{-1} (kg)	413	**47.96%**
Total chlorophyll content (%)	8	**0.93%**
Dry matter content (%)	11	**1.28%**
Total	**861**	**100%**

Chapter - 5

DISCUSSION

For selection to be effective, genetic variability must be present in the breeding materials, thus, the success of a breeding programme depends, in part upon choosing breeding stocks that have sufficient genetic variability. The use of germplasm in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.] with a view to increase genetic variability and introduce new allelic resources in the gene repository is a key to increase productivity level of bottle gourd under temperate conditions of Kashmir valley which is a limiting factor as availability of good and sufficient quantity of fresh fruits as well dry fruits during winter months has been a problem as the valley has a typical temperate climate with long duration of winter season. Efforts are required to be made to develop/identify cultivars with high yield potential in order to increase the production of fruits. Classification of total variability into its heritable and non-heritable components such as, phenotypic and genotypic coefficients of variations, heritability estimates and expected genetic advance is of paramount importance in understanding the genetic makeup of any breeding material under improvement.

Variances arising due to differences among genotypes in the present investigation were highly significant for all the characters. This was in confirmation of the results reported by many workers (Burton, 1953; Prasad and Prasad 1979; Pal and vani 1988; Sharma and Dhankar 1990; Narayan *et al*., 1996; Pandit *et al*., 2009). Components of phenotypic variability estimated for all the traits indicated that wide range of variability existed for days to first male flower (57.00-40.33 days), days to first female flower (67.66-50.00 days), node number at which first female flower appeared (2.00-9.33), ratio of female to male flower (0.34-1.16), number of secondary branches (3.00-7.00), days to first fruit harvest (99.33-79.00 days), number

of fruits plant^{-1} (3.66-8.33), fruit length (15.53-41.53 cm), fruit girth (14.20-39.53 cm), average fruit weight (0.72-2.01 kg), total fruit yield plant^{-1} (2.91-8.22 kg), chlorophyll content (2.33-12.33 percent), dry matter content (3.00-15.33). A wide range of variations existing for various quantitative traits has also been reported in Bottle gourd by various workers (Prasad *et al*., 1993; Narayan *et al*., 1996; Singh *et al*., 2008 and Pandit *et al*., 2009). The studies suggest that it should be possible to isolate superior genotypes during the selection process.

The estimates of phenotypic variance were higher than the corresponding estimates of genotypic variance for all the traits, indicating thereby, the influence of environment in the expression of these traits. Since these estimates individually or solely do not provide means to assess the nature of genetic variability, phenotypic and genotypic coefficient of variation were also estimated. Highest coefficient of variation was recorded for total fruit yield plant^{-1} followed by number of secondary branches and average fruit weight.

The estimates of PCV followed the same trend suggesting thereby that the scope for improvement of these traits during selection could be based on phenotypic variability. Moderately high values of PCV and GCV have been reported in fruit length and fruit weight (Pandit *et al*., 2009).

The estimates of heritability are of considerable practical importance to the breeder as they help in the formation of an efficient and pragmatic programme. Heritability (broad sense) estimates are more informative as they indicate relative importance of genotypic and environmental contribution to the variability exhibited and the reliance that can be placed on phenotypic value during selection. The estimate of heritability for different characters ranged from 0.26 (node number at which first female flower appeared) to 0.96 (days to first male flower). The results are in general agreement with the findings of other workers (Panwar *et al*., 1977 and Sharma *et al*.,

1983) in Bottle gourd and (Reddy and Rao, 1984 and Kadam and Kale, 1985) in Ridge gourd and (Chaudhari *et al*., 1991) in Bitter gourd and (Krishna Prasad and Singh 1993) in Cucumber. The genetic advance being the function of heritability, selection intensity and phenotypic standard deduction, indicates the magnitude of improvement in the desired direction that can be expected in a particular character by selecting a certain portion of the population. In the present study high heritability was coupled with high genetic advance (as percent of mean) in total fruit yield plant^{-1}, number of secondary branches, dry matter content average fruit weight and number of fruits plant^{-1} whereas moderate values of genetic advance was exhibited by node number at which first female flower appeared, ratio of female to male flower, fruit length, fruit girth and chlorophyll content. Days to first fruit harvest had low value. Similar results were reported by several workers (Panwar *et al*., 1977). High genetic advance (as percent of mean) was also reported by (Reddy and Rao 1984) in fruit yield plant^{-1}, fruit weight and number of fruits plant^{-1}. The characters having high heritability failed to express high genetic advance (as percent of mean) as reported by (Sharma, 1983).

Improvement in all the traits excepting days to first fruit harvest, days to first female flower and days to first male flower can be made through selection in the existing germplasm material. For other traits hybridization followed by selection is expected to yield some good recombinants.

Progress of selection depends not only on the proportion of genetic variance that a breeder uses in determining the magnitude of heritability but the practical objective also includes assessment of nature and magnitude of interrelationship existing among characters of economic worth, and the once that contribute to their performance directly or indirectly. Indirect selection methods make it possible to select individuals that are likely to be superior and enable the breeder to eliminate the materials that will probably give poor yields (Gallais, 1984). However, characters

known to be associated with high yielding ability must be observable easily and rapidly (Peltonen- Sainio, 1990). Yield, as it is well known, is a complex trait and its performance is the result of interaction of several traits. Estimates of genotypic and phenotypic correlations among the characters have therefore, been found useful in planning and evaluating breeding programmes (Johnson *et al*., 1955; Aljibouri *et al*., 1958). Genotypic correlation coefficients provide a measure of the genetic association among characters and give an indication of characters that could be useful so as to identify more important ones for a particular selection programme. The practical utility of selection of a given character as a measure of improving another character depends on the extent to which they are related and this relation depends not only on the genotypic correlation but also on the phenotypic correlation and variances (phenotypic and genotypic) of characters included in the selection scheme. Correlation among total fruit yield plant^{-1} and other quantitative traits are important in Bottle gourd breeding programme because cultivars need to have good productivity in quantitative traits besides good quality.

The correlation coefficients, in the present investigation both at the phenotypic and genotypic levels, indicated that character association in general were more favourable for breeding high yielding cultivars in. The estimates of genotypic correlation coefficients were mostly found to be higher in magnitude, though similar in direction than their corresponding estimates of phenotypic correlation coefficients, and the findings were in general agreement with the earlier reports of (Narayan *et al*., 1996; Badade *et al*., 2001; Kumar *et al*., 2007; Yadav *et al*., 2007 and Pandit *et al*., 2009). Days to first fruit harvest showed significant and negative association with number of fruits plant^{-1} at genotypic as well as phenotypic levels and fruit girth, fruit length, average fruit weight, total fruit yield, chlorophyll content, dry matter content only at genotypic level. These yield contributing traits also showed positive interrelationship with each other. Total fruit yield plant^{-1} showed significant and

positive correlation with number of fruits plant^{-1}, fruit length, fruit girth, average fruit weight plant^{-1}, total chlorophyll content and dry matter content plant^{-1} at genotypic as well as phenotypic levels. Similar findings were reported by (Prasad *et al*., 1993) in Bottle gourd, of fruit yield plant^{-1}and with number of fruits plant^{-1}, average fruit weight and number of female flowers plant^{-1} were found to be significant and positive. Similar findings were reported by (Narayan *et al*., 1996; Badade *et al*., 2001; Kumar *et al*., 2007; Yadav *et al*., 2007 and Pandit *et al*., 2009) in Bottle gourd, (Doijode, 1984) in Pumpkin, Choudhary *et al*., 1987; Singh *et al*., 2002 and Rao *et al*., 2004) in Cucumber, (Dora *et al*., 2002) in Pointed gourd, (Choudhary *et al*., 2003) in Muskmelon, and (Rolonia *et al*., 2003) in Watermelon, and (Narankutty *et al*., 2006) in Snake gourd.

Total fruit yield plant^{-1} showed a significant negative correlation with days to first male flower at both levels and non- significant negative association with days to first female flower and node number at which first female flower appeared. Similar findings were reported by (Sharma and Dhankar, 1993) in days to first female flower.

Interrelationship among various quantitative traits and yield contributing traits was observed to be significant and positive both at genotypic and phenotypic level. The results clearly revealed a scope of simultaneous improvement of these traits selection.

The days to appearance of first female flower were significantly and negatively correlated with No. of secondary branches plant^{-1}, number of secondary branches plant^{-1}, dry matter content at both genotypic and phenotypic levels and for fruit girth and average fruit weight only at genotypic level. It was significantly and positively correlated with days to first fruit harvest at both genotypic as well as phenotypic levels. It was non-significantly and negatively correlated with node number at which first female flower appeared, ratio of female to male flower, total

fruit yield plant^{-1}, total chlorophyll content at both genotypic as well as phenotypic levels and for fruit girth, average fruit weight only at phenotypic level. It was non-significantly and positively correlated with fruit length at both genotypic as well as phenotypic levels. Number of secondary branches plant^{-1} showed significant and positive correlation with average fruit weight plant^{-1}, fruit length, number fruits plant^{-1} at only genotypic level, and for chlorophyll content, dry matter content at both genotypic as well as phenotypic levels. It showed significant negative association with days to first fruit harvest at only genotypic level. It showed non-significant and negative correlation with days to first fruit harvest, fruit girth only at phenotypic level. It showed non-significant and positive correlation with total fruit yield plant^{-1} at both levels genotypic as well as phenotypic levels, for fruit girth only at genotypic level, for number of fruits plant^{-1}, fruit length, and average fruit weight only at phenotypic level. Days to first fruit harvest showed significant and negative association with number of fruits plant^{-1} at genotypic as well as phenotypic levels and fruit girth, fruit length, average fruit weight, total fruit yield, chlorophyll content, dry matter content only at genotypic level. It showed non-significant negative correlation with fruit girth, fruit length, average fruit weight, total fruit yield, chlorophyll content and dry matter content only at phenotypic level. Number of fruits plant^{-1} showed significant and positive correlation with total fruit yield, chlorophyll content and dry matter content at genotypic as well as phenotypic levels and for fruit girth, average fruit weight only at genotypic level and for fruit length only at phenotypic level. It showed non-significant positive correlation with average fruit weight, fruit girth only at phenotypic level and for fruit length only at genotypic level. Fruit length showed non-significant negative correlation with fruit girth only at genotypic level. It also showed non-significant positive correlation with fruit girth and chlorophyll content at phenotypic level and for average fruit weight plant^{-1} at genotypic level and for dry matter content at genotypic as well as phenotypic levels. It showed significant

positive correlation with total fruit yield plant^{-1} at genotypic as well as phenotypic levels and for average fruit weight at only phenotypic level and for chlorophyll content only at genotypic levels. Fruit girth showed significant positive correlation with average fruit weight plant^{-1} and total fruit yield plant^{-1} at genotypic as well as phenotypic levels. It also showed non-significant positive correlation with chlorophyll content and dry matter content plant^{-1} at genotypic as well as phenotypic levels. Average fruit weight plant^{-1} showed significant positive correlation with total fruit yield plant^{-1} at genotypic as well as phenotypic levels and for chlorophyll content and dry matter content plant^{-1} only at genotypic level. It showed non-significant positive correlation with chlorophyll content and dry matter content plant^{-1} only at phenotypic level. Similar findings were reported by (Narayan *et al*., 1996; Badade *et al*., 2001; Kumar *et al*., 2007; Yadav *et al*., 2007 and Pandit *et al*., 2009) in Bottle gourd, (Doijode 1984) in Pumpkin, Choudhary *et al*., 1987; Singh *et al*., 2002 and Rao *et al*., 2004) in Cucumber, (Dora *et al*., 2002) in Pointed gourd, (Choudhary *et al*., 2003) in Muskmelon, and (Rolonia *et al*., 2003) in Watermelon, and (Narankutty *et al*., 2006) in Snake gourd.

Degree of relationship through the estimate of correlation simply measures the nature of symmetrical association between various traits. However, it does not provide adequate information concerning the magnitude of direction and contribution a particular trait makes to the ultimate economic product. In order to determine an efficient criterion for selection of various quantitative traits to improve the yield performance, it is essential to know the direct and indirect contribution of the traits towards this improvement through the study of cause and effect relationship. Recourse was taken to formulate this causal scheme in present investigation to generate information on the direct and indirect effect of different traits on yield. The application of path coefficient analysis was preceded by the formulation of the causal

scheme based on the a priori knowledge of the causal relations among the various independent and dependent variables.

Accordingly days to first male flower, days to first female flower, node number at which first female flower appeared, ratio of female to male flower, number of secondary branches plant^{-1}, days to first fruit harvest, number of fruits plant^{-1}, fruit length, fruit girth, average fruit weight, total chlorophyll content, and total dry matter content were taken as independent variables and their contribution towards total fruit yield plant^{-1} (dependant trait) was determined.

Average fruit weight recorded highest positive direct effect on total fruit yield plant^{-1} followed by fruit length, dry matter content and days to first male flower. Total chlorophyll content, fruit girth and ratio of female to male flower revealed weak positive effect. Highly significant and positive genotypic correlation of number of fruits plant^{-1} with total fruit yield plant was observed mainly due to indirect effect of this trait via average fruit weight (0.3357), total chlorophyll content (0.2662). Significant genotypic correlation of fruit girth with dependant variable, at genotypic level was observed to be mainly due to strong positive indirect effect via average fruit weight (0.2684) and total chlorophyll content (0.0720). Average fruit weight exhibited a strong positive direct effect on total fruit yield plant^{-1}. However, the highly significant negative correlation of this trait with total fruit yield plant^{-1} was supported by strong indirect negative effect via number of secondary branches plant^{-1}. Dry matter showed a strong direct effect on total fruit yield plant^{-1}, however strong correlation of dry matter with total fruit yield plant^{-1} was due to weak indirect positive effect via average fruit weight and total chlorophyll content. Total chlorophyll showed a weak positive direct effect on total fruit yield plant^{-1}, however strong correlation of total chlorophyll content with total fruit yield plant^{-1} was due to strong indirect positive effect via fruit girth and average fruit weight. The study of direct and indirect effects clearly indicated that average fruit weight and fruit length

were the most important traits that influenced the dependant variable through direct effect. Path analysis revealed a residual variance of 0.16 indicating thereby that percent accounted for by the path analysis. Similar effect have also been reported for Average fruit weight (kg), fruit length (cm) and various traits by (Narayan *et al*., 1996; Badade *et al*., 2001; Kumar *et al*., 2007; Yadav *et al*., 2007 and Pandit *et al*., 2009) in Bottle gourd, (Doijode 1984) in Pumpkin, Choudhary *et al*., 1987; Singh *et al*., 2002 and Rao *et al*., 2004) in Cucumber, (Dora *et al*., 2002) in Pointed gourd, (Choudhary *et al*., 2003) in Muskmelon, and (Rolonia *et al*., 2003) in Watermelon, and (Narankutty *et al*., 2006) in Snake gourd.

Genetic diversity, an important parameter to identify the genotype for hybridization involving genetically diverse parents is known to provide an opportunity for bringing together gene constellation yielding desirable transgressive segregates in advanced generations. However, postulation of a rational criterion for identification of such parents is still a line problem in plant breeding. To consider geographic diversity among parents an index of genetic diversity has been equally acclaimed in numerous published reports.

On the other hand, Murthy and Arunachalam (1965) hypothesied that Mahalanobis (1928) generalized distance, a measure of metric distance between population centroids, could be a very useful multivariate statistical tool for effective discrimination among parents on the basis of genetic diversity. Precise information about genetic divergence is critical for a productive breeding programme, as genetically diverse parents are known to produce high heterotic effects increasing consequently yield desirable segregants.

High yielding parents with greater genetic diversity are required to develop productive hybrids. For identifying genetically diverse parents for hybridization,

multivariate analysis (Mahalanobis; D^2 statistics, 1936) has been used in almost all crop species. However such information is limited in Bottle gourd.

The D^2 statistic gives a result based on the magnitude of divergence dependent on the sample size. This technique has been extensively used by numerous workers in classificatory problems (Rao, 1952) in understanding the nature of genetic divergence and for selecting diverse parents for successful hybridization in out breeding population, such as self incompatible Brassica, (Murty and Arunachalam, 1965, 1966) and in self pollinated crops, such as Linseed (Anand and Murty, 1968), Wheat (Jatasra and Paroda, 1978).

Genetic diversity in biological populations has been found to occur due to several causes. Human selection has led to quite a big array of varieties grown for the same end product and thus, effected their diversity, whereas stress conditions, natural selection and genetic drift maintained divergence. (Ram and Panwar, 1970; Das and Borthakur, 1973).

Studies in number of crop species with different breeding systems by means of D^2 statistic suggested that genetic diversity need not be directly related to geographic diversity (Murty and Arunachalam, 1965). Experimental evidences in Drosophila (Brunic, 1954; Wallse, 1955) have demonstrated that crosses of strains of diverse origin exhibited greater heterotic response than crosses of strains of same origin.

In present study 42 genotypes were evaluated to estimate the diversity as per Mahalanobis D^2 statistics. Analysis of variance for dispersion revealed that the genotypes tested expressed significant variability for all quantitative and quality characters. The 'V' statistics which is a Wilk's criterion was significant and its value was 0.005812. Genetic divergence was estimated for forty two genotypes of Bottle gourd.

Based on the performance of the genotypes, forty two genotypes (including checks) got grouped into 4 clusters as per Mahalanobis D^2 analysis employing Tocher's method (Rao, 1952). Cluster I comprised of maximum cultivars (29) followed by cluster II (9), cluster III (3) and cluster IV (1). Cluster I grouped Punjab Round, Local long green and NDBG round-2 whereas SKBG-12 got grouped in cluster II along with PSPL, NDBG-123, Pusa Naveen and PBOG-89. The single genotype Shalimar Improved got clubbed in cluster IV, whereas PBOG-7, ABGS-99 and Bhagirathi go grouped in cluster III. Clustering of genotypes into different groups through D^2 statistics has also been reported by Badade *et al*., 2001 in Bottle gourd. It also quoted that there were factors responsible for genetic divergence which may be useful for heterosis breeding Bottle gourd.

The pattern of group constellations proved that geographical diversity was not an essential factor to group the genotypes from a particular source or origin into one particular cluster. This means that geographic diversity, though important, was not only factor in determining the genetic divergence (Yadav *et al*., 2001 and Veerabadhiran and Kennedy, 2002). The clustering of genotypes from different eco-geographic locations into one cluster could be attributed to the exchange of breeding materials from one place to another, this may also be due to the fact that the unidirectional selection practised for a particular trait at several places produced similar phenotypes which were aggregated in one cluster irrespective of their distant geographic origin. On the other hand, many genotypes originating from one place were scattered over different clusters. Such genetic diversity among the genotypes of common geographic origin could be attributed to factors like heterogeneity, genetic architecture of populations, past history of selection, developmental traits and degree of general combining ability (Murty and Arunachalam, 1966). The mean intra and inter cluster distance (D^2) value revealed that cluster III had the highest intra cluster distance (D^2) value of 167.00 followed by cluster I (96.92) and cluster II (95.64). The

inter cluster distance (D^2) value was highest between cluster II and III (658.09) followed by cluster III and IV (475.36), cluster II and IV (414.76), cluster I and III (265.21). The minimum inter cluster distance was observed between cluster I and IV (255.75) and cluster I and II (227.84). (Singh and Lal, 2002) also reported similar type of finding in Muskmelon. The result clearly indicate that tremendous potential exist for introgressing the allelic resources present in these genotypes through a systematic breeding and selection approach so as to recover high yielding quality recombinants.

Cluster means for different traits revealed that the magnitude of differences among the mean of traits for different traits was significant. The range of variation in cluster means for days to first female flower was 42.00 in cluster IV to 55.33 in cluster III. Minimum mean of days to first fruit harvest was recorded in cluster IV (81.00) and maximum in cluster III (95.78). The range of variation in cluster means for number fruits plant^{-1} was 3.49 in cluster I to 5.89 in cluster II. Cluster mean for fruit length ranges from 26.21 in cluster III to 41.53 in cluster IV. Cluster mean of fruit girth ranges from 18.69 in cluster III to 28.30 in cluster IV. The range of variation in cluster means for average fruit weight was from 0.65 in cluster III to 2.24 in cluster IV. The cluster mean total fruit yield plant^{-1} ranges from 2.19 in cluster III to 4.47 in cluster IV. The mean total chlorophyll content ranges from 5.78 in cluster III to 7.33 in cluster IV. The mean dry matter content ranges from 5.56 in cluster I to 8.37 in cluster II. The results clearly indicate that cluster means of different clusters identify the characters to be chosen for hybridization.

The percent contribution of the traits towards total genetic divergence revealed that total fruit yield plant^{-1} was the main factor contributing towards divergence (47.96 percent) followed by number of fruits plant^{-1} (17.77 percent), days to first female flower (13.01 percent), days to first male flower (10.10 percent), average fruit weight (2.56 percent), number of secondary branches plant^{-1} (2.09

percent), fruit length (1.97 percent) and dry matter content (1.28 percent). The minimum contribution towards divergence was from ratio of female to male flower, fruit girth and total chlorophyll content (0.93 percent), node number at which first female flower appeared (0.35 percent) and days to first fruit harvest (0.12 percent). De *et al*., (1988) proposed that traits contributing maximum towards the D^2 value need to be given greater emphasis for deciding on the clusters to be chosen for the purpose of further selection and parents for hybridization.

Based on the findings of present investigation the following conclusion could be drawn:

I. The material selected possessed vide range of variability for all the characters as indicated by magnitude of *per se* performance, phenotypic and genotypic coefficients of variations.

II. High heritability with high genetic advance revealed that traits contributing to total fruit yield plant^{-1} could be need fully utilized for improvement of yield.

III. Average fruit yield plant^{-1} and number of fruits plant^{-1} are important traits and due emphasis should be given to these while selecting for higher total yield plant^{-1}.

IV. Clustering pattern indicated that geographical diversity need not necessarily be related to genetic diversity. Crosses between genotypes belonging to cluster IV and cluster II are likely to exhibit heterosis. Shalimar Improved can be used as one of parents in future improvement programmers.

Chapter - 6

SUMMARY AND CONCLUSION

The present investigation "Variability and Divergence in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]'' was undertaken to elicit information on genetic variability, heritability and to predict the gains realized through selection, character association, cause and effect relationship and divergence in 42 Bottle gourd genotypes including 2 checks (SKBG-12 and Shalimar Improved). The experiment was carried out with 3 replications at the Randomized Block Design with 3 replications at the experimental farm of the Division of Vegetable Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar. The observations were recorded for 13 characters viz., days to first male flower, days to first female flower, node number at which first female flower appeared, ratio of female to male flower, number of secondary branches plant^{-1}, days to first fruit harvest, number of fruits plant^{-1}, fruit length (cm), fruit girth (cm), average fruit weight (kg), total fruit yield plant^{-1} (kg), total chlorophyll content (%) and total dry matter content (%). Data was subjected to various statistical and biometrical analysis and results obtained are summarized in present chapter.

Wide spectrum of variability was observed for all the quantitative and quality traits. All the traits except days to first fruit harvest and days to first female flower exhibited low phenotypic and genotypic coefficient of variation with the former being higher in magnitude than the latter. The range for phenotypic coefficient of variation is (6.34-61.64), the range for genotypic coefficient of variation is (3.92-50.92). Days to first fruit harvest exhibited low phenotypic and genotypic coefficient of variation (6.34-3.92).

Heritability estimates (broad sense) coupled with high estimates from expected genetic gain (as percent of mean) were observed for total fruit yield plant^{-1}

followed by days to first flower, days to first female flower, total dry matter content, number of secondary branches plant^{-1}, average fruit weight (kg) and number of fruits plant^{-1}.

Genotypic correlation coefficient were comparatively higher in magnitude through similar in direction than their corresponding phenotypic correlation coefficient for most of the traits. Total fruit yield plant^{-1} showed significant and positive correlation with number of fruits plant^{-1}, fruit length, fruit girth, average fruit weight plant^{-1}, total chlorophyll content and dry matter content plant^{-1}. It has a significant negative correlation with days to first male flower. Interrelationship among various quantitative and yield contributing traits was also observed to be significant and positive overall. Dry matter content showed significant negative correlation with days to first male flower, days to first female flower and days to first fruit harvest.

Path coefficient analysis of total fruit yield plant^{-1} at the genotypic level revealed that average fruit weight, fruit length and dry matter yield were the main component that directly influenced the total fruit yield plant^{-1}. Significant and negative correlation of total fruit yield plant^{-1} with total chlorophyll content was mainly via days to first fruit harvest. The estimates of residual variability demonstrate that most of the traits have been considered in the evaluation of selective potential of present material.

D^2 statistics grouped all the genotypes into 4 clusters. Cluster I had the maximum number of genotypes (29) followed by cluster II (9), cluster III (3) and cluster IV (1). In general the clustering pattern indicating that no parallelism existed between geographical location and divergence.

Average inter-cluster D^2 values were maximum between cluster II and III (658.06) followed by cluster III and IV (475.36) and cluster II and IV (414.76).

Maximum intra cluster distance was observed in cluster III (167.00) followed by cluster I (96.92) and cluster II (95.64). Cluster means for different traits exhibited substantial variability. Genotypes that showed earliness were grouped in cluster II, these genotypes also exhibited highest cluster means for days to first fruit harvest, fruit length and fruit girth. Highest cluster mean for yield characters were observed by genotypes grouped in cluster IV. For quality traits the highest cluster means were observed by cluster IV (chlorophyll content) and cluster II (dry matter content).

Component analysis of the phenotypic divergence among the materials revealed that percent divergence was contributed by traits like total fruit yield plant^{-1}, number of fruits plant^{-1}, average fruit weight and fruit length.

Based on the findings of the present investigation the conclusion drawn for further improvement of Bottle gourd genotypes for cultivation in Kashmir valley is that genotypes SKBG-12, Pusa Naveen, NDBG-123 and PSPL (cluster II) and genotype Shalimar Improved (cluster IV) show a lot of genetic diversity, so crosses between these genotypes are likely to produce new recombinants with desired traits.

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Appendix – 1

List of gerplasm lines of Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]

S. No.	**Genotype**	**Source**
1.	AJBG – 9	Ambajogai, Rahuri
2.	AJBG – 99 – 1	--do--
3.	AJBG – 4002	--do--
4.	ABGS – 99	--do--
5.	DARL - 28	DARL, Pithoragarh
6.	DBG – 5	UAS, Dharwad
7.	DBG – 6	--do--
8.	Bhagirathi	PAU, Ludhiana
9.	Guttka	--do--
10.	Punjab Round	--do--
11.	NDBG – 123	NDUAT, Faizabad
12.	NDBG – 140	--do--
13.	NDBG – 601	--do--
14.	NDBG – 622	--do--
15.	NDBG – 5006	--do--
16.	NDBG – 619	--do--
17.	NDBG – 613 –4	--do--
18.	NDBG –133	--do--
19.	NDBG – 104	--do--
20.	NDBG – 129	--do--
21.	NDBG – Round – 2	--do--
22.	F – S – 1	--do--
23.	F – G – 2	--do--

24.	F – S – 10	--do--
25.	Narendra Rashmi	--do--
26.	Narendra Madhuri	--do--
27.	Narendra Dharidhar	--do--
28.	Pusa Naveen	IARI, New Delhi
29.	Pusa Summer Prolific Long	--do--
30.	PBOG – 4	GBPUAT, Pant Nagar
31.	PBOG – 7	--do--
32.	PBOG - 6	--do--
33.	PBOG – 8	--do--
34.	PBOG – 89	--do--
35.	PBOG – 92	--do--
36.	Thar Samriddhi	JAU, Gujarat
37.	JBOGL – 03 – 1	--do--
38.	JBG – 50	--do--
39.	VRBG – 2	IIVR, Varanasi
40.	Local Long Green	SKUAST – K, Srinagar
41.	Shalimar Improved	--do--
42.	SKBG – 12	--do--

Appendix – 2

Mean performance of various genotypes in Bottle gourd

S No.	Genotype	Days to first male flower	Days to first female flower	Node number of first female flower	Ratio of female to male flower	Number of secondary branches	Days to first fruit harvest	Number of fruits plant^{-1}	Fruit length (cm)	Fruit girth (cm)	Average fruit weight	Total fruit yield plant^{-1}	Chlor-ophyll content (%)	Dry matter content (%)
1.	PBOG – 4	51.66	61.33	4.66	0.44	3.33	91.33	2.33	34.00	20.66	1.13	2.81	7.33	3.33
2.	PBOG – 7	54.00	65.00	3.00	0.44	3.00	94.33	4.66	32.66	17.93	1.16	2.93	6.66	8.33
3.	PSPL	42.66	52.66	5.33	0.55	4.00	83.00	7.33	34.80	20.83	1.25	4.22	9.66	9.00
4.	PBOG - 6	49.33	60.00	4.66	0.55	3.33	89.33	4.33	29.66	25.03	0.74	3.00	7.00	8.00
5.	PBOG – 8	40.33	50.00	8.00	0.73	3.33	80.66	3.33	29.66	23.20	0.72	3.13	6.66	9.00
6.	NDBG – 123	42.66	54.00	6.00	0.71	5.00	83.33	6.33	35.86	26.30	0.84	5.02	9.33	11.33
7.	SKBG – 12	43.33	54.66	5.66	1.13	4.00	83.66	8.00	37.90	28.96	1.59	8.22	12.3	15.33
8.	NDBG – 140	50.33	60.33	4.33	0.63	3.66	90.33	3.33	32.50	27.33	0.85	3.77	4.33	4.00
9.	Narendra Madhuri	44.66	55.33	6.66	0.83	3.56	85.00	4.00	18.56	39.53	1.34	6.91	7.33	8.00
10.	NDBG – 601	43.33	54.00	9.33	1.03	3.33	83.33	2.33	33.50	23.10	0.85	3.61	8.00	6.00
11.	NDBG – 622	48.33	57.33	8.33	0.81	3.33	88.66	1.66	27.46	18.30	0.88	3.29	5.66	6.33
12.	Narendra Rashmi	47.66	58.66	6.66	0.99	3.33	88.00	2.00	24.36	20.26	0.81	3.19	6.00	7.33
13.	NDBG – 5006	51.33	61.33	7.00	0.82	3.42	91.00	2.66	40.86	21.40	0.61	3.08	5.00	4.00
14.	NDBG – Round – 2	46.66	56.00	4.66	1.16	3.50	87.66	5.33	15.53	26.30	1.07	2.68	5.33	6.00
15.	Narendra 133	48.66	58.66	6.00	0.56	3.33	89.66	2.66	40.66	31.23	1.29	4.38	4.33	3.00
16.	NDBG – 613 – 4	52.66	63.33	8.33	0.81	3.33	93.33	3.66	26.63	17.46	0.61	2.69	6.33	5.33
17.	NDBG – 619	52.33	63.00	5.33	0.48	3.66	92.66	2.33	38.16	23.33	0.55	2.84	4.66	6.33
18.	F – G – 2	50.33	59.66	6.66	0.87	3.14	90.00	2.00	24.06	30.60	0.70	2.79	6.00	3.00
19.	NDBG – 104	52.33	61.66	4.00	0.36	3.48	92.66	4.00	27.56	26.56	0.57	2.64	3.33	4.66
20.	NDBG – 129	48.00	58.66	4.33	0.46	3.66	89.66	2.66	26.60	22.76	0.82	3.72	6.66	6.33

21.	F – S – 10	52.33	61.00	8.00	0.72	3.89	92.00	4.33	23.33	16.96	0.48	2.85	4.33	3.00
22.	F – S – 1	45.66	55.00	4.66	0.39	4.33	86.33	3.33	16.66	14.20	0.53	2.65	6.66	4.66
23.	Narendra Dharidhar	41.33	53.00	5.33	0.60	3.66	82.33	6.00	31.63	24.33	0.85	2.69	4.00	7.33
24.	Thar Samriddhi	48.68	54.00	6.33	0.80	3.33	89.33	4.00	18.70	30.76	0.64	2.62	4.00	6.33
25.	Local Long Green	45.33	56.33	7.00	0.66	5.66	86.66	6.66	33.26	18.96	0.70	2.64	8.66	9.00
26.	AJBG – 4002	42.00	53.00	4.66	0.60	7.00	82.00	6.66	37.03	24.40	0.55	4.91	5.33	6.66
27.	ABGS – 99	57.00	52.33	5.00	0.59	6.00	98.33	3.66	26.53	22.66	0.75	4.56	4.33	8.00
28.	Shalimar Improved	42.00	67.33	3.33	0.45	6.00	81.00	4.00	41.53	28.30	1.23	4.47	7.33	8.00
29.	Pusa Naveen	45.33	51.33	3.00	0.34	5.00	85.33	8.33	29.40	25.33	2.01	6.77	7.00	7.33
30.	DBG – 5	48.00	55.33	6.33	0.50	3.58	89.00	4.33	25.56	31.03	1.45	3.39	6.00	5.00
31.	JBOGL – 03 –1	44.00	59.00	5.00	0.67	3.79	85.66	5.33	34.73	30.26	0.85	2.97	6.33	3.66
32.	Punjab Round	43.33	55.00	6.00	0.66	6.00	82.33	2.33	30.53	29.06	0.64	3.61	8.00	5.33
33.	Guttka	49.66	53.00	3.33	0.53	3.66	79.00	5.00	24.13	27.96	0.49	3.70	4.66	7.00
34.	PBOG – 89	44.00	52.33	4.33	0.60	3.33	84.33	4.66	32.53	22.86	0.64	2.65	3.00	3.33
35.	DBG – 6	45.00	59.33	4.66	0.58	3.66	85.66	2.33	23.06	19.16	0.49	2.69	2.66	6.66
36.	AJBG – 9	45.66	55.00	3.78	0.43	6.00	87.33	3.33	22.00	25.76	0.39	2.69	8.66	8.00
37.	AJBG – 99 – 1	46.66	56.66	4.33	0.56	6.66	87.66	2.33	19.50	19.56	0.82	2.66	8.66	4.00
38.	Bhagirathi	55.00	63.33	4.66	0.46	3.79	94.66	2.66	19.43	15.46	0.75	2.67	6.33	5.66
39.	VRBG – 2	43.66	55.00	4.66	0.46	4.00	84.00	2.33	29.66	19.86	1.18	4.76	2.33	4.00
40.	PBOG – 92	49.33	58.33	5.00	0.77	4.00	89.33	4.33	35.23	28.63	0.71	2.64	7.00	7.66
41.	JBG – 50	46.66	56.66	6.33	0.78	3.94	87.66	3.00	22.50	27.06	0.49	2.69	5.66	4.33
42.	DARL - 28	48.66	58.00	3.66	0.93	3.68	88.33	6.33	22.56	22.60	0.67	4.82	7.00	7.00
Mean		47.38	57.29	5.44	0.65	3.86	87.52	4.03	28.82	24.20	0.78	2.61	6.19	6.34
S.E.D±		0.46	0.49	1.18	0.13	0.78	2.51	0.87	3.75	3.12	0.16	0.30	1.06	0.96

Certificate

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This is to certify that all the modifications/corrections as suggested by External Examiner(s) during evaluation and viva-voce examination in the manuscript entitled, **"Variability and Divergence studies in Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]" submitted by Ms. Vaidya Aashish Vivek (Regd. No. 2010-A-848-M)** have been taken care of before final binding of the same.

Dr. Kouser Parveen Wani
Major Advisor