GENETIC VARIABILITY STUDIES IN BITTER GOURD (*Momordica charantia* L.)

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By

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CERTIFICATE

This is to certify that the thesis entitled **"GENETIC VARIABILITY STUDIES IN BITTER GOURD (*Momordica charantia* L.)"** *submitted by* **Miss. M. SANGEETA KUTTY,** *for the degree of* **MASTER OF SCIENCE (AGRICULTURE)** *in* **HORTICULTURE,** *of the University of Agricultural Sciences, Dharwad is a record of research work done by her during the period of her study in this university under my guidance and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.*

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Introduction

I. INTRODUDTION

Bitter gourd (*Momordica charantia* L.) is an important commercial cucurbit belonging to the family cucurbitaceae, genus *Momordica*. It is a large genus with many species of annual or perennial climbers of which *Momordica charantia* L. is widely cultivated. The crop is highly cross pollinated due to monoecy. Its native home is tropical Asia particularly East India and South China i.e., Indo Burman centre of origin. Bitter gourd is widely distributed in China, Malaysia, India, tropical Africa and North and South America. The green fruits are superior with regard to nutritive value and can very well be compared with any other vegetable. The fruits contain 2.1 g of protein, 1.8 mg of iron, 20 mg of calcium, 88 mg of vitamin C, 55 mg of phosphorus and 210 I. U. of vitamin A in 100 g of edible portion. The immature fruits are boiled, curried, stuffed or sliced and fried, before consumption. The fruits are also pickled, canned and dehydrated. Numerous medicinal properties of nearly all parts of the plant have been reported. The fruits are used as tonic, purgative, stomachiac carminative, antihelminthic anti-inflammatory, febrifuge, vulnerary, stimulant, thermogenic, antidiabetic etc. (Longman, 1995). During the past decade the antidiabetic properties of the crop have been studied extensively and a hypoglycemic principle called Charantin has been

isolated. The bitter principle in bitter gourd is mormodicine an alkaloid which is different from cucurbitacins present in other genera of cucurbits.

The crop is extensively grown in China, Japan, South East Asia, tropical Africa and South America. In India, Karnataka, Maharashtra, Tamil Nadu and Kerala are the major bitter gourd growing states. The crop is cultivated over an area of 1075 hectares in Karnataka with a production of 7943 tonnes and productivity of 7.36 tonnes per hectare. In Dharwad district the crop occupies an area of 5 hectares with a production of 25 tonnes and productivity of 5 tonnes per hectare (Anon., 2000).

Inspite of the potential economic and medicinal importance of the crop due attention was not given towards a need based crop improvement programme. However, recently the cultivation of bitter gourd has become increasingly popular, because of the growing awareness of the antidiabetic property and nutritive value of the crop among consumers. Due to the efforts of many vegetable breeders marked improvement in yield has been achieved and a good number of new varieties and hybrids have been developed.

Nevertheless, there is a long way to go with bitter gourd improvement work especially to get resistant sources for pest and disease. Therefore, the improvement work should be focused on

selection of genotypes for better yield, superior quality and resistance to biotic stresses.

Selection is an intrinsic part of all vegetable crop improvement programmes and it is as old as cultivation itself. For the effective selection information on the nature and magnitude of variation available in the material with regard to component characters contributing to yield and the part played by the environment in the expression of these plant characters is essential. In selecting a plant or a type one should be reasonably sure of the superiority of the selection being inherited by the progenies. This is because a sizable part of the phenotypic variation is caused by environmental factors. The biometrical methods applied in crop improvement programmes provide means of evaluating the phenotypic expression of characters in terms of their genotypic worth.

The genetic parameters such as genotypic coefficient of variation, heritability and genetic advance enable selection on a sound genetic basis. Selection helps in improving the yield. However, selection based on yield alone is often misleading because it is one of the most complex characters being dependent on its components for its full expression. For rational improvement of yield and its components, association of component characters with

yield and among the components themselves should be found out by estimating the correlation coefficients.

Association of characters determined by correlation coefficients, although useful will not provide an exact picture of the relative importance of direct and indirect influence of each of the characters towards yield. Path coefficient analysis has been employed in many vegetables in order to overcome the unreliability of correlation coefficients. This technique involves effective partitioning of the correlation coefficients into measures of direct and indirect effects on yield. Besides these, a knowledge of the genetic diversity among the genotypes is essential. Selection of genetically divergent varieties is important for exploitation of heterosis and in the development of transgressive segregrants for an efficient breeding programme.

Occurrence of fruit fly and downy mildew are a major constraint in bitter gourd cultivation. Screening of the available genotypes for their resistance to fruit fly and downy mildew is therefore very essential to locate resistant types. These resistant genotypes can be further exploited for developing pest and disease resistant varieties.

Information on the genetic variability, character association, path coefficient analysis, genetic divergence and pest and disease

resistant sources is inadequate in bitter gourd. Hence, the evaluation of available germplasm in this regard is highly necessary. Moreover, there is an imperative need for developing varieties suited to the agro-climatic conditions of Karnataka. The study was therefore undertaken utilizing the considerable amount of variability observed in bitter gourd in India.

The principle objectives of the present investigation are,

1. To study the extent of genetic variability available for different characters in bitter gourd genotypes.
2. To study the correlation and path coefficient among different characters in the genotypes.
3. To study the genetic divergence in bitter gourd genotypes
4. To screen the bitter gourd genotypes against fruit fly infestation and downy mildew incidence.
5. To identify genotypes which are superior for yield and other economic characters.

Review of Literature

II. REVIEW OF LITERATURE

Bitter gourd is one of the important cucurbitaceous vegetables grown in our country. Of late the crop has gained significance with respect to area, production, medicinal value and its contribution to human nutrition. The main aim of vegetable breeder is the improvement of both quantitative and qualitative characters of the plant. In order to achieve this it is essential to understand the genetic architecture of the various important characters and inter relationship among them. In the present investigation an attempt has been made to study genetic variability, heritability, genetic advance, character association, path coefficient analysis, genetic divergence and source of resistance for pest and disease. The available literature pertaining to the investigation is reviewed under the following heads.

2.1 Genetic variability, heritability and genetic advance

2.2 Character association

2.3 Path coefficient analysis

2.4 Genetic divergence

2.5 Source of resistance for pest and disease

2.1 GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

2.1.1 Genetic variability

Planning and execution of vegetable breeding programme for the improvement of quantitative attributes depends to a great extent upon the magnitude of genetic variability present in the crop. The genetic and environmental components of variation were discussed in the early part of the century by Johannsen (1909) who attributed the variation in a segregating population to both heritable and non heritable factors and the variation in a pureline to only environmental factors. Nelson and Ehle (1909) and East (1916) later confirmed Johannsen's work and showed that continuous variation also confirmed to Mendelian genetics. The genetic variance was further subdivided into three sub-components by Fisher (1918), as variance due to additive effects of genes due to dominance deviation from additive scheme attributable to inter allelic interaction. Based on the study on non segregating populations Charles and Smith (1939), Powers (1942), separated genetic variance from total variance using estimates of environmental variance.

The existence of high variability with respect to all the vegetative, productive and quality characters were observed by many workers. Srivastava and Srivastava (1976) obtained maximum

GCV for number of fruits per plant (37.45) and minimum for number of male flowers per plant (11.47) in ten lines of bitter gourd. In sponge gourd wide variability for most of the yield attributing characters was observed by Panwar *et al.* (1977). Similar observations were reported by Singh *et al.* (1977) in bitter gourd. Ramachandran and Gopalakrishnan (1979) and Mangal *et al.* (1981) reported, highest GCV and PCV for yield per plant in bitter gourd. In ridge gourd highly significant differences for almost all characters except vine length was recorded by Kadam and Kale (1987). Highest PCV and GCV was recorded for fruits per vine by Sahni *et al.* (1987) in ridge gourd. Similar results were obtained by Singh *et al.* (1987) in pointed gourd and Chaudhari *et al.* (1991) in bitter gourd.

In ridge gourd high PCV and GCV for node number of first female flower, female flowers per plant, sex ratio on whole plant, fruits per plant, fruit weight, seeds per fruit and yield per plant was noticed by Varalakshmi *et al.* (1995). Whereas, in bitter gourd wide range of phenotypic variability was recorded for yield per plant, vine length, leaf area per vine, fruit weight and fruits per vine by Rajput *et al.* (1996).

Singh *et al.* (1996) recorded highest PCV and GCV for node number of first female flower and lowest for days to first picking in

bottle gourd genotypes. Wide range of variability for all characters under study has also been reported by Hawalader *et al.* (1999) in bitter gourd and Sarnaik *et al.* (1999) in ivy gourd. Bisognin and Storck (2000) found significant estimates for genetic variance of large fruit diameter and neck diameter in bottle gourd genotypes.

In pumpkin high estimates of both PCV and GCV were obtained for yield and number of fruits per plant by Mohanty and Mishra (1999) and Mohanty (2000).

2.1.2 Heritability

In crop improvement the genetic component of variation is important since only this component is transmitted to the next generation. The ratio of genotypic variance to total variance (phenotypic variance) is known as heritability. It denotes the proportion of phenotypic variance that is due to genotype i.e., heritable. The heritability thus estimated is termed as broadsense heritability and serves as a useful tool in the process of selection to the breeder.

High heritability estimates were reported for yield per plant by Srivastava and Srivastava (1976), Singh *et al.* (1977), Ramchandran and Gopalkrishnan (1979), Mangal *et al.* (1981) and Chaudhari *et al.* (1991) in bitter gourd. Fruit length, fruit weight, number of

lateral branches per plant and female flowers per plant also showed high values of heritability in bitter gourd (Srivastava and Srivastava, 1976). Similar results were obtained by Panwar *et al.* (1977) in sponge gourd.

In bitter gourd leaf length and plant height also recorded high heritability values (Mangal, 1981).

Kadam and Kale (1987) noticed high heritability for days to flowering in ridge gourd, while Sahini *et al.* (1987) recorded high heritability for fruit weight in the same crop. High heritability for fruits per vine, female flowers per vine, node number of first female flower and number of primary branches, was observed by Singh *et al.* (1987) in pointed gourd and Varalakshmi *et al.* (1995) in ridge gourd. Rajput *et al.* (1996) recorded high heritability for leaf area per vine in bitter gourd. Whereas, Singh *et al.* (1996) observed highest heritability for vine weight and yield ratio. In bottle gourd cultivars number of male flowers, number of female flowers and fruit ~~field~~ yield per plant exhibited high heritability (Hawaldar *et al.*, 1999). Whereas, moderate heritability for fruit shape was recorded by Bisognin and Storck (2000) in the same crop.

In pumpkin high heritability for average fruit weight, days to anthesis of first female flower, number of fruits and primary branches per plant was obtained by Mohanty and Mishra (1999).

Whereas, Mohanty (2000) reported high heritability estimates for flesh thickness and vine length in the same crop.

2.1.3 Genetic advance

Genetic advance is the measure of the improvement that can be achieved by practising selection in a population. Since, the estimates of heritability give no indication of the amount of progress expected from the selection, they are most meaningful when accompanied by estimates of genetic advance. High genetic advance coupled with high heritability is an indication of more additive gene action (Panse and Sukhatme, 1967). High genetic advance for number of fruits per plant was observed by Srivastava and Srivastava (1976) and Singh *et al.* (1977) in bitter gourd.

Singh *et al.* (1977) reported high genetic gain for yield per plant in bitter gourd, which was supported by findings of Ramachandran and Gopalakrishna (1979), Mangal *et al.* (1981) and Chaudhari *et al.* (1991). In sponge gourd high genetic advance was obtained for fruit length and days to flower by Panwar *et al.* (1977). High genetic advance was observed for fruit volume in ridge gourd by Kadam and Kale (1987). Whereas, Sahni *et al.* (1987) reported high genetic advance for fruit weight in the same crop. Low genetic advance for fruits per vine, female flowers per vine, node number of first female flower and branches per vine was reported by Singh *et*

al. (1987) in pointed gourd. Varalakshmi *et al.* (1995) obtained high genetic gain for node number of first female and male flower, length of main axis, number of primary branches, fruit length, fruit weight, fruit weight and sex ratio in ridge gourd. In bitter gourd highest genetic advance was recorded for leaf area per vine by Rajput *et al.* (1996). Whereas, in bottle gourd genotype, highest genetic advance was observed for vine length by Singh *et al.* (1996). Hawalder *et al.* (1999) reported high genetic advance for number of female and male flowers and fruit yield per plant in bottle gourd.

In pumpkin high genetic gain as percentage of mean for yield per plant, number of fruits per plant and low genetic gain for number of primary branches per plant was recorded by Mohanty and Mishra (1999) and Mohanty (2000).

2.2 CHARACTER ASSOCIATION

The expression of a character in a plant is the consequence of a chain of inter-relationships between characters either directly, or through other events. The correlation of characters may be due to genetic linkage or pleotrophy (Harland, 1939). Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the components on which selection can be based for improvement. There are three types of correlations viz., phenotypic, genotypic and environmental

correlation. Phenotypic correlation is the observable correlation between two variables and includes both genotypic and environmental effects. Genotypic correlation on the other hand is the inherent association between two variables.

High positive correlation of number of lateral branches per plant with yield per plant at genotypic level and with number of fruits per plant at genotypic and phenotypic level was observed by Srivastava and Srivastava (1976) in bitter gourd. They also observed negative correlation of days to first female flower opening with number of fruits per plant and number of female flowers per plant. Similar observations were recorded by Panwar *et al.* (1977) in sponge gourd.

Ramachandran and Gopalakrishnan (1979) observed highest positive correlation of vine length with yield per plant followed by fruit weight, fruit length and number of fruits per plant in bitter gourd.

Days to first flowering was positively associated with node of first female flower, days for fruit maturity and per cent dry matter in fruits in bitter gourd and bottle gourd genotypes (Pal and Vani, 1986). In pointed gourd high positive correlation of fruit length, fruit diameter and seed weight with yield was observed by Singh *et al* 1987. They also found high positive correlation of seed weight

and number of seeds per fruit with fruit weight. While, in bitter gourd, Lawande and Patil (1989) observed that shelf life was positively associated with fruit yield. Strong positive correlation of yield per vine with most vegetative and fruit characters was reported by Rajput *et al.* (1995) in bitter gourd.

Thakur *et al.* (1996) reported strong positive association of fruit weight with downy mildew , and days to first harvest with days to 50 per cent harvest in bitter gourd. They also observed negative association of yield with yellow mosaic virus and downy mildew. Also in bitter gourd, number of fruits and total yield was negatively correlated with fruit fly infestation (Thakur *et al.*, 1996).

In bottle gourd genotypes significant positive correlation of yield with node number of first female flower and number of fruits per plant was recorded by Singh *et al.* (1996) Kumar and Singh (1998) and Hawalader *et al.* (1999).

The attributes negatively correlated with yield in bottle gourd were vine weight and yield ratio (Singh *et al.*, 1996), node number of first female flower, days to first harvest and vine length (Kumar and Singh, 1998). Rao *et al.* (1999) reported significant positive correlation of yield with fruits per vine, fruit weigh, fruit volume and fruit girth in ridge gourd. Similar observations were recorded by

Sarkar *et al.* (1999) in pointed gourd and Sarnaik *et al.* (1999) in ivy gourd.

Significant positive correlation of yield with number of branches per vine, percent of female flowers and number of fruits per vine, while negative correlation with days to male and female flower opening and weight of deformed fruits per vine was recorded by Badade *et al.* (2001) in bottle gourd.

2.3 PATH COEFFICIENT ANALYSIS

Correlation coefficient alone when considered as the criterion for selection for high yield, would be misleading. As such a character may not be directly correlated with yield but may further depend on other characters. The concept of path coefficient analysis was originally developed by Wright (1921), but the technique was used in plant breeding by Dewey and Lu (1959). A path coefficient is a standardized partial regression coefficient and as such measures the direct influence of one variable upon other, and permits separation of the correlation coefficient into components of direct and indirect effects. The path analysis reveals whether the association of the independent characters with dependent variable is due to their direct effect on it or is a consequence of their indirect effect via some other trait. If the correlation between dependent variable and independent characters is due to direct

effects of the characters, it reflects a true relationship between them and selection can be practised from such a character in order to improve dependent variable. But, if the association is mainly through indirect effect of the characters through another component character, breeder has to select latter, through which the indirect effect is exerted. The use of this technique requires cause and effect situation among the variable (Singh and Chaudhary, 1977).

Srivastava and Srivastava (1976) observed maximum direct effect of number of female flowers per plant on yield in bitter gourd. They also found that the contribution of almost all characters towards yield was through number of lateral branches per plant, number of female flowers per plant and number of fruits per plant. On the contrary Ramachandran (1978) reported maximum direct effect of fruit weight on yield in bitter gourd.

In pointed gourd direct influence of days to flowering, fruit diameter, fruit weight, fruit size and seed weight, on yield was observed by Singh *et al.* (1987). Similar results were obtained by Singh *et al.* (1993) in the same crop.

Rajput *et al.* (1995) reported high positive direct effect of dry matter per vine and per cent fruit set on yield in bitter gourd. Whereas, strong negative effect of days to first female flower and days to first harvest on yield was also observed. Kumar and Singh

(1998) suggested that maximum weightage should be given on average fruit weight and number of fruits per plant for improving yield in bottle gourd. These results were supported by Shaha *et al.* (1999) and Rao *et al.* (1999) in ridge gourd and Sarkar *et al.* (1999) in pointed gourd.

In bottle gourd highest contribution of female flowers per plant to fruit yield was observed by Hawalder *et al.* (1999).

2.4 GENETIC DIVERGENCE

The magnitude of divergence between two groups under consideration is provided by D^2 statistic developed by Mahalanobis (1936). It considers the variation produced by any character and their consequent effect that it bears on other characters.

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

others in different vegetable crops viz., in tomato (Sachan and Sharma, 1971), in chilli (Singh and Singh, 1976), in brinjal (Lal and Srivastava, 1978) etc.

Kadam and Kale (1985) grouped 30 cultivars of ridge gourd into 20 clusters based on D^2 values. They observed that deformed fruits per vine, yield per vine, fruit number per vine, fruit volume and chlorophyll 'a' content were important factors contributing towards divergence. Low intra cluster and high inter cluster values among seven clusters of watermelon was observed by Sidhu and Brar (1985). They reported that average fruit weight contributed maximum towards divergence. In cucumber Prasad *et al.* (1993) grouped 32 genotypes into eight clusters and reported highest mean value for yield per plant in cluster I and VII.

Wahab and Gopalakrishnan (1993) formed five clusters from 50 genotypes of bitter gourd. They found maximum genetic distance between cluster IV and V. Similarly, Parhi *et al.* (1993) reported considerable diversity among 6 clusters for characters like 100 seed weight, number of seeds per plant and yield per plant in 13 varieties of bitter gourd.

No association between geographical distance and genetic divergence was observed in five clusters of ridge gourd (Varalakshmi *et al.*, 1994). There was substantial variation in cluster mean for

whole plant sex ratio, fruit weight, fruit number per plant and yield per plant.

In pointed gourd six clusters were formed of 23 genotypes by Prasad and Singh (1997). They observed maximum contribution to genetic divergence by fruit volume. While Singh and Lal (2000) reported maximum contribution of node number at which first female flower occurs ,towards divergence in melon. Similar study was conducted by Badade *et al.* (2001), they grouped 20 clusters of bottle gourd into 10 clusters. They also found that vine length, number of branches, per cent of female flowers, fruits per vine, fruit length and yield per vine were important factors contributing of divergence.

Ram (2001) grouped 167 genotypes of pointed gourd into 8 clusters, among these clusters, cluster 8 and 5 were most divergent.

2.5 SOURCE OF RESISTANCE FOR PEST AND DISEASE

2.5.1 Fruit fly infestation

The fruit fly (*Dacus cucurbitae* Coquillet) is among the most serious insect pests attacking cucurbit fruits in India. The fly prefers green and tender fruits in cucurbits. The attack by fly on fruit not only reduces yield but also affects quality. It is estimated

that more than 50 per cent of the cucurbit fruits are partially or fully damaged by the fruit fly (Lall and Sinha, 1959).

Among all cucurbits bitter gourd is the most preferred host (Srinivasan, 1959). This is only a partial success in the management of this pest through systemic insecticides (Agarwal *et al.*, 1987). Moreover the use of pesticides also leads to environmental pollution. Hence, development of resistant varieties is the most desirable method of controlling this pest. The environmental factors like temperature and relative humidity also affect the infestation by fruit fly (Shivarkar and Dumbre, 1985 and Su, 1986).

Four strains of bitter gourd, green rough, green smooth, white rough and white smooth were found resistant to melon fruit fly (Fernando and Mudurawana, 1941). Lall and Sinha (1974) evaluated six bitter gourd cultivars for resistance to pest and found cultivar short green kareli as resistant to fruit fly. Gupta and Verma (1978) observed 41.08 per cent, fruit damage and 56.98 per cent of unconsumable portion in an infested fruit.

Variety, Phule BG-4 was reported comparatively resistant to fruit fly (Anon., 1990). Twenty eight genotypes were screened and none of them were found free from attack of the pest (Thakur *et al.*, 1992). Lowest attack was found in Acc28 and highest in 22-D-10.

Out of 10 varieties of bitter gourd studied 'Priya' was most susceptible with 45.46 per cent fruit damage (Thakur *et al.*, 1994). None of the varieties were free from attack. However, Acc13 followed by Acc23 and BG-4 proved to be resistant.

Tewatia and Dhankhar (1996) recorded maximum (86.4%) fruit infestation per plant in Arka Harit followed by Pusa do mausami (85.7%), which are too highly susceptible genotypes of bitter gourd.

Of the 10 varieties studied, BG14 was found promising, based on resistance to fruit fly infestation and yield (Thakur *et al.*, 1996). ARU-41 followed by Arka Harit showed maximum percentage fruit fly infestation. Borah and Dutta (1997) observed 47.66 per cent of fruit infestation and marketable fruit percentage of 61.86 in bitter gourd. Forty five cultivars were evaluated for resistance to fruit fly (Tewatia *et al.*, 1998) and cvs. Faizabad collection-17 and Kerala collection-1 were designated as resistant.

2.5.2 Downy mildew incidence

Downy mildew caused by *Pseudoperenospora cubensis* is an important disease of cucurbits (Singh, 1987). Cucumber and muskmelon are most seriously affected hosts. Other hosts are ridge gourd, bitter gourd, bottle gourd, snake gourd, watermelon, pumpkin, squash, ash gourd and wild cucurbits. The fungus attacks

leaves causing pale yellow angular patches, which are vein limited and later turns brownish yellow (Butler, 1918). Finally the whole leaf turns yellow, withers and falls.

Bains and Jhooty (1976) reported that downy mildew was less severe on bitter gourd, bottle gourd and snake gourd while Mahrishi and Siradhana (1988) reported that it was most destructive on different cucurbits including bitter gourd. Phookan and Gogoi (1995) also reported heavy damage of bitter gourd by downy mildew. Thus, there is need to screen the bitter gourd genotypes against the disease and develop resistant varieties.

Reddy *et al.* (1995) screened 13 cultivars of bitter gourd for resistance to downy mildew. The incidence of disease varied significantly with cultivar and plant growth. Karlhatti showed complete resistance during early growth stages while local cultivars Siddavanahalli and Bellary exhibited the lowest incidence of mildew in later stages of growth.

Thirty genotypes of bitter gourd were evaluated against disease and the genotypes BL-240 was observed to have lowest disease index, while Pusa do mausami had the highest (Thakur *et al.*, 1996).

Jamadar and Desai (1999) screened 10 cvs. of ridge gourd for downy mildew infection. None of them showed immune or highly

resistant reaction. Raichur local-1, Raichur local-2 and Jumnal local showed moderate resistance.

In the same crop, Thammaiah *et al.* (1999) reported that Raichur local-2 recorded lowest incidence of downy mildew under Raichur conditions. Under Bijapur conditions Pusa Nasdar showed highest disease incidence while Raichur local-2, the least.

The resistance of different cultivars of ridge gourd to downy mildew was studied by Xie-Wen-Hua *et al.* (1999). They reported negative correlation of poly phenol oxidase activity, the ratio of reducing sugar to total sugar and stomatal density on lower epidermis with disease resistance. Cultivars with higher content of total sugars were more resistant to downy mildew.

Material and Methods

III. MATERIAL AND METHODS

The present investigation on "Genetic variability studies in Bitter gourd (*Momordica charantia* L.)" was undertaken during the year 2001 (August-December). The details of the materials used and experimental and statistical procedures employed for the study are outlined in this chapter.

3.1 EXPERIMENTAL SITE

Field experiment was conducted on inceptisols (red clay loam) of the Olericulture Unit, Department of Horticulture, University of Agricultural Sciences, Dharwad. The physical and chemical properties of the soil are presented in Appendix II.

3.2 LOCATION OF EXPERIMENTAL SITE AND CLIMATE

The experiment site is situated in the agro-climatic zone-8 (Northern transitional zone) of Karnataka state. Geographically, Dharwad is located at 15^0 26' North latitude, $76^0$27' east longitude and at altitude of 678 m above mean sea level.

The average total rainfall for last 51 years (1950-2000) is 784.73 mm, fairly well distributed from April to October. The mean monthly maximum temperature ranges between 27.02°C (August) to 37.10°C (April), while mean monthly minimum temperature ranges

from 13.41°C (December) to 21.45°C (May). The mean monthly relative humidity (RH) ranges between 51.25 (February) and 87.88 (July).

During the experimentation period (August-December) total rainfall of 128.7 mm was received which was distributed from August to October. The details of the meteorological data for the year 2001 and the average of last 51 years as recorded at meteorological observatory of Main Research Station, University of Agricultural Sciences, Dharwad is presented in Appendix I.

3.3 EXPERIMENTAL MATERIAL

Forty bitter gourd genotypes collected from different parts of the country were used for the study. The list of genotypes along with their source and morphological characters is presented in Table 1.

3.4 DETAILS OF EXPERIMENT

The experiment was laid out in randomized block design (RBD) with two replications. Each genotype was represented by six plants in three pits, per replication. The spacing adopted was 1.2 x 1.2 m. the seeds were soaked in water for 24 hours and were sown in prepared pits at the rate of four seeds per pit. After germination two seedlings were retained per pit and the rest were removed.

Table 1. Morphological characters and source of bitter gourd genotypes.

Sl. No.	Genotype	Fruit colour	Fruit shape	Fruit size	Ridge type	Source
1.	IC 45352	Medium Green	Spindle	Long	Smooth	K.A.U; Kerala
2.	Konkantara	Dark Green	Spindle	Medium long	Pointed	C.C.S.H.A.U; Haryana
3.	DWD-2/A	Light Green	Elongate	Medium long	Pointed	U.A.S. DWD
4.	IC 85619	Dark green	Elongate	Long	Blunt	K.A.U;Kerala
5.	Green long	Dark green	Spindle	Long	Blunt	Adhik seeds, Bangalore
6.	White long	Light green	Elongate	Long	Pointed	Adhik seeds, Bangalore
7.	Arka Harit	Medium green	Spindle	Small	Smooth	I I.H.R, Bangalore
8.	Pusa Visheh	Dark green	Spindle	Medium long	Blunt	C.C.S.H.A.U; Haryana
9.	Pusa domausami	Dark green	Elongate	Long	Pointed	C.C.S.H.A.U; Haryana
10.	Solancole-3	Dark green	Elongate	Long	Blunt	C.C.S.H.A.U; Haryana
11.	IC 44418	Medium green	Elongate	Medium long	Pointed	K.A.U;Kerala
12.	IC 44419	Dark green	Spindle	Medium long	Pointed	K.A.U;Kerala
13.	IC 32817	Light green	Elongate	Medium long	Pointed	K.A.U;Kerala
14.	IC 85614	Medium green	Elongate	Long	Pointed	K.A.U;Kerala
15.	IC 68250A	Medium green	Elongate	Long	Blunt	K.A.U;Kerala
16.	IC 85626	Medium green	Elongate	Long	Pointed	K.A.U;Kerala
17.	IC 68316	Whitish green	Spindle	Medium long	Pointed	K.A.U;Kerala
18.	IC 85606A	Whitish Green	Spindle	Medium long	Blunt	K.A.U;Kerala
19.	IC 68285	Medium green	Elongate	Medium long	Pointed	K.A.U;Kerala
20.	IC 50526	Medium green	Spindle	Small	Pointed	K.A.U;Kerala
21.	IC 68310	Medium green	Spindle	Long	Pointed	K.A.U;Kerala
22.	IC 68225	Whitish green	Spindle	Medium long	Pointed	K.A.U;Kerala
23.	IC 85618	Medium green	Elongate	Medium long	Pointed	K.A.U;Kerala
24.	IC 85670	Dark green	Spindle	Medium long	Pointed	K.A.U;Kerala
25.	Nakhara	Medium green	Elongate	Medium long	Pointed	O.U.A.T, Orissa
26.	IC 68232	Light green	Elongate	Medium long	Pointed	K.A.U;Kerala
27.	IC 68292	Medium green	Elongate	Medium long	Pointed	K.A.U;Kerala
28.	PRD-1	Dark green	Elongate	Long	Smooth	Local selection Haryana
29.	PRD-2	Dark green	Elongate	Extra long	Smooth	Local selection Haryana
30.	PRD-5	Dark green	Spindle	Medium long	Blunt	Local selection Haryana
31.	PRD-4	Dark green	Spindle	Medium long	Blunt	Local selection Haryana
32.	PRD-3	Medium green	Spindle	Medium long	Smooth	Local selection Haryana
33.	BLG-1	Light green	Elongate	Long	Smooth	Local selection Bangalore
34.	BLG-2	Medium green	Elongate	Long	Smooth	Local selection Bangalore
35.	DWD-5	Medium green	Elongate	Long	Blunt	U.A.S. DWD
36.	DWD-2	Light green	Elongate	Extra long	Pointed	U.A.S. DWD
37.	NDN-1	Dark green	Spindle	Medium long	Pointed	U.A.S. DWD
38.	NRN-1	Medium green	Elongate	Long	Blunt	U.A.S. DWD
39.	DWD-1	Light green	Spindle	Medium long	Pointed	U.A.S. DWD
40.	DWD-4	Whitish green	Spindle	Medium long	Pointed	U.A.S. DWD

Recommended package of practises were followed during the crop period.

3.5 OBSERVATIONS RECORDED

Observations were recorded on the following characters. Entire population was considered for all characters except for fruit characters, in which case 10 fruits per genotype in each replication were chosen at random. The mean value of the data obtained from each plot was taken to represent a particular genotype with respect to a character. The details of observations recorded and techniques adopted for recording the data were as follows.

3.5.1 Vine length

The length of vine from ground level to the tip was measured (in cm) after final harvest.

3.5.2 Number of primary branches per plant

The number of branches developed from the main vine was counted after final harvest

3.5.3 Number of nodes per vine

The number of nodes per vine on the main stem was counted after final harvest.

3.5.4 Internodal length

After final harvest five internodal lengths were recorded (in cm) per vine at random and average values were calculated.

3.5.5 Days to opening of first female flower

The number of days taken by the first female flower of all plants, to open, from the date of sowing was recorded

3.5.6 Node at which first female flower appears

The node number from the cotyledonous leaves, at which the first female flower appeared was recorded.

3.5.7 Number of leaves at 50 per cent flowering stage

Total number of leaves were counted at 50 per cent flowering stage (when half the plants of a genotype were in flowering stage) and recorded.

3.5.8 Days to first harvest

Number of days taken from sowing to the harvest of first marketable fruit was recorded. Stage of marketable maturity was judged by experience on the basis of change in colour as well as texture of surface of fruits.

3.5.9 Days taken for development of fruit

Number of days taken from the opening of first female flower to the harvest of first marketable fruit was recorded.

3.5.10 Productive length of vine

Length of vine was measured (in cm) from the apex of the main shoot upto the first fruiting node at the time of final harvest.

3.5.11 Fruit girth

The girth in the middle portion of the fruit was recorded in cm.

3.5.12 Size of cavity

The breadth of the cavity after removal of seed mass gave size of cavity (in cm).

3.5.13 Flesh thickness

The flesh thickness was recorded (in cm) after cutting the fruit at the center.

3.5.14 Number of seeds per fruit

The fruits were cut open and the total number of seeds per fruit were counted and recorded.

3.5.15 Fruit length

Length of the fruit was measured from the stalk end to the blossom end with the help of a thread.

3.5.16 Number of fruits per plant

Number of fruits harvested from time to time was recorded. The cumulative total of all the harvests gave the total number of fruits per plant.

3.5.17 Total yield per plant

The cumulative yield (in kg) of all the harvests gave the total yield per plant.

3.5.18 Fruit weight (FW)

Fresh fruit weight was recorded at the time of harvest in g.

3.5.19 Fruit fly infestation

The number of fruits infested by fruit fly were counted and expressed as percentage of total fruits. Further the genotypes were grouped into different categories based on per cent fruit infestation as given below.

Per cent fruit infestation	Reaction category
0-5	Resistant
6-10	Moderately resistant
11-20	Moderately susceptible
21-50	Susceptible
>50	Highly susceptible

3.5.20 Downy mildew incidence

The disease intensity was recorded as per cent leaf area infected further the genotypes were scored following zero to five diseases rating scale (Girisha, 1989) as given below.

Sl. No.	Per cent leaf area infected	Score	Reaction category
1.	0	0	Immune
2.	1-10	1	Resistant
3.	11-25	2	Moderately resistant
4.	26-50	3	Moderately susceptible
5.	51-75	4	Susceptible
6.	76-100	5	Highly susceptible

3.6 STATISTICAL ANALYSIS

The statistical analysis of the data (on the mean values of individual characters) was done at the Computer Centre, University of Agricultural Sciences, Dharwad. The various statistical methods followed are furnished below.

3.6.1 Analysis of variance (ANOVA)

Analysis of variance for all characters of genotypes in Randomised block design (RBD) was carried out following Cochran and Cox (1959).

ANOVA

Source	DF	Mean sum of squares	F ratio	Expected sum of squares
Replication	(r-1)	Mssr	Mssr/Msse	-
Genotypes	(v-1)	Mssg	Mssg/Msse	Ve + Vg
Error	(r-1) (v-1)	Msse	-	Ve
Total	(vr-1)	-	-	-

Where,

r = Number of replications

v = Number of genotypes

Mssr = Mean sum of squares due to replication

Mssg = Mean sum of squares due to genotypes/variety

Msse = Mean sum of squares due to error

Ve = Error variance

Vg = Genotypic variance

Statistical significance of variation due to genotypes was tested by comparing calculated values to table F values at 1 per cent and 5 per cent level of probability

3.6.2 Components of variance

The components of variance computed were genotypic and phenotypic based on ANOVA table.

Genotypic variance (Vg)

$$Vg = \frac{Mssg - Msse}{r}$$

Phenotypic variance (Vp)

$$Vp = Vg + Ve$$

3.6.3 Coefficient of variability

Genotypic and phenotypic coefficient of variability were computed according to Singh and Chaudhary (1977).

Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sigma_g}{\overline{X}} \times 100$$

Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sigma_p}{\overline{X}} \times 100$$

Where,

σ_g = Genotypic standard deviation

σ_p = Phenotypic standard deviation

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

3.6.4 Heritability (broad sense)

Heritability in broad sense was calculated as a ratio of genetic variance to total variance (Singh and Chaudhary, 1977) and expressed as percentage.

$$h^2bs = \frac{Vg}{Vp} \times 100$$

Where,

h^2bs = heritability broad sense

Vg = genotypic variance

Vp = Phenotypic variance

3.6.5 Genetic advance (GA)

Genetic advance was calculated using formula given by Johnson *et al.* (1955).

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

h^2 - Broad sense heritability

σp - Phenotypic standard deviation

K - Selection differential (2.06 at 5% selection intensity)

3.6.6 Genetic advance (% of mean) GAM

Genetic advance as percentage of mean was computed by formula.

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

3.6.7 Correlation coefficients

Genotypic (r_g), phenotypic (r_p) and environmental (r_e) correlation coefficients were estimated using following formula (Al-Jibouri *et al.*, 1958).

$$r_g\,(xy) = \frac{COV_{xy}\,(g)}{\sqrt{V_x(g) \times V_y(g)}}$$

$$r_p\,(xy) = \frac{COV_{xy}\,(p)}{\sqrt{V_x(p) \times V_y(p)}}$$

$$r_e\,(xy) = \frac{COV_{xy}\,(e)}{\sqrt{V_x(e) \times V_y(e)}}$$

Where,

COV_{xy} (g) – Genotypic co-variance between x and y

COV_{xy} (p) - Phenotypic co-variance between x and y.

COV_{xy} (e) - Environmental co-variance between x and y

$V_x(e)$ - Environmental variance of character x

$V_x(g)$ - Genotypic variance of character x

V_x (p) - Phenotypic variance of character x

V_y (e) - Environmental variance of character y

V_y (g) - Genotypic variance of character y

V_y (p) -Phenotypic variance of character y

The significance was tested against 'r' value given by Fisher and Yates (1963).

3.6.8 Path coefficient analysis

The path coefficient analysis was performed as given by Wright (1921), Dewley and Lu (1959). The following set of simultaneous equations were formed and solved for estimating the direct and indirect effects.

$$r_{1y} = a + r_{12}b + r_{13}c + \text{----------} + r_{11}i$$

$$r_{2}y = r_{21}a + b + r_{23}c + \text{----------} + r_{21}i$$

$$r_{3}y = r_{31}a + r_{32}b + c + \text{----------} + r31i$$

$$r_{n}y = r_{n1}a + r_{12}b + r_{13}c + \text{----------} + i$$

Where,

r_{1y} to r_{ny} = coefficients of correlation between causal factors 1 to n and dependent character y.

r_{12}, r_{21}, r_{31} ---------r_{ni} = Coefficients of correlation among the causal factors I to n.

a, b, c ---------- i = direct effects of characters a to i on the dependent character y.

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

3.6.9 Genetic diversity

3.6.9.1 Mahalanobis D^2 analysis

Mahalanobis (1936) D^2 statistic was used for assessing the genetic divergence between any two populations comprising 40 genotypes. The generalized distance between any two population is given by formula $D^2 = \Sigma\Sigma\ \lambda^{ij}\ \delta i \delta j$

Where,

D^2 = square of generalized distances

λ^{ij} = Reciprocal of common dispersal matrix

$\delta i = (\mu_{i1} - \mu_{i2})$

$\delta j = (\mu_{j1} - \mu_{j2})$

μ = general mean

Since the formula for computation requires inversion of high order determinant, transformation of the original correlated unstandardized character means (Xs) to standardized uncorrelated variables (Ys) was done to simply the computational procedure. The D^2 values were obtained as the sum of squares of the differences between pairs of corresponding uncorrelated (Ys) values of any two genotypes (Rao, 1952).

3.6.9.2 Clustering of D^2 values

All the n (n-1)/2 D^2 values were clustered using Tocher's method (Rao 1952).

3.6.9.3 Intra cluster distances

The intra cluster distances were calculated by the formula given by Singh and choudhary (1977).

Square of intra cluster distance = $\Sigma D_i^2/n$.

Where, ΣD_i^2 in the sum of distances between all possible combinations of the entries included in a cluster

n = number of all possible combinations.

3.6.9.4 Inter cluster distances

The inter cluster distances were calculated by the formula described by Singh and Choudhary (1977).

Square of inter cluster distance = $\Sigma D_i^2/n_i n_j$.

Where, ΣDi2 is sum of distances between all possible combination ($n_i n_j$) of the entries included in the cluster study (i and j).

n_i = number of entries in cluster i

n_j = number of entries in cluster j

Experimental Results

IV. RESULTS

The present study was carried out with 40 genotypes of bitter gourd during 2001 (August-December) with a view to find out the extent of genetic variability, degree of association, relative importance of various metric traits upon fruit yield, genetic divergence and source of resistance for pest and disease.

The results of the experiment are presented under following headings.

4.1 Analysis of variance

4.2 Genetic variability

4.3 Character association

4.4 Path coefficient analysis

4.5 Genetic divergence

4.6 Source of resistance for pest and disease

4.1 ANALYSIS OF VARIANCE

The mean sum of squares due to various sources of variation for different characters of bitter gourd genotypes is presented in Table 2. The results indicated highly significant variation among genotypes for the characters *viz.*, vine length, number of branches

Table 2. Analysis of variance for quantitative characters in 40 bittergourd genotypes.

Source of variation	DF	Mean sum of squares																		
		VL	NOB	NON	IL	DFF	NFF	NOL	DFH	DDF	PLV	FG	SC	FT	NOS	FL	NOF	FY	FW	FFI	DMI
1. Replication	1	3147	0.04	0.38	6.52	14.87	0.11	3038	10.81	0.88	1130	0.94	0.24	0.001	0.39	0.511	25.31	0.08	148.96	13.33	1.8
2. Treatment	39	4491.28**	1.29**	84.40**	2.36**	58.96	19.89**	19617.01**	58.16	9.63**	6108.87**	0.73**	0.35**	0.030**	80.50**	23.03**	161.42**	1.13**	977.04**	99.48**	5.59**
3. Error	39	492.46	0.59	8.09	0.53	43	10.44	517.56	46.75	2.64	1694.87	0.21	0.09	0.001	12.88	9.09	27.33	0.07	59.69	16.55	0.87
Sem±		15.691	0.543	2.011	0.514	4.636	2.284	16.089	4.834	1.148	29.11	0.324	0.212	0.022	2.537	2.131	3.696	0.187	5.463	2.876	0.659
CD at 5%		37.36	1.29	4.78	1.22	11.03	5.43	38.31	11.51	2.73	69.31	0.77	0.5	0.052	6.04	5.07	8.8	0.44	13	6.84	1.56
CD at 1%		53.75	1.86	6.88	1.76	15.87	7.82	55.12	16.56	3.93	99.73	1.1	0.72	0.075	8.69	7.3	12.66	0.64	18.71	9.85	2.25

** Significant at 1% probability

* Significant at 5% probability

per pant, number of nodes per vine, internodal length, node number of first female flower, number of leaves at 50 per cent flowering stage, days taken for development of fruit, productive length of vine, number of fruits per plant, total yield per plant, fruit length, fruit girth, fruit weight, flesh thickness, number of seeds per fruit, size of cavity, fruit fly infestation and downy mildew incidence. However, variation due to genotypes for days to opening of first female flower and days to first harvest were non significant.

4.2 GENETIC VARIABILITY

The genetic variability estimates including genotype means, range, genotypic, phenotypic and environmental variances, PCV, GCV, heritability and genetic advance (Table 3) for different characters are presented as indicated.

4.2.1 Vine length

A wide range of variation, from 90.40 to 271.30 cm was observed for vine length, with a mean of 179.34 cm. The variances observed were environmental (492.46), genotypic (1999.40) and phenotypic (2491.86). The estimates of phenotypic and genotypic coefficient of variation were 27.83 and 24.93, respectively. High heritability estimate of 80.2 per cent was associated with high genetic advance (82.51).

Table 3. Components of variance and estimates of genetic parameters for twenty characters in bitter gourd.

Characters	Range	Mean	PCV (%)	GCV (%)	H (%)	GA (K-2.06)	GAM (%)	V_P	V_G	V_E
Vine length (cm)	90.4-271.3	179.34	27.83	24.93	80.2	82.51	46.00	2491.86	1999.4	492.46
No. of branches	2.5-5.75	4.10	23.65	14.37	37.0	0.74	18.04	0.94	0.35	0.59
No. of nodes per vine	12.0-38.15	25.25	26 .93	24.46	82.5	11.56	45.78	46.24	38.15	8.09
Internodal length (cm)	4.5-10.02	6.97	17.27	13.76	63.4	1.57	22.52	1.44	0.915	0.53
Days to opening of first female flower	41.5-61.5	51.08	13.98	5.53	15.7	2.30	4.50	50.98	7.98	43.0
Node number of first female flower	3.5-15.3	9.86	39.48	22.03	31.1	2.50	25.35	15.16	4.72	10.44
No. of leaves at 50% flowering	189.0-518.5	322.91	31.07	30.26	94.9	196.06	60.71	10067.36	9549.6	517.76
Days to first harvest	55.5-78.5	65.21	11.11	3.66	10.9	1.62	2.48	52.45	5.70	46.75
Days to development of fruit	10-20	14.17	17.48	13.18	56.9	2.90	20.46	6.14	3.5	2.64
Productive length of vine (cm)	130.5-366.5	244.16	25.58	19.24	56.6	72.78	29.80	3901.87	2207.0	1694.87
Fruit girth (cm)	2.45-4.95	3.76	18.26	13.65	55.9	0.79	21.01	0.46	0.265	0.20
Size of cavity (cm)	1.70-3.5	2.33	20.36	15.37	57.0	0.56	24.03	0.22	0.13	0.09
Flesh thickness (cm)	0.31-0.89	0.57	21.71	21.28	96.0	0.25	43.85	0.015	0.014	0.001
No. of seeds per fruit	11.5-37.5	22.52	30.34	25.82	72.4	10.19	45.24	46.69	33.81	12.88
Fruit length (cm)	10.28-24.8	14.93	26.83	17.68	43.4	3.58	23.97	16.06	6.97	9.09
No. of fruits per plant	8.5-44.5	21.96	44.23	37.28	71.0	14.22	64.75	94.39	67.06	27.33
Total yield per plant (kg)	0.39-3.74	1.34	58.10	54.22	87.1	1.40	104.4	0.596	0.526	0.07
Fruit weight (g)	21.65-109.65	66.77	34.10	32.07	88.5	41.50	62.15	518.36	458.67	59.69
Fruit fly infestation	2.40-28.25	12.63	60.27	50.95	71.5	11.21	88.75	58.01	41.46	16.55
Downy mildew incidence	1.00-5.00	3.25	26.26	22.42	72.9	2.70	39.41	3.23	2.36	0.87

4.2.2 Number of primary branches per plant

Genotypes differed for average number of primary branches per plant and ranged from 2.5 (in genotype DWD-2) to 5.75 (in genotype NRN-1) with mean of 4.10. The phenotypic variance (0.94) was higher than genotypic variance (0.35) and environmental variance was 0.59. The estimates of phenotypic and genotypic coefficient of variation were 23.65 and 14.37, respectively. Moderate heritability estimate of 37.0 per cent was associated with low genetic advance (0.74).

4.2.3 Number of nodes per vine

The range observed was from 12.00 in genotype PRD-2 to 38.15 in genotype IC85626 with general mean of 25.25. The variances observed were environmental (8.09), genotypic (38.15) and phenotypic (46.24). The estimates of phenotypic and genotypic coefficient of variation were 26.93 and 24.46, respectively. Low genetic advance (11.56) was associated by high estimate of heritability (82.5).

4.2.4 Internodal length

The lowest internodal length was observed in genotype Arka Harit (4.50 cm) and highest in genotype IC68316 (10.02 cm). The general mean was 6.97 cm. The components of variance *viz.*, genotypic,

phenotypic and environmental were 0.915, 1.44 and 0.53, respectively. The estimate of PCV was 17.27 and GCV was 13.76. The heritability estimate was comparatively higher (63.4) than genetic advance (1.57).

4.2.5 Days to opening of first female flower

Genotypic differences were noticed for days to opening of first female flower, the value being 41.50 in genotype IC44419 and 61.5 in genotype IC50526. The general mean for this character was 51.08. The phenotypic variance (50.98) was highest followed by environmental (43.0) and genotypic (7.98) variances. The estimate of PCV was 13.98 and that of GCV was 5.53. Low heritability (15.7) coupled with low genetic advance (2.30) was obtained for this character.

4.2.6 Node number of first female flower

The genotypes varied among themselves for this character from 3.5 (in genotype IC45352) to 15.3 (in genotype NRN-1) with mean value of 9.86. The environmental variance value was 10.44 and that of genotypic variance was 4.72. The phenotypic variance was 15.16. Estimates of phenotypic and genotypic coefficients of variance were 39.48 and 22.03, respectively. Moderate heritability (31.1) with low genetic advance (2.5) was observed for this trait.

4.2.7 Number of leaves at 50 per cent flowering stage

Wide range was observed for this character from 189.0 to 518.5 with mean value of 322.91. Among components of variance, phenotypic variance (10067.36) was maximum followed by genotypic (9549.6) and environmental (517.76) variances. Estimates of PCV and GCV were 31.07 and 30.26, respectively. Both heritability (94.9) and genetic advance (196.06) was high.

4.2.8 Days to first harvest

Days to first harvest was from 55.50 in genotype IC44419 to 78.50 in genotype IC50526 with mean value of 65.21. The components of variance *viz.*, genotypic, environmental and phenotypic were 5.70, 46.75 and 52.45, respectively. The estimates of PCV and GCV were 11.11 and 3.66, respectively. Genetic advance (1.62) and heritability (10.9) were low for this trait.

4.2.9 Days taken for development of fruit

Genotypes showed considerable variation for this trait and range was from 10.0 in genotype NDN-1 to 20.0 in genotype IC85614 with the mean value of 14.17. The maximum variance was observed due to phenotype (6.14) followed by genotype (3.5) and environment (2.64). PCV (17.48) was higher than GCV (13.18). Low genetic advance (2.90) and moderate heritability (56.9) was obtained.

4.2.10 Productive length of vine

Wide range was observed, from 130.5 cm in genotype Solan cole-3 t. 366.5 cm in genotype NDN-1 with mean of 244.16 cm. The variance due to genotype, phenotype and environment were 2207.0, 3901.87 and 1694.87, respectively. The estimate of PCV and GCV were 25.58 and 19.24, respectively. Moderate heritability (56.6) with high genetic advance (72.78) was observed for this trait.

4.2.11 Fruit girth

The fruit girth varied from 2.45 cm in genotype IC68292 to 4.95 cm in genotype PRD-3 with mean of 3.76 cm. The components of variance *viz.*, genotypic, phenotypic and environmental were 0.265, 0.46 and 0.20, respectively. The phenotypic and genotypic coefficient of variation were 18.26 and 13.65, respectively. Low genetic advance (0.79) with moderate heritability (55.9) was observed.

4.2.12 Size of cavity

Size of cavity ranged from 1.70 to 3.5 cm with mean of 2.33 cm. The components of variance *viz.*, genotypic, phenotypic and environmental were 0.13, 0.22 and 0.09, respectively. The PCV and GCV values were 20.36 and 15.37, respectively. Low genetic advance (0.56) with moderate heritability (57.0) was observed.

4.2.13 Flesh thickness

Flesh thickness ranged from 0.31 to 0.89 cm with mean of 0.57 cm. The components of variance *viz.*, genotypic phenotypic and environmental were 0.014, 0.015 and 0.001, respectively. The PCV and GCV values were 21.71 and 21.28, respectively. High heritability (96.0) with low genetic advance (0.25) was observed.

4.2.14 Number of seeds per fruit

The seed number varied from 11.5 per fruit in genotype IC68232 to 37.5 in genotype IC68250A, with the mean of 22.52. The influence of phenotypic variance (46.69) on seed number was more than the genotypic (33.81) and environmental variance (12.88). The GCV (25.82) was lower than PCV (30.34). Low genetic advance (10.19) with high heritability (72.4) was observed for this trait.

4.2.15 Fruit length

Wide range of 10.28 cm (in genotype IC50526) to 24.80 cm (in genotype DWD-2) was observed for fruit length (Plate 1&2). The general mean value was 14.93 cm. The influence of phenotypic variance (16.06) on fruit length was higher than genotypic (6.97) and environmental (9.09) variance. The PCV and GCV values were 26.83 and 17.68, respectively. Moderate heritability (43.4) with low genetic advance (3.58) was observed for this character.

Plate 1. Whitish green genotypes showing variability in size.

Plate 2. Genotypes showing variability for colour and size.

4.2.16 Number of fruits per plant

Wide range was observed for this character. The number of fruits per plant ranged from 8.5 (DWD-4) to 44.5 (IC68285). The average number of fruits per plant was 21.96. The components of variance *viz.*, genotypic, phenotypic and environmental were 67.06, 94.39 and 27.33, respectively. The PCV and GCV values were 44.23 and 37.28, respectively. Genetic advance of 14.22 with high heritability (71.0) was observed.

4.2.17 Fruit weight

Fruit weight ranged from 21.65 g in genotype Arka Harit to 109.65 g in genotype IC 68250A with mean value of 66.77 g. The components of variance *viz.*, genotypic, phenotypic and environmental were 458.67, 518.36 and 59.69, respectively. The PCV and GCV values were 34.10 and 32.07, respectively. High heritability (88.5) with moderately high genetic advance (41.50) was observed for this trait.

4.2.18 Fruit yield

The magnitude of variation among the genotypes with respect to fruit yield ranged from 0.39 kg in genotype Nakhara to 3.74 kg in genotype BLG-1 with mean of 1.34 kg. The genotypic, phenotypic and environmental variances were 0.526, 0.596 and 0.07, respectively.

The PCV and GCV values were 58.10 and 54.22, respectively. High heritability (87.1) with low genetic advance (1.4) was observed.

4.2.19 Fruit fly infestation

Production of bitter gourd fruits is reduced due to fruit fly infestation. This has been known to be attracted by some but not all genotypes. Therefore, it is presumed that resistance/tolerance to fruit fly infestation could be due to non attraction of the pest and their relative harbouring. A greater range of variation from 2.40 in genotype BLG-1 to 28.25 in genotype Pusa do mausami was observed. The general mean was 12.63. Among the components of variance least damage occurred by environment (16.55) compared to genotype (41.46) and phenotype (58.01). The PCV and GCV values were 60.27 and 50.95, respectively. Genetic advance of 11.21 and high heritability of 71.5 was observed among the genotypes.

4.2.20 Downy mildew incidence

The downy mildew incidence scores ranged from 1.00 to 5.00 with mean of 3.25. While greater magnitude was noticed due to phenotypic (3.23) and genotypic (2.36) variance, the environmental influence (0.87) was lowest. The PCV and GCV values were 26.26 and 22.42, respectively. High heritability (72.9) with low genetic advance (2.70) was observed.

4.3 CHARACTER ASSOCIATION

The phenotypic and genotypic correlation coefficient among 12 characters (which had strong association with yield) are presented in Table 4 and 5, respectively.

4.3.1 Phenotypic correlations

Phenotypic correlations among 12 characters were computed. The correlations are described below and presented in Table 4 .

Positive and highly significant correlation of days to opening of first female flower with node number of first female flower (0.342), number of leaves at 50 per cent flowering stage (0.255) and days to first harvest (0.937) was observed. Correlation with other characters were non significant. The association of node number of first female flower was significant and positive with days to first harvest (0.240) and number of fruits (0.231). Number of leaves at 50 per cent flowering showed highly significant positive association with fruit yield (0.317), fruit weight (0.445), fruit length (0.431) and number of seeds per fruit (0.408). Significant positive association of number of leaves at 50 per cent flowering with days to first harvest (0.233) was observed.

Fruit length was positively and highly significantly associated with fruit yield (0.495) (plate 3&4), fruit weight (0.492) and number

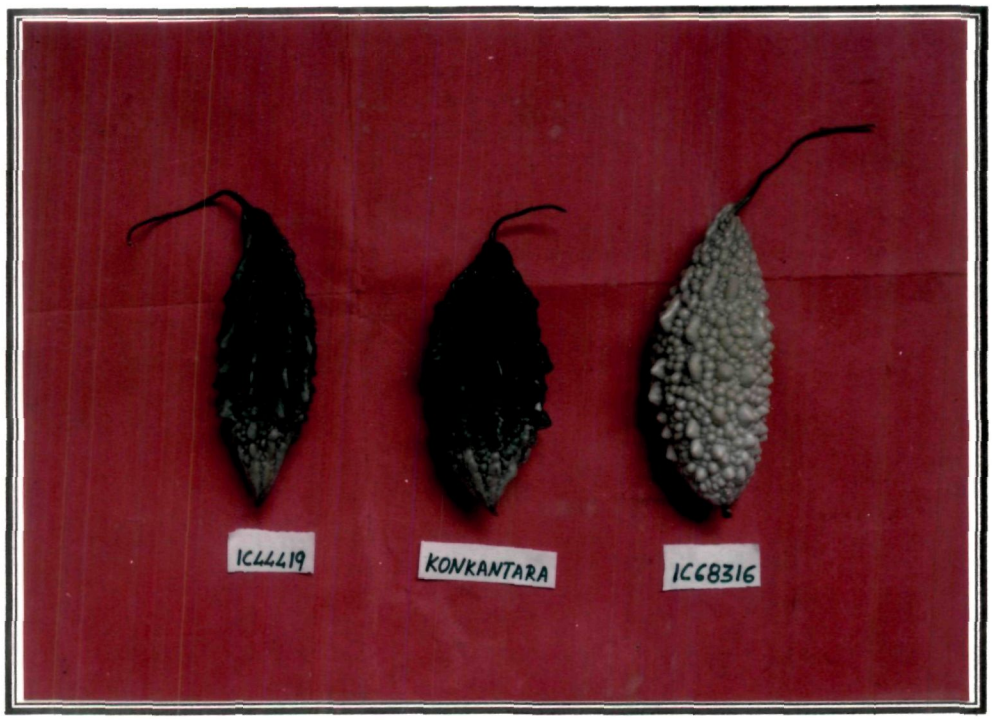


Plate 3. Small fruited genotypes

Plate 4. Long fruited genotypes.

Table 4. Phenotypic correlation coefficient among twelve quantitative characters in bitter gourd.

Characters	Days to first female flower opening	Node No. of first female flowering	Number of leaves at 50% flowering	Days to first harvest	Productive length of vine	No. of seeds per fruit	Fruit length	No. of fruits per plant	Total yield per plant	Fruit weight	Fruit fly infestation	Downy mildew incidence
Days to first female flower opening	1.00	0.342**	0.255*	0.937**	-0.066	0.054	-0.008	-.0.128	-0.11	0.065	-0.042	-.0.136
Node No. of first female flowering		1.00	0.190	0.240*	0.184	-0.168	0.149	0.231*	0.145	-0.181	-0.071	-0.328**
Number of leaves at 50% flowering			1.00	0.233*	-0.027	0.408**	0.431**	0.000	0.317**	0.445**	-0.057	-0.084
Days to first harvest				1.00	-0.073	0.083	0.000	-0.135	0.011	0.064	-0.073	-0.128
Productive length of vine					1.00	-0.026	0.203	0.229*	0.186	-0.091	-0.169	-0.470**
No. of seeds per fruit						1.00	0.365**	0.052	0.353**	0.638**	-0.119	0.197
Fruit length							1.00	0.265*	0.495**	0.492**	-0.151	-0.163
No. of fruits per plant								1.00	0.750**	-0.017	-0.421**	-0.444**
Total yield per plant									1.00	0.519**	-0.409**	-0.480**
Fruit weight										1.00	0.016	0.036
Fruit fly infestation											1.00	0.425**
Downy mildew incidence												1.00

* = Significant at 5% level of probability
** = Significant at 1% level of probability

of fruits per plant (0.265). Number of fruits was positively and highly significantly associated with fruit yield(0.750), while negative and highly significant correlation was observed with fruit fly infestation (-0.421) and downy mildew incidence (-0.444). Thus, influence of pest and disease on the fruit yield was noticed. Positive and highly significant correlation of fruit yield with fruit weight (0.519) was observed. The association of fruit yield was negative and highly significant with fruit fly infestation (-0.409) and downy mildew incidence (-0.480).

Number of seeds per fruit showed highly significant positive association with fruit yield (0.353), fruit weight (0.638) and fruit length (0.365). The association of productive length of vine was positive and significant with number of fruits per plant (0.229).

4.3.2 Genotypic correlations

Genotypic correlation among 12 characters were computed and presented in Table 5. Days to opening of first female flower and days to first harvest (0.754) number of leaves at 50 per cent flowering (0.402) fruit length (0.476) and fruit weight (0.268) were significantly and positively correlated. The negative and highly significant correlation of days to opening of first female flower with number of fruits per plant (-0.589) was observed. The association of node number of first female flower was highly significant and

Table 5. Genotypic correlation coefficient among twelve quantitative characters in bitter gourd.

Characters	Days to first female flower opening	Node No. of first female flowering	Number of leaves at 50% flowering	Days to first harvest	Productive length of vine	No. of seeds per fruit	Fruit length	No. of fruits per plant	Total yield per plant	Fruit weight	Fruit fly infestation	Downy mildew incidence
Days to first female flower opening	1.000	-0.117	0.402**	0.754**	0.200	-0.016	0.476**	-0.589**	-0.074	0.268*	0.126	0.170
Node No. of first female flowering		1.000	0.242*	-0.642**	0.694**	-0.400**	0.587**	0.263*	0.280*	-0.192	-0.319**	-0.481**
Number of leaves at 50% flowering			1.000	0.387**	-0.028	0.469**	0.655**	0.026	0.354**	0.485**	-0.097	-0.073
Days to first harvest				1.000	0.202	0.024	0.445**	-0.662**	-0.046	0.336**	-0.004	0.087
Productive length of vine					1.000	-0.166	0.121	0.340**	0.247*	-0.179	-0.289**	-0.666**
No. of seeds per fruit						1.000	0.399**	0.069	0.419**	0.798**	-0.080	0.294**
Fruit length							1.000	0.325**	0.646**	0.665**	-0.221*	-0.299**
No. of fruits per plant								1.000	0.766**	0.000	-0.442**	-0.468**
Total yield per plant									1.000	0.549**	-0.396**	-0.551**
Fruit weight										1.000	0.021	0.018
Fruit fly infestation											1.000	0.489**
Downy mildew incidence												1.000

* = Significant at 5% level of probability
** = Significant at 1% level of probability

positive with productive length of vine (0.694) and fruit length (0.587), while significant and positive with number of leaves at 50 per cent flowering, number of fruits per plant (0.263) and fruit yield (0.280). Highly significant and negative association of node number of first female flower with days to first harvest (-0.642), number of seeds (-0.400), fruit fly infestation (-0.319) and downy mildew incidence (-0.481) was observed.

Number of leaves at 50 per cent flowering stage was highly significantly and positively associated with days to first harvest (0.387), number of seeds per fruit (0.469), fruit length (0.655), fruit yield (0.354) and fruit weight (0.485).

The association of fruit length was highly significant and positive with number of fruits per plant (0.325), fruit yield (0.646) and fruit weight (0.665). Fruit length also showed negative and highly significant association with the downy mildew incidence (-0.299), while negative and significant association with fruit fly infestation (-0.221). Number of fruits per plant was highly significantly and positively associated with fruit yield (0.766), while the association with fruit fly infestation (-0.442) and downy mildew incidence (-0.468) was highly significant and negative.

Fruit yield showed highly significant and positive association with fruit weight (0.549), while the association with fruit fly

infestation (-0.396) and downy mildew incidence (-0.551) was negative and highly significant.

The association of number of seeds per fruit was highly significant and positive with fruit length (0.399), fruit yield (0.419) and fruit weight (0.798). Productive length of vine was highly significantly and positively associated with number of fruits per plant (0.340) and fruit yield (0.247), while highly significantly and negatively associated with fruit fly infestation (-0.289) and downy mildew incidence (-0.666).

4.4 PATH COEFFICIENT ANALYSIS

The path coefficient analysis was computed to find out relative contribution of a set of 11 characters (which had positive correlation with yield) towards fruit yield in bitter gourd. The genotypic and phenotypic correlation were partitioned into direct and indirect effects of component characters on yield and data is presented in Table 6 and 7.

The total fruit yield was considered as effect dependent on 11 independent variables, which were considered as cause. The independent characters were days to opening of first female flower, node number of first female flower, number of leaves at 50 per cent flowering stage, days to first harvest, productive length of vine,

Table 6. Genotypic path analysis for total yield per plant.

Characters	Days to first female flower opening	Node No. of first female flowering	Number of leaves at 50% flowering	Days to first harvest	Productive length of vine	No. of seeds per fruit	Fruit length	No. of fruits per plant	Fruit weight	Fruit fly infestation	Downy mildew incidence	Correlation with yield
Days to first female flower opening	**0.187**	0.025	0.052	-0.140	0.021	0.004	0.033	-0.378	0.164	-0.012	-0.029	-0.074
Node No. of first female flowering	-0.022	**-0.213**	0.031	0.120	0.072	0.087	0.041	0.169	-0.117	0.030	0.082	0.280
Number of leaves at 50% flowering	0.075	-0.051	**0.129**	-0.072	-0.003	-0.102	0.046	0.017	0.295	0.009	0.012	0.354
Days to first harvest	0.141	0.137	0.050	**-0.186**	0.021	-0.005	0.031	-0.424	0.205	0.000	-0.015	-0.046
Productive length of vine	0.037	-0.148	-0.004	-0.038	**0.104**	0.036	0.008	0.218	-0.109	0.027	0.114	0.247
No. of seeds per fruit	-0.003	0.085	0.060	-0.005	-0.017	**-0.218**	0.028	0.044	0.486	0.007	-0.050	0.419
Fruit length	0.089	-0.125	0.084	-0.083	0.013	-0.087	**0.070**	0.208	0.405	0.021	0.051	0.646
No. of fruits per plant	-0.110	-0.056	0.003	0.123	0.035	-0.015	0.023	**0.641**	0.000	0.041	0.080	0.766
Fruit weight	0.050	0.041	0.062	-0.063	-0.019	-0.174	0.046	0.000	**0.609**	-0.002	-0.003	0.549
Fruit fly infestation	0.023	0.068	-0.012	0.001	-0.030	0.017	-0.015	-0.283	0.013	**-0.093**	-0.084	-0.396
Downy mildew incidence	0.032	0.102	-0.009	-0.016	-0.069	-0.064	-0.021	-0.300	0.011	-0.045	**-0.171**	-0.551

Residual = 0.0839

(Direct effect on main diagonal)

number of seeds per fruit, fruit length, number of fruits per plant, fruit weight, fruit fly infestation and downy mildew incidence.

4.4.1 Genotypic path analysis

Days to opening of first female flower had direct positive (0.187) effect on yield. Indirect positive effects were seen through fruit weight (0.164), fruit length (0.033), number of seeds (0.004), productive length of vine (0.021), number of leaves at 50 per cent flowering (0.052) and node number of first female flower (0.025). Whereas, number of fruits per plant had negative direct effect (-0.378).

Node number of first female flower had direct negative effect (-0.213) on yield. Negative indirect effect was seen through days to opening of first female flower (-0.022) and fruit weight (-0.117). Low positive indirect effects were seen through other characters like days to first harvest (0.120), number of fruits per plant (0.169), productive length of vine (0.072) etc.

Number of leaves at 50 per cent flowering stage had direct positive effect (0.129) on yield. Indirect positive effects were seen through fruit weight (0.295), fruit length (0.046), number of fruit per plant (0.017) and days to first female flower opening (0.075). Negative indirect effects were seen through characters *viz.*, node

number of first female flower (-0.051), days to first harvest (-0.072), productive length of vine (-0.003) and number of seeds per fruit (-0.102).

Days to first harvest showed direct negative effect (-0.186). Positive indirect effects were seen through fruit weight (0.205), node number of first female flower (0.137) and days to opening of first female flower (0.141). Negative indirect effects were seen through number of fruits per plant (-0.424) and number of seeds per fruit (-0.005).

Productive length of vine had positive direct effect (0.104) on yield. Positive indirect effects were seen through number of fruits per plant (0.218), fruit length (0.008) and number of seeds per fruit (0.036). Low indirect effects were seen via other characters.

Number of seeds per fruit showed direct negative effect (-0.218). But, this negative effect was made up by high positive indirect effect via fruit weight (0.486). Low indirect effects were seen via other characters like fruit length (0.028), number of fruits (0.044), productive length of vine (-0.017) days to first harvest (-0.005) etc.

Fruit length showed low positive direct effect (0.070) on yield. But, this low positive direct effect was made up by high positive

indirect effect via fruit weight (0.405). Positive indirect effects were also seen through number of fruits per plant (0.208), number of leaves at 50 per cent flowering (0.084), productive length of vine (0.013) etc. Negative indirect effects were seen through days to first harvest (-0.083), number of seeds per fruit (-0.087) and node number of first female flower (-0.125).

Number of fruits per plant had high direct positive effect (0.641) on yield, Indirect positive effects were seen through days to first harvest (0.123), fruit length (0.023), productive length of vine (0.035) etc. Negative indirect effects were seen through number of seeds per fruit (-0.015), days to first female flower opening (-0.110) and node number of first female flower (-0.056).

Fruit weight had high direct positive effect (0.609) on yield. Low indirect effects were seen via other characters like fruit length (0.046), number of leaves at 50 per cent flowering (0.062), node number of first female flower (0.041), number of seeds per fruit (-0.174), productive length of vine (-0.019), fruit fly infestation (-0.002), downy mildew incidence (-0.003) etc.

Fruit fly infestation had negative direct effect (-0.093) on yield. Negative indirect effects were seen through number of fruits per plant (-0.283), fruit length (-0.015), productive length of vine (-

0.030) and number of leaves at 50 per cent flowering (-0.012). Low positive indirect effects were seen through other characters.

Downy mildew incidence had negative direct effect (-0.171) on yield. Negative indirect effects were seen through number of leaves at 50 per cent flowering (-0.009), days to first harvest (-0.016)(, productive length of vine (-0.069), number of seeds per fruit (-0.064), fruit length (-0.021) and number of fruits per plant (-0.300). Low positive indirect effects were seen through other characters. Residual factor's direct effect was negligible.

4.4.2 Phenotypic path analysis

Phenotypic path to yield per plant was computed. Direct and indirect effects due to different characters were obtained. In following lines the effects are highlighted. Table 7 shows the results of this analysis.

Days to opening of first female flower showed low negative direct effect (-0.04) on yield, very low indirect positive effects were seen through days to first harvest (0.057) and fruit weight (0.033). Other characters had negligible indirect effects.

Node number of first female flower showed very low positive direct effect (0.009) on yield. Low positive indirect effect was seen through number of fruits per plant (0.153). The indirect effects due

Table 7. Phenotypic path analysis for total yield per plant.

Characters	Days to first female flower opening	Node No. of first female flowering	Number of leaves at 50% flowering	Days to first harvest	Productive length of vine	No. of seeds per fruit	Fruit length	No. of fruits per plant	Fruit weight	Fruit fly infestation	Downy mildew incidence	Correlation with yield
Days to first female flower opening	**-0.040**	0.003	0.017	0.057	0.000	-0.001	0.000	-0.085	0.033	0.003	0.023	-0.11
Node No. of first female flowering	-0.014	**0.009**	0.013	0.015	-0.001	0.002	0.001	0.153	-0.093	0.004	0.055	0.145
Number of leaves at 50% flowering	-0.010	0.002	**0.069**	0.014	0.000	-0.006	0.003	0.000	0.228	0.004	0.014	0.317
Days to first harvest	-0.038	0.002	0.016	**0.061**	0.000	-0.001	0.000	-0.089	0.033	0.005	0.021	0.011
Productive length of vine	0.003	0.002	-0.002	-0.004	**-0.007**	0.000	0.002	0.151	-0.047	0.011	0.078	0.186
No. of seeds per fruit	-0.002	-0.002	0.028	0.005	0.000	**-0.014**	0.003	0.034	0.326	0.007	-0.033	0.353
Fruit length	0.000	0.001	0.030	0.000	-0.001	-0.005	**0.008**	0.174	0.252	0.010	0.027	0.495
No. of fruits per plant	0.005	0.002	0.000	-0.008	-0.002	-0.001	0.002	**0.659**	-0.009	0.027	0.074	0.750
Fruit weight	-0.003	-0.002	0.031	0.004	0.001	-0.009	0.004	-0.011	**0.511**	-0.001	-0.006	0.519
Fruit fly infestation	0.002	-0.001	-0.004	-0.005	0.001	0.002	-0.001	-0.278	0.008	**-0.063**	-0.071	-0.409
Downy mildew incidence	0.005	-0.003	-0.006	-0.008	0.003	-0.003	-0.001	-0.293	0.018	-0.027	**-0.167**	-0.480

Residual : 0.1137

(Direct effect on main diagonal)

to other characters were negligible. Number of leaves at 50 per cent flowering showed low positive direct effect (0.069) on yield. Low positive indirect effects were seen through fruit weight (0.228) and days to first harvest (0.014). Other characters had negligible indirect effects.

Days to first harvest showed low positive direct effect (0.061) on yield, but other characters had negligible indirect effects. Productive length of vine showed negligible negative direct effect on yield. Very low positive indirect effect was seen through number of fruits per plant (0.151), but other characters had negligible indirect effects.

The direct effects of number of seeds per fruit was negligible. Positive indirect effect was seen through fruit weight (0.326), number of fruits per plant (0.034) and number of leaves at 50 per cent flowering (0.028). Other characters showed negligible indirect effects.

The direct effect of fruit length was negligible. Low positive indirect effect was seen through fruit weight (0.252) and number of fruits per plant (0.174). But, other characters had negligible indirect effects. Number of fruits per plants showed high positive direct effect (0.659) on yield. Other characters showed negligible indirect effects. Fruit weight showed high positive direct effect

(0.511) on yield, but other characters showed negligible indirect effects.

Fruit fly infestation showed low negative direct effect (-0.063) on yield. Negative indirect effect was seen through number of fruits per plant (-0.278). Other characters showed negligible indirect effect. Downy mildew incidence showed negative direct effect (-0.167) on yield. Negative indirect effect was seen through number of fruits per plant (-0.293). But, other characters had negligible indirect effects. Residual factors had very low direct effect.

4.5 GENETIC DIVERSITY

4.5.1 Contribution of different characters towards genetic divergence

The relative ranking of different characters showed that the maximum contribution towards the total genetic divergence (Table 8) was made by number of leaves at 50 per cent flowering (63.72%). It was followed by productive length of vine (31.28%) and fruit weight (4.10%). Relatively less contribution was given by number of fruits per plant (0.64%) and days to first female flower opening (0.26%).

Table 8. Contribution of each character towards total genetic divergence

Sl. No.	Character	Contribution (%)
1.	Days to opening of first female flower	0.26
2.	Node at which first female flower appears	0.00
3.	Number of leaves at 50 per cent flowering stage	63.72
4.	Days to first harvest	0.00
5.	Productive length of vine	31.28
6.	Number of seeds per fruit	0.00
7.	Fruit length	0.00
8.	Number of fruits per plant	0.64
9.	Total yield per plant	0.00
10.	Fruit weight	4.10
11.	Fruit fly infestation	0.00
12.	Downy mildew incidence	0.00

4.5.2 Group constillation : Intra and inter cluster distance

The average D^2 values within (intra) and between (inter) clusters are presented in Table 9. Using the estimated D^2 values as the squares of generalized distance, 40 genotypes were grouped into 10 clusters, following the method suggested by Tocher (Rao, 1952). The inter cluster D^2 values of 10 clusters showed that maximum genetic divergence existed between cluster VI and IX (D^2 = 324.518) followed by cluster VII and IX (D^2 = 322.698). The minimum genetic divergence was between cluster III and V (D^2 = 75.548) followed by cluster III and IX (D^2 = 84.671).

Among intra cluster distance maximum genetic divergence was observed in cluster II (D^2 = 74.010) while minimum in cluster V (D^2 = 40.633).

The composition of genotypes in different clusters is presented in Table 10. Cluster I had maximum number of genotypes (16) followed by cluster II which had 11 genotypes. Cluster I had maximum distance with cluster VI (D^2 = 251.215) and minimum with cluster III (D^2 = 91.907). It had an intra cluster D^2 value of 68.697. Cluster II had maximum distance with cluster IX (D^2 = 289.220) and minimum with cluster VII (D^2 = 104.468). The intra cluster D^2 value was 74.010.

Table 9. Intra and inter cluster distance in 10 clusters.

Clusters	I	II	III	IV	V	VI	VII	VIII	IX	X
I	68.697	192.438	91.907	122.521	104.246	251.215	200.940	178.835	143.858	135.506
II		74.010	213.419	239.313	154.310	108.633	104.468	113.837	289.220	167.542
III			0.000	182.624	75.548	250.818	250.305	159.258	84.671	194.536
IV				73.588	195.692	317.291	204.897	262.751	216.750	116.663
V					40.633	182.909	201.690	95.071	151.462	181.047
VI						49.187	177.392	99.188	324.518	250.536
VII							0.000	188.363	322.698	123.683
VIII								0.000	231.807	217.062
IX									0.000	251.171
X										0.000

Table 10. Composition of bitter gourd genotypes in different clusters

Cluster No.	No. of genotypes in each cluster	Genotypes
I	16	Konkatara, DWD-2/A, IC 44418, IC 32817, IC 68250A, IC85626, IC 68316, IC 85606A, IC 68285, IC 50526, IC 68225, IC 85618, IC 68232, IC68292, PRD-1 and IC85670
II	11	IC 45352, Pusa Visheh, Pusa domausami, PRD-2, PRD-5, PRD-4, BLG-2, DWD-5, NRN-1, DWD-1 and DWD-4
II	1	IC 68310
IV	4	IC 44419, Nakhara, solancole -3, PRD-3
V	2	Green long, IC 85614
VI	2	BLG-1, DWD-2
VII	1	IC 85619
VIII	1	White long
IX	1	NDN-1
X	1	Arka Harit

Cluster IV displays third position in its composition consisting of 4 genotypes. The maximum inter cluster distance was with cluster VI (D^2 = 317.291) and minimum with cluster X (D^2 = 116.663). The intra cluster distance for cluster IV was 73.588.

Cluster V and VI consisted of two genotypes each, while cluster III, VII, VIII, IX, X were solitary with one genotype each.

4.5.3 Cluster means

Cluster means were computed in all the 10 clusters for 12 characters studied and is presented in Table 11. Cluster III required least days (43.25) for first female flower opening. Whereas, cluster IX took maximum days (60.00) to first female flower opening. Node number of first female flower was least for cluster IV (6.06) and maximum for cluster VI (13.25). The mean values for number of leaves at 50 per cent flowering were maximum (496.0) in cluster VI followed by cluster II (432.77). The minimum value (189.0) was in cluster IX.

The maximum value (73.0) for days to first harvest was shown by cluster VII followed by cluster IX (70.0). The minimum cluster mean (57.15) was found in cluster X. For productive length of vine the cluster mean was maximum (366.5) in cluster IX and minimum

Table 11. Cluster means for 12 quantitative characters in bitter gourd.

Sl. No.	Characters	Clusters									
		I	II	III	IV	V	VI	VII	VIII	IX	X
1.	Days to first female flower opening	49.18	54.44	43.25	49.18	42.75	54.25	56.5	52.25	60.00	43.5
2.	Node No. of first female flowering	9.42	10.34	10.45	6.06	8.00	13.25	10.00	11.25	12.0	6.5
3.	Number of leaves at 50% flowering	260.68	432.77	255.00	213.75	319.50	496.00	411.50	410.50	189.0	308.5
4.	Days to first harvest	66.32	67.85	58.45	65.21	61.25	68.25	73.00	66.75	70.0	57.15
5.	Productive length of vine	239.46	228.68	331.50	173.25	317.00	219.75	140.00	328.00	366.5	147.65
6.	No. of seeds per fruit	20.38	16.87	15.00	23.50	25.50	30.75	26.50	21.50	22.5	13.75
7.	Fruit length	13.16	16.26	15.80	12.88	18.22	20.30	17.30	16.15	10.90	6.95
8.	No. of fruits per plant	24.87	18.50	15.00	18.50	23.75	37.50	15.00	17.50	15.50	18.50
9.	Total yield per plant	1.32	1.25	0.75	1.31	1.84	3.38	1.18	1.44	0.43	0.50
10.	Fruit weight	60.38	73.70	54.30	76.06	75.62	89.92	82.25	80.80	25.40	21.65
11.	Fruit fly infestation	17.25	14.81	23.50	12.87	7.40	4.62	10.05	7.60	7.50	25.60
12.	Downy mildew incidence	33.75	52.77	34.5	80.37	25.50	11.25	92.0	10.0	29.0	75.0

(140.0) in cluster VII. Cluster mean for number of seeds was highest (30.75) in cluster VI and lowest (13.75) in cluster X.

Cluster mean for fruit length was maximum (20.30) in cluster VI and minimum (6.95) in cluster X. For number of fruits per plant cluster VI showed the highest mean value of 37.5 followed by cluster I (24.87). The lowest value (15.00) was shown by cluster III and VII.

The cluster VI had the highest mean (3.38) fruit yield per plant followed by cluster V (1.84) and cluster VIII (1.44). The lowest mean fruit yield per plant (0.43) was reported in cluster IX.

Cluster VI showed highest cluster mean (89.92) for fruit weight, followed by cluster VII (82.25) and cluster VIII (80.80). The lowest cluster mean (21.65) was recorded in cluster X.

The genotypes in cluster X were most susceptible to fruit fly infestation (25.60) followed by cluster III (23.5). The resistant genotypes were found in cluster VI (4.62). Cluster VII showed highest cluster mean (92.0) for downy mildew incidence followed by cluster IV (80.37) and cluster X (75.0), while cluster VIII exhibited lowest cluster mean (10.0) followed by cluster VI (11.25) and cluster V (25.5).

4.6 SOURCE OF RESISTANCE FOR PEST AND DISEASE

4.6.1 Fruit fly infestation

Comparative resistance of different genotypes of bitter gourd to fruit fly is presented in Table 12.

The fruit infestation recorded as percentage of fruits infested, ranged from 2.40 to 28.25. The lowest (2.40%) incidence of fruit fly infestation was recorded in BLG-1 and highest (28.25%) in Pusa do mausami. The mean fruit infestation was 12.63.

Based on per cent fruit infestation the genotypes were grouped into different categories (Table 13). Out of 40 genotypes, 7 were resistant, 12 were moderately resistant, 15 were moderately susceptible, the rest were susceptible. None of the genotypes were found to be highly susceptible.

4.6.2 Downy mildew incidence

Comparative resistance of different genotypes of bitter gourd to downy mildew disease is presented in Table 14.

The disease intensity recorded as per cent leaf area infected ranged from 10.0 to 98.0. The lowest intensity (10.0%) was recorded in genotypes white long and BLG-1 and highest (98%) in genotype Solan cole – 3, the mean disease severity was 43.27 per cent.

Table 12. Comparative resistance of different bitter gourd genotypes to fruit fly.

Sl. No.	Genotype	Fruit fly infestation (%)
1.	IC45352	6.70
2.	Konkantara	4.10
3.	DWD-2/A	8.85
4.	IC85619	10.05
5.	Green long	9.55
6.	White long	7.60
7.	Arka Harit	25.60
8.	Pusa Visheh	9.75
9.	Pusa do mausami	28.25
10.	Solan cole-3	23.50
11.	IC44418	3.65
12.	IC44419	6.60
13.	IC32817	4.75
14.	IC85614	5.25
15.	IC68250A	17.50
16.	IC856256	12.50
17.	IC68316	11.50
18.	IC85606A	4.55
19.	IC68285	16.00
20.	IC50526	11.60
21.	IC68310	23.50
22.	IC68225	13.50
23.	IC85618	6.60
24.	IC85670	18.25
25.	Nakhara	18.10
26.	IC68232	17.10
27.	IC68292	19.35
28.	PRD-1	20.00
29.	PRD-2	8.60
30.	PRD-5	12.25
31.	PRD-4	13.70
32.	PRD-3	6.25
33.	BLG-1	2.40
34.	BLG-2	4.60
35.	DWD-5	24.25
36.	DWD-2	6.85
37.	NDN-1	7.50
38.	NRN-1	17.00
39.	DWD-1	23.65
40.	DWD-4	14.25
	Mean	**12.63**

Table 13. Grouping of bitter gourd genotypes into different categories on the basis of per cent fruit infestation.

Sl. No.	Per cent fruit infestation	Reaction	No. of genotypes	Genotypes
1.	0-5	Resistant	7	Konkantara, IC4418, IC32817, K85606A, BLG-1, BLG-2, IC85614
2.	6-10	Moderately resistant	12	IC45352, DWD-2/A, Green long, White long, Pusavisheh, IC44419, IC85618, PRD-2, PRD-3, DWD-2, NDN-2, IC85619
3.	11-20	Moderately susceptible	15	IC85626, IC68316, IC68285, IC50526, IC68225, IC85670, Nakhara, IC68232, IC68292, PRD-1, PRD-5, PRD-4, NRN-1, DWD-4, IC68250A
4.	21-50	Susceptible	6	Arka Harit, Pusa do mausami, Solan cole-3, IC68310, DWD-5, DWD-1
5.	>50	Highly susceptible	-	-

Table 14. Comparative resistance of different bitter gourd genotypes to Downy mildew incidence.

Sl. No.	Genotype	Downy mildew incidence (%)	Score (0-5)
1.	IC45352	29.5	3
2.	Konkantara	37.0	3
3.	DWD-2/A	41.0	3
4.	IC85619	92.0	5
5.	Green long	33.5	3
6.	White long	10.0	1
7.	Arka Harit	75.0	4
8.	Pusa Visheh	60.0	4
9.	Pusa do mausami	96.0	5
10.	Solan cole-3	98.0	5
11.	IC44418	22.5	2
12.	IC44419	30.0	3
13.	IC32817	27.0	3
14.	IC85614	17.5	2
15.	IC68250A	78.5	5
16.	IC856256	30.0	3
17.	IC68316	22.5	2
18.	IC85606A	29.0	3
19.	IC68285	30.0	3
20.	IC50526	21.5	2
21.	IC68310	34.5	3
22.	IC68225	50.0	3
23.	IC85618	37.5	3
24.	IC85670	40.0	3
25.	Nakhara	96.0	5
26.	IC68232	32.5	3
27.	IC68292	32.5	3
28.	PRD-1	37.5	3
29.	PRD-2	23.0	2
30.	PRD-5	93.5	5
31.	PRD-4	87.5	5
32.	PRD-3	97.5	5
33.	BLG-1	10.0	1
34.	BLG-2	35.5	3
35.	DWD-5	57.5	4
36.	DWD-2	12.5	2
37.	NDN-1	29.0	3
38.	NRN-1	38.0	4
39.	DWD-1	32.5	3
40.	DWD-4	27.5	3
	Mean	43.275	3.25

Based on per cent leaf area infected and scores, the genotypes were grouped into different categories (Table 15). Out of the 40 genotypes, 8 were highly susceptible, 4 were susceptible, 20 were moderately susceptible, 6 were moderately resistant and 2 were resistant. None of the genotypes were immune to this disease.

Table 15. Grouping of bitter gourd genotypes on the basis of downy mildew incidence into different categories.

Sl. No.	Per cent leaf area infected	Score	Reaction	No. of genotypes	Genotypes
1.	0	0	Immune	-	-
2.	1-10	1	Resistant	2	White long, BLG-1
3.	11-25	2	Moderately resistant	6	IC44418, IC85614, IC68316, IC50526, PRD-2, DWD-2
4.	26-50	3	Moderately susceptible	20	IC45352, Konkantara, DWD-2/A, Green long, IC44419, IC32817, IC85626, IC85606A, IC68285, IC68310, IC68225, IC85618, IC85670, IC68232, IC68292, PRD-1, BLG-2, NDN-1, DWD-1, DWD-4
5.	51-75	4	Susceptible	4	Arkaharit, Pusa Visheh, DWD-5, NRN-1
6.	76-100	5	Highly susceptible	8	PRD-3, PRD-4, PRD-5, Nakhara, IC68250A, Solan cole-3, Pusa domausami, IC85619

Discussion

V. DISCUSSION

Before aiming an improvement in a crop it is essential to have knowledge of the variability present in the population. The existence of genetic variability among the genotypes for the character to be improved is the most important basic factor for successful selection.

Evaluation of large number of genotypes is the basic step for successful breeding programme. The genotypic and environmental variance and their interaction (G x E) can be determined by employing useful biometrical tools.

Some of these parameters include genotypic (GCV) and phenotypic (PCV) coefficients of variation, heritability and genetic advance. Genotypic and phenotypic correlations help, to base selection procedure to a required balance when two opposite desirable characters affecting the principle characters are being selected. It also helps to improve different characters simultaneously (Falconer, 1981).

Path analysis critically breaks up correlations into direct and indirect effects of component character on dependent variable.

The D^2 statistics enables to study the genetic divergence among the genotypes. The results of clustering analysis gives an insight about diverse nature of the genotypes in a cluster.

In bitter gourd the crop productivity is limited by pests and disease. The full potential of available sources of resistance can only be realized if the genotypes are screened against major pest (fruit fly) and disease (downy mildew), which will help for identification of resistant source and in successful introgression into commercial variety.

The principle concern of the present investigation was to study the genetic variability and character association in 40 genotypes of bitter gourd. The findings of the experiment conducted are discussed here.

5.1 GENETIC VARIABILITY

The analysis of variance indicated highly significant variation among genotypes for all characters studied, except days to opening of first female flower and days to first harvest. This indicated presence of high degree of variation and diversity among the forty genotypes. Similar results were obtained by Singh *et al.* (1977), Ramachandran (1978), Indiresh (1979), Hawalader *et al.* (1999) and Sarnaik *et al.* (1999).

High phenotypic variance was recorded for vine length, number of leaves at 50 per cent flowering, productive length of vine and fruit weight. But, phenotypic variance is not very reliable, since it

includes both genetic and environmental effects. Thus, it is essential to split total variance into genetic and non-genetic components. Almost all characters except number of primary branches per plant, days to opening of first female flower, node number of first female flower, days to first harvest and fruit length showed more genotypic variance than environmental. This indicated that genetic component in total variation is more and environmental influence is less in case of these traits. Thus, selection scheme planned based on these characters will have high selection response. Higher values of all three variations for characters like vine length, number of leaves at 50 per cent flowering and productive length of vine, indicates presence of significant variation for these characters in the genotypes under study. Similar findings were reported by Singh *et al.* (1977) and Ramachandran (1978), Kadam and Kale (1987) in ridge gourd, Rajput *et al.* (1996), Sarnaik *et al.* (1999) in Ivy gourd and Bisognin and Storck (2000) in bottle gourd.

The magnitude of variance, as such does not reveal the relative amount of variability as ascertained through coefficients of variation. PCV was higher than GCV for all the characters (Fig. 1). Characters like vine length, number of nodes per vine, number of leaves at 50 per cent flowering, flesh thickness and fruit weight,

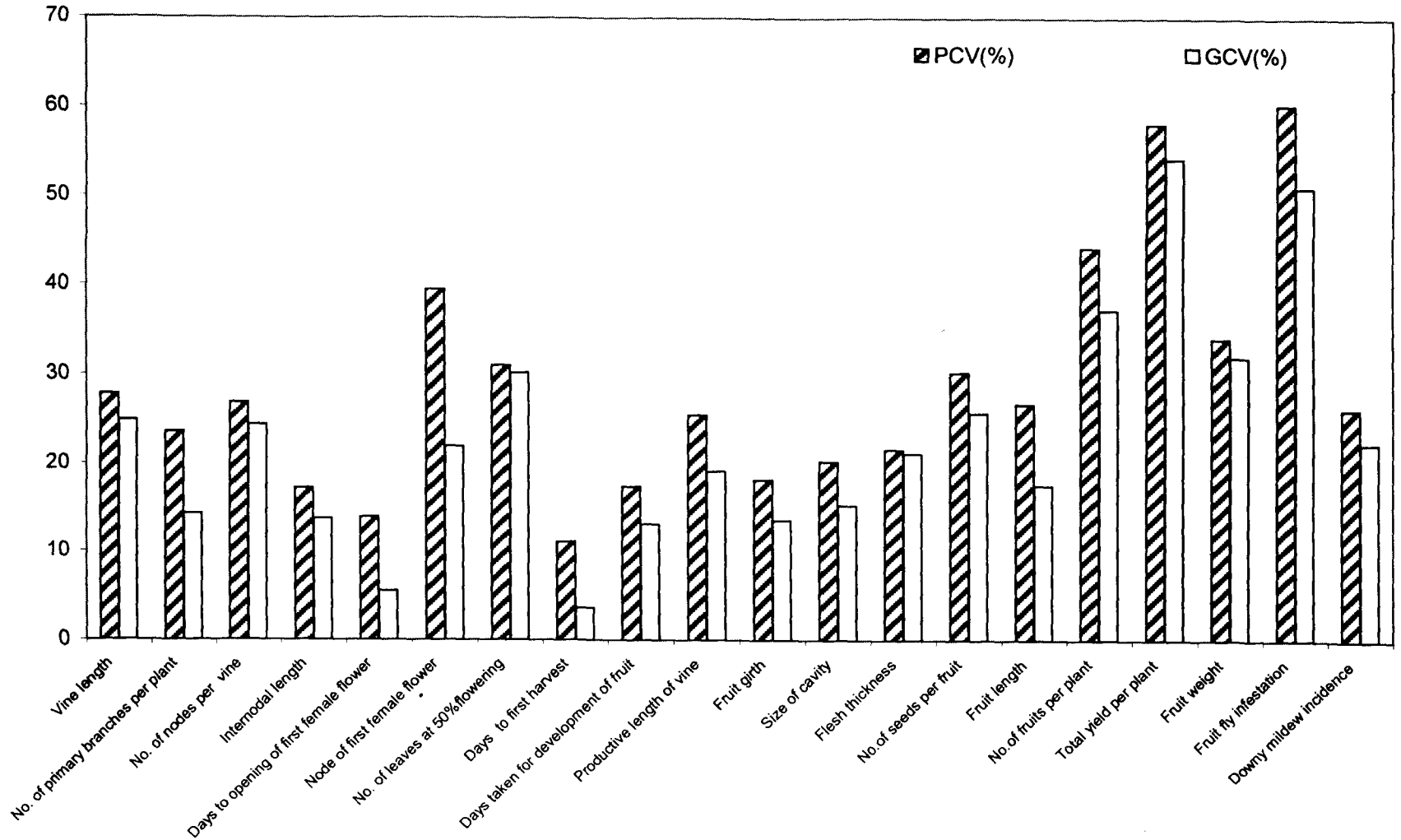


Fig. 1. Phenotypic and genotypic coefficients of variaton for quantitative characters.

showed narrow differences between phenotypic and genotypic coefficient of variation, indicating less influence of environment in the expression of these characters. Thus, selection for these characters would be more effective. The other characters showed moderate to high differences between GCV and PCV indicating more sensitivity of these characters to environmental factors. Thus, response to selection would be poor. Similar results were reported by Srivastava and Srivastava (1976), Ramachandran (1978), Mangal *et al.* (1981), Rajput *et al.* (1996).

High values for GCV was recorded for yield and yield attributing characters like fruit weight, number of fruits per plant, number of seeds per fruit. Similar results were obtained by Singh *et al.* (1977), Ramachandran and Gopalakrishnan (1979), Mangal *et al.* (1981) and Rajput *et al.* (1996).

However, the effectiveness of selection for any character depends not only on the amount of phenotypic and genotypic variability but also on estimates of heritability. Heritability value indicates the heritable portion of variation. Burton (1952) had suggested that genotypic coefficient of variation together with heritability estimates would give the best picture of the amount of progress to be expected by selection. Broad sense heritability estimates for vine length, number nodes per vine, flesh thickness,

number of leaves at 50 per cent flowering, number of seeds per fruit, number of fruits per plant, fruit yield per plant, fruit weight, fruit fly infestation and downy mildew incidence were high ranging from 71.0 per cent to 96.0 per cent. Thus, these characters are less influenced by environmental factors and are under the additive gene effect. The results were in confirmity with Srivastava and Srivastava (1976), Singh et al. (1977), Ramachandran and Gopalakrishnan (1979), Mangal et al. (1981) and Mohanty and Mishra (1999).

The attributes like number of branches per plant, internodal length, node number of first female flower, days to first harvest, productive length of vine, fruit girth, size of cavity and fruit length exhibited moderate heritability estimates, meaning that these characters are moderately influenced by environment (Fig. 2). These observations were in confirmity with the earlier results obtained by Chaudhari *et al.* (1991) and Rajput *et al.* (1996). Low heritability estimate was shown for days to first female flower opening and days to first harvest, thus limiting the scope of selection for these traits.

Heritability estimates along with genetic gain (genetic advance as per cent mean) is more useful than heritability alone in predicting the resultant effect for selecting the best individuals (Johnson *et al.*, 1955). Genetic advance is the measure of improvement that can be achieved by practising selection in a

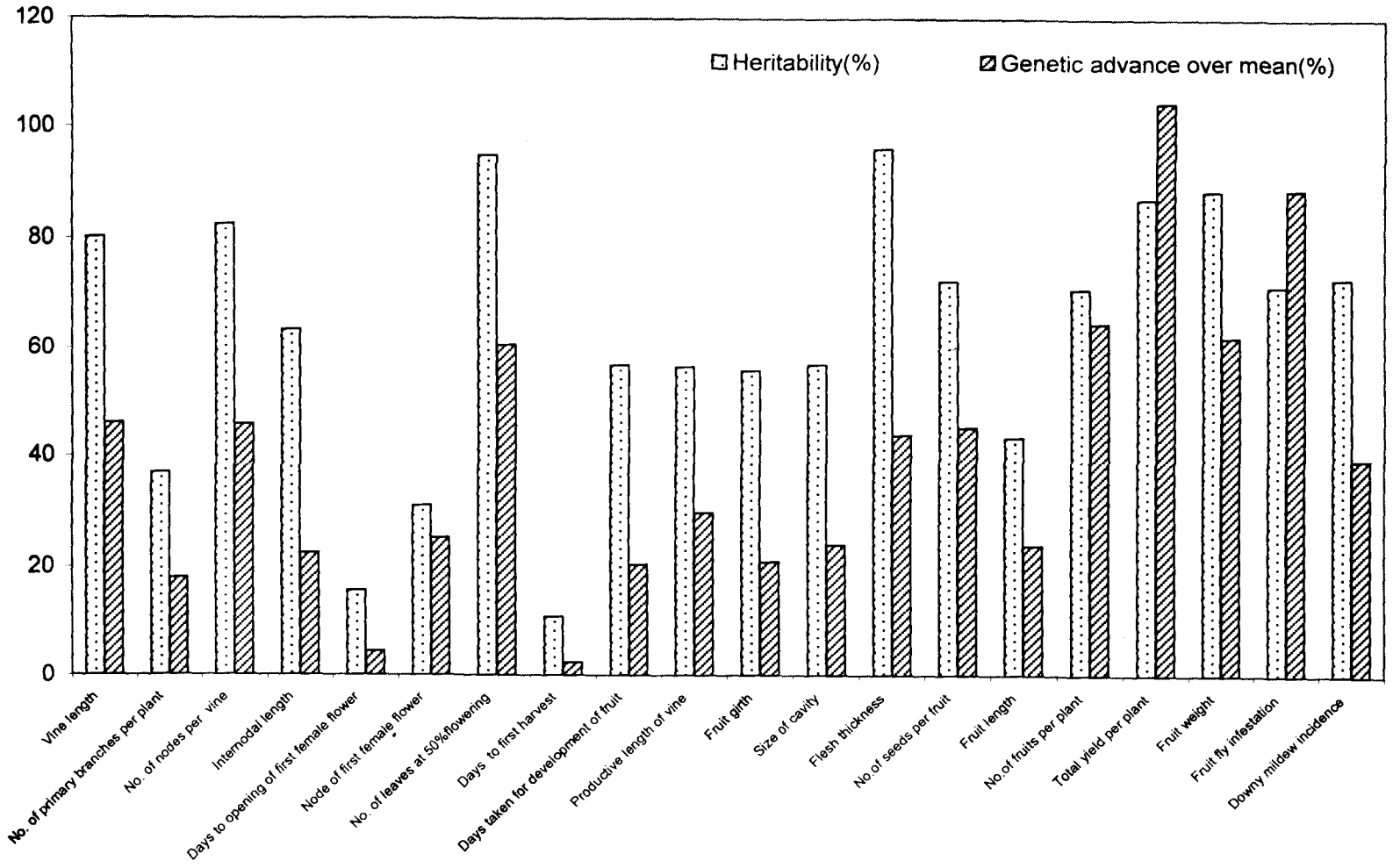


Fig. 2. Heritability(bs) and Genetic advance over mean *for quantitaive characters.*

population. High heritability with low genetic advance indicates importance of non-additive gene action, while high heritability with high genetic advance indicates additive gene effects.

In the present study high genetic advance over mean coupled with high heritability was observed in characters like vine length, number of nodes per vine, internodal length, number of leaves at 50 per cent flowering stage, flesh thickness, number of seeds, number of fruits per plants, fruit weight, fruit yield, fruit fly infestation and downy mildew incidence. While moderate heritability with high genetic advance over mean was observed for productive length of vine, node number of first female flower, days to development of fruit, fruit girth, size of cavity and fruit length. Thus, these characters were under additive gene effects and could be improved by simple selection schemes. Number of primary branches per plant showed moderate heritability with moderate genetic advance over mean. Hence, could be improved by following vigorous selection procedures. Days to first female flower opening and days to first harvest showed low values for heritability and genetic advance over mean, thus there is little scope for selection. These findings are in accordance with Srivastava and Srivastava (1976), Ramachandran (1978), Mangal *et al.* (1981), Varalakshmi *et al.* (1995) in ridge gourd and Rajput *et al.* (1996).

5.2 CHARACTER ASSOCIATION

In any crop improvement programme, it becomes necessary to have simultaneous progress of more than one character, especially in the case of complex character like yield, which is influenced by many other traits. This is due to the physiological and linkage relationships of genes governing various characters. Hence, knowledge of correlations between different economical characters are of importance in selection programmes. Positive correlation makes simultaneous improvement in two or more attributes possible, whereas negative association indicates the need to compromise between desirable characters.

For a rational approach towards the improvement of yield selection has to be made for the components of yield, since there may not be genes for yield *per se*, but only for various yield components (Grafius, 1959). Therefore, it is essential to comprehend the interrelations of various yield components in an inter linked system.

The simple correlation study is inadequate to measure the association as different genotypes are susceptible to environment to varying degrees. Estimates of phenotypic and genotypic correlations pave way for understanding environmental influence on heredity expression.

In the present investigation, except in a few cases, the genotypic correlations were higher than phenotypic correlations, indicating little influence of environment and the presence of inherent association between various characters. Higher magnitude of genotypic correlation was observed earlier also by Srivastava and Srivastava (1976).

In all instances, however, more reliance may be placed on the genotypic correlations. Yield per plant showed positive and significant correlation with number of leaves at 50 per cent flowering stage, number of seeds per fruits, fruit length, number of fruits per plant and fruit weight both at genotypic and phenotypic level (Plate 5a & 5b). While correlation of fruit yield with node number of first female flower and productive length of vine was positive and significant only at genotypic level. Since, these associations are in the desirable direction, selection for these traits may improve the yield per plant. Ramachandran and Gopalakrishanan (1979) made similar observations in case of number of fruits per plant, fruit weight, fruit length and vine length, Singh *et al.* (1996) reported significant positive association of yield with node number of first female flower in bottle gourd.

Days to opening of first female flower was positively and significantly associated with node number of first female flower,

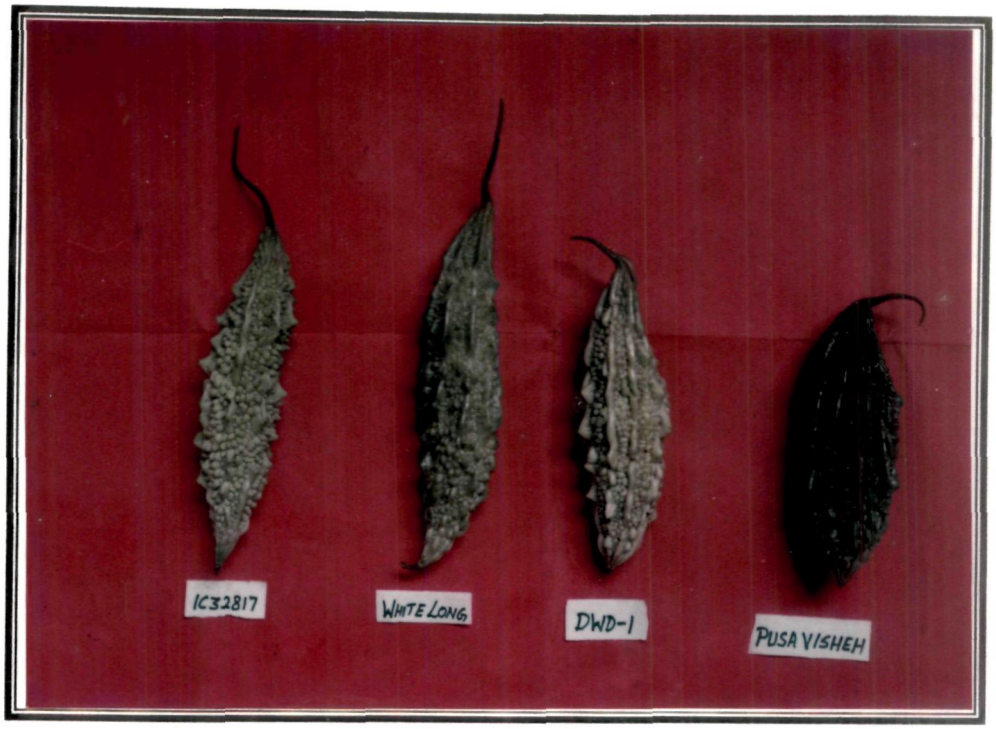


Plate 5a. Medium long fruited genotypes.

Plate 5b. Medium long fruited genotypes.

number of leaves at 50 per cent flowering stage, days to first harvest, fruit length and fruit weight, while number of fruits were negatively correlated. This showed that an early flowering variety will produce the first female flower at a lower node, than a late variety. Similarly an early flowering variety will produce an early harvest of the crop, while a late variety will provide less number of fruits per plant with higher fruit weight and fruit length. Higher photosynthetic efficiency in late varieties, due to enhanced number of leaves per plant will lead to higher fruit weight and fruit length. Similar results were obtained by Pal and Vani (1986).

Number of seeds per fruit showed significant positive correlation with fruit length, fruit yield per plant and fruit weight both at genotypic and phenotypic level. Hence, selection for more number of seeds per fruit can bring about improvement in yield and fruit size. Similar results were obtained by Singh *et al.* (1987) in pointed gourd. Number of fruits per plant and total yield per plant were negatively and highly significantly associated with fruit fly infestation both at phenotypic and genotypic level. Thus, higher the fruit fly infestation equally drastic will be the yield reduction, since the pest causes direct damage to the fruit. Similar results were obtained by Thakur *et al.* (1996). The negative correlation between fruit length and fruit fly infestation (at genotypic level) indicates

that with the severity of attack by the pest, further development of fruit is hampered.

Total yield per plant, number of fruits per plant, productive length of vine and node number of first female flower showed significant negative association with downy mildew incidence at both the phenotypic and genotypic level. This indicated significant yield loss due to occurrence of downy mildew disease. Similar results were obtained by Thakur *et al.* (1996).

5.3 PATH COEFFICIENT ANALYSIS

Association of characters determined by correlation coefficients will not provide exact picture of the relative importance of direct and indirect influence of each of the characters towards yield. Path coefficient analysis furnishes a means of measuring the direct effect of each trait, as well as, the indirect effect through other yield components.

In the present study path analysis was performed for total yield per plant. Both genotypic and phenotypic path were worked out, but genotypic path should be considered with more weightage as phenotypic path will have a greater influence of environmental factors.

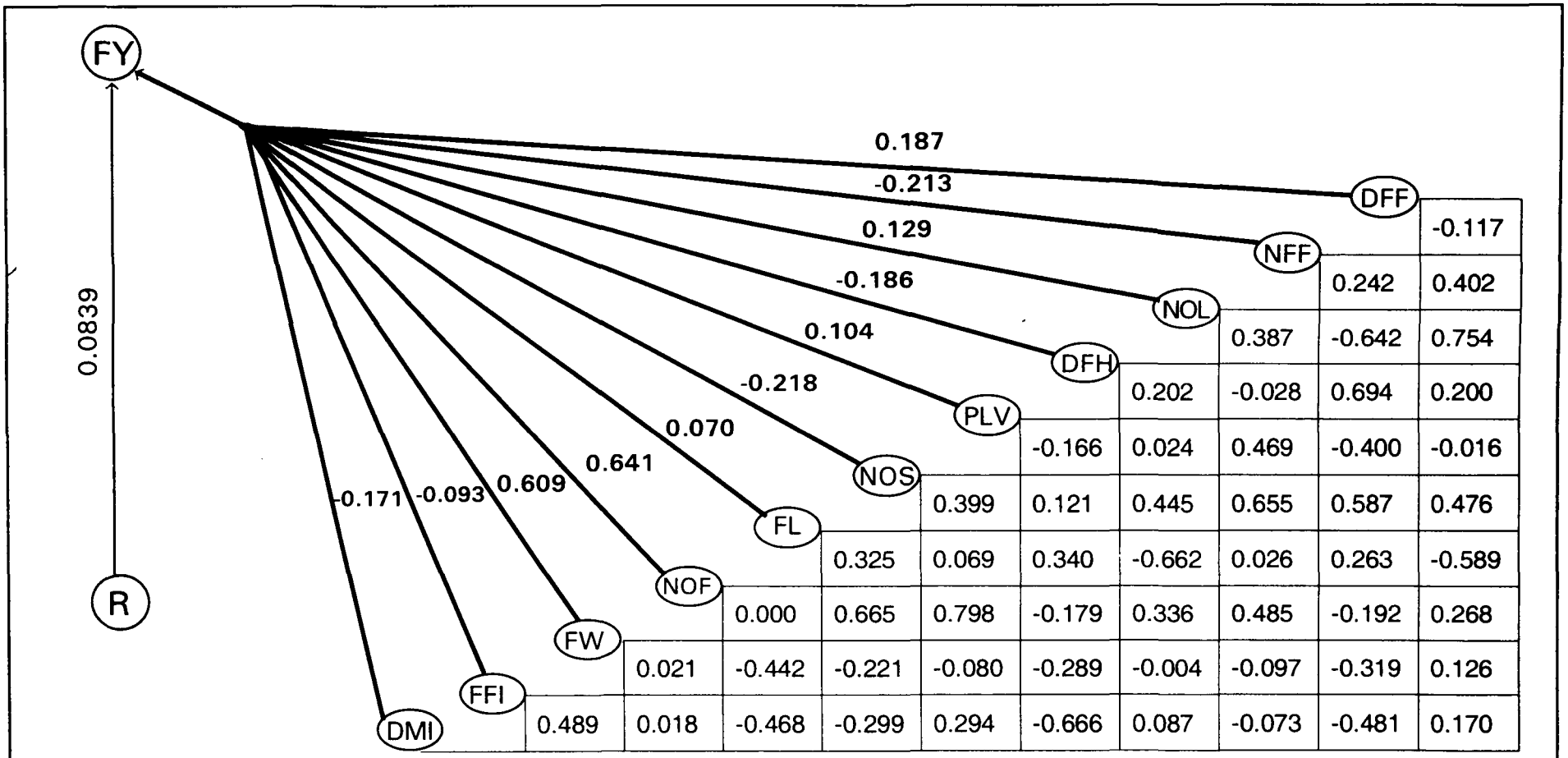
Among the 12 characters studied, number of fruits per plant and fruit weight had high direct effect on yield at both phenotypic and genotypic levels. Similar results were obtained by Ramachandran (1978).Days to first female flower opening showed positive direct effect in genotypic path, which was reduced by negative indirect effect through days to first harvest, which also showed negative direct effect on yield. In both cases high negative indirect effect was observed through number of fruits per plant, indicating similar trends that of genotypic correlation studies wherein maturity is negatively correlated with yield per plant.

Though low positive direct effect of number of leaves at 50 per cent flowering was observed, higher positive indirect effect through fruit weight resulted in increased genotypic correlation with yield. Similarly low positive direct effect of productive length of vine coupled with higher positive indirect effect through number of fruits per plant resulted in significant genotypic correlation with yield.

Number of seed per fruit showed negative direct effect, but high indirect positive effect was observed through fruit weight. Thus, increasing the over all genotypic correlation with yield. Eventhough fruit length showed low positive direct effect, the high indirect effects through fruit weight and number of fruit per plant, explains the high genotypic correlation with yield.

Number of fruits per plant and fruit weight were the most important factors contributing to yield per plant as they showed very high direct effects. Fruit fly infestation showed low negative direct effect on yield, but the high negative correlation coefficient was due to negative indirect effects through number of fruits per plant, fruit length, productive length of vine and number of leaves at 50 per cent flowering. Downy mildew incidence showed negative direct effect which was further enhanced by negative indirect effects through number of fruits per plant, fruit length, number of seeds per fruit, productive length of vine, days to first harvest and number of leaves at 50 per cent flowering, resulting in high negative correlation coefficient.

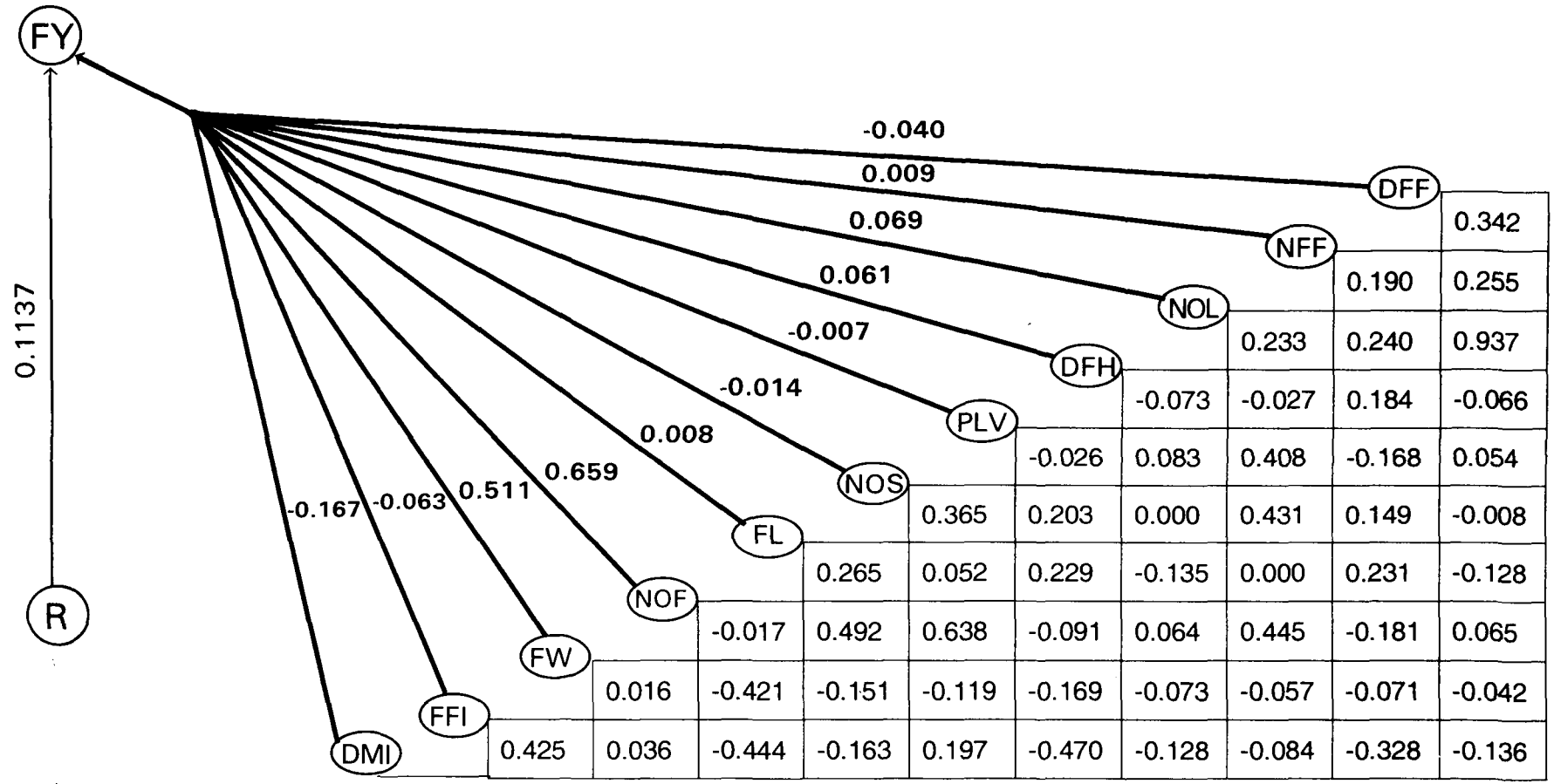
From the breeders point of view, the characters with high positive correlation and high direct effects are useful for selection. Thus, it can be concluded that number of fruits per plant and fruit weight are the most important factors influencing yield through direct effect coupled with high positive correlation and also by indirect effects through other characters (Fig 3). In phenotypic path also similar trends were observed in case of direct and indirect effects as well as correlation of the characters with yield, number of fruits per plant and fruit weight were the most important attributes contributing to yield (Fig. 4).



Arrow indicates direct effect, thin lines indicate correlation coefficients

DMI - Downy mildew incidence
FFI - Fruit fly infestation
FW - Fruit weight
NOF - Number of fruits per plant
FL - Fruit length
NOS - Number of seeds per fruit
PLV - Productive length of vine
DFH - Days to first harvest
NOL - Number of leaves at 50% flowering
NFF - Node of first female flower
DFF - Days to opening of first female flower
FY - Total yield per plant
R - Residual effect

Fig. 3: Genotypic path diagram for total yield per plant



Arrow indicates direct effect, thin lines indicate correlation coefficients

DMI - Downy mildew incidence
FFI - Fruit fly infestation
FW - Fruit weight
NOF - Number of fruits per plant
FL - Fruit length
NOS - Number of seeds per fruit
PLV - Productive length of vine
DFH - Days to first harvest
NOL - Number of leaves at 50% flowering
NFF - Node of first female flower
DFF - Days to opening of first female flower
FY - Total yield per plant
R - Residual effect

Fig. 4: Phenotypic path diagram for total yield per plant

The observations are in confirmity with authors like Srivastava and Srivastava (1976), Ramachandran (1978), Singh *et al.* (1993) in pointed gourd, Kumar and Singh (1998) in bottle gourd, Shaha *et al.* (1999) in ridge gourd, Rao *et al.* (1999) in ridge gourd and Sarkar *et al.* (1999) in pointed gourd.

5.4 GENETIC DIVERGENCE

The 40 bitter gourd genotypes were grouped into 10 clusters using Tocher's method (Rao, 1952) employed on the Mahalanobis's generalized distance (D^2) values. Cluster I accounted for 16 genotypes followed by cluster II with 11 genotypes. Thus the first two clusters alone accounted for 27 genotypes out of 40 genotypes under study. Cluster III, VII, VIII, IX, X were solitary having single genotype each, indicating a distinct diversity among the genotypes.

Formation of solitary clusters is due to geographical barriers preventing gene flow, or intensive natural or artificial selection for diverse adoptive gene complexes. However, grouping pattern indicated that geographical diversity did not seem to have a direct association with genetic diversity. This is evidenced by the genotypes originating in different geographical region occupying same cluster, while different genotypes with same origin occupying different clusters. Similar findings were earlier reported by Wahab

and Gopalakrishanan (1993) and Varalakshmi *et al.* (1994) in ridge gourd.

The maximum contribution to the total divergence was from number of leaves at 50 per cent flowering followed by productive length of vine, fruit weight, number of fruits per plant and days to first female flower opening, which lead to grouping of genotypes into different clusters. This contribution is an important consideration for the purpose of further selection and choice of parents for hybridization. However, Parhi *et al.* (1993) reported that 100 seed weight contributed maximum towards divergence, followed by number of seeds per fruit and yield per plant. These differences in the contributing factors for genetic divergence is attributed to different genotypes under study, environmental conditions, method of analysis etc.

The main objective of D^2 analysis is to identify diverse clusters and select genotypes from them for hybridization. In the present study cluster V showed the lowest (D^2 = 40.633) intracluster distance, while cluster II the highest (D^2 = 74.010). The highest diversity within cluster II may be due to both natural and artificial selection forces among genotypes. Intercluster distance was minimum between the clusters III and V followed by clusters III and IX indicating the genotypes of these clusters were genetically close.

Intercluster distance was maximum between clusters VI and IX followed by clusters VII and IX indicating the genotypes belonging to these clusters could be used as parents in hybridization programme to get higher heterotic hybrids and/or isolate a good variant as a genotype from the segregating population. Similar views were expressed by Wahab and Gopalakrishanan (1993), Parhi *et al.* (1993), Prasad and Singh (1997) and Ram (2001) in pointed gourd.

The mean obtained for various characters from varying number of genotypes in each cluster gives an idea of the diversity among the clusters compared. It also helps to group clusters according to their average performance. Cluster V, III and X were early flowering types, while clusters VII and IX were late flowering types. Cluster III, VII and IX can be categorized as low fruit bearing group, whereas, cluster VI was high fruit bearing one. In case of yield per plant clusters VI and V were high yielders. Whereas, clusters IX, X and III were low yielders and rest of the clusters were medium yielders. It was observed that the high yielders also produced more number of fruits per plant indicating a direct relationship between these characters.

The genotypes with low incidence of fruit fly infestation were congregated in the clusters VI, V, IX and VIII. While clusters VI, and VIII showed lowest levels of downy mildew incidence, indicating the

resistant sources in these clusters. Cluster VI included genotypes with most of the superior traits like highest fruit yield per plant, fruit weight, number of fruits per plant, fruit length, number of seeds per fruit, number of leaves at 50 per cent flowering, lowest level of fruit fly infestation and second lowest level downy mildew incidence. Thus, the genotypes from cluster VI could be utilized as potential parents in breeding programme. Similar, results were obtained by other scientists Parhi *et al.* (1993), Prasad *et al.* (1993) in cucumber, Varalakshmi *et al.* (1994) in ridge gourd and Ram (2001) in pointed gourd.

5.5 SOURCE OF RESISTANCE FOR PEST AND DISEASE

5.5.1 Fruit fly infestation

The fruit fly is most serious pest of cucurbits defying chemical control in India (Bose and Som, 1990). Any breeding programme for selection of best ideotype involving resistance to pest, must begin with extensive screening of genotypes. Success in locating resistance/tolerance to fruit fly for hybridization is directly related to the availability of diversity in germplasm. This necessitated the search for genes in available genotypes. In view of that an attempt was made to screen genotypes belonging to diverse origin for resistance to fruit fly.

The percentage of fruit fly infestation in 40 bitter gourd genotypes is shown in Fig. 5. None of the genotypes were free from attack. The frequency distribution of fruit fly infestation in the 40 genotypes is shown in Fig. 6. It was observed that 17.5 per cent of genotypes were resistant, 30 per cent were moderately resistant, 37.5 per cent were moderately susceptible and 15 per cent were susceptible. Genotypes BLG-1, IC44418, Konkantara, IC85606A and BLG-2 showed the lowest levels of fruit infestation. Based on the yield and component characters and resistance to fruit fly BLG-1 proved most promising. Resistance sources of fruit fly, in bitter gourd have been reported by other scientists like Lall and Sinha (1974), Thakur *et al.* (1992), Tewatia and Dhankhar (1996), Thakur *et al.* (1996) and Tewatia *et al.*(1998).

5.5.2 Downy mildew incidence

Downy mildew caused by *Pseudoperonospora cubensis* is an important disease causing severe damage in bitter gourd (Phookan and Gogoi, 1995). However, works on screening the bitter gourd genotypes against this disease are limited (Thakur *et al.*, 1996). Thus, it is necessary to screen different bitter gourd genotypes against the disease under different agro-climatic conditions. In the present study 40 bitter gourd genotypes were screened for resistance to downy mildew. The per cent downy mildew incidence

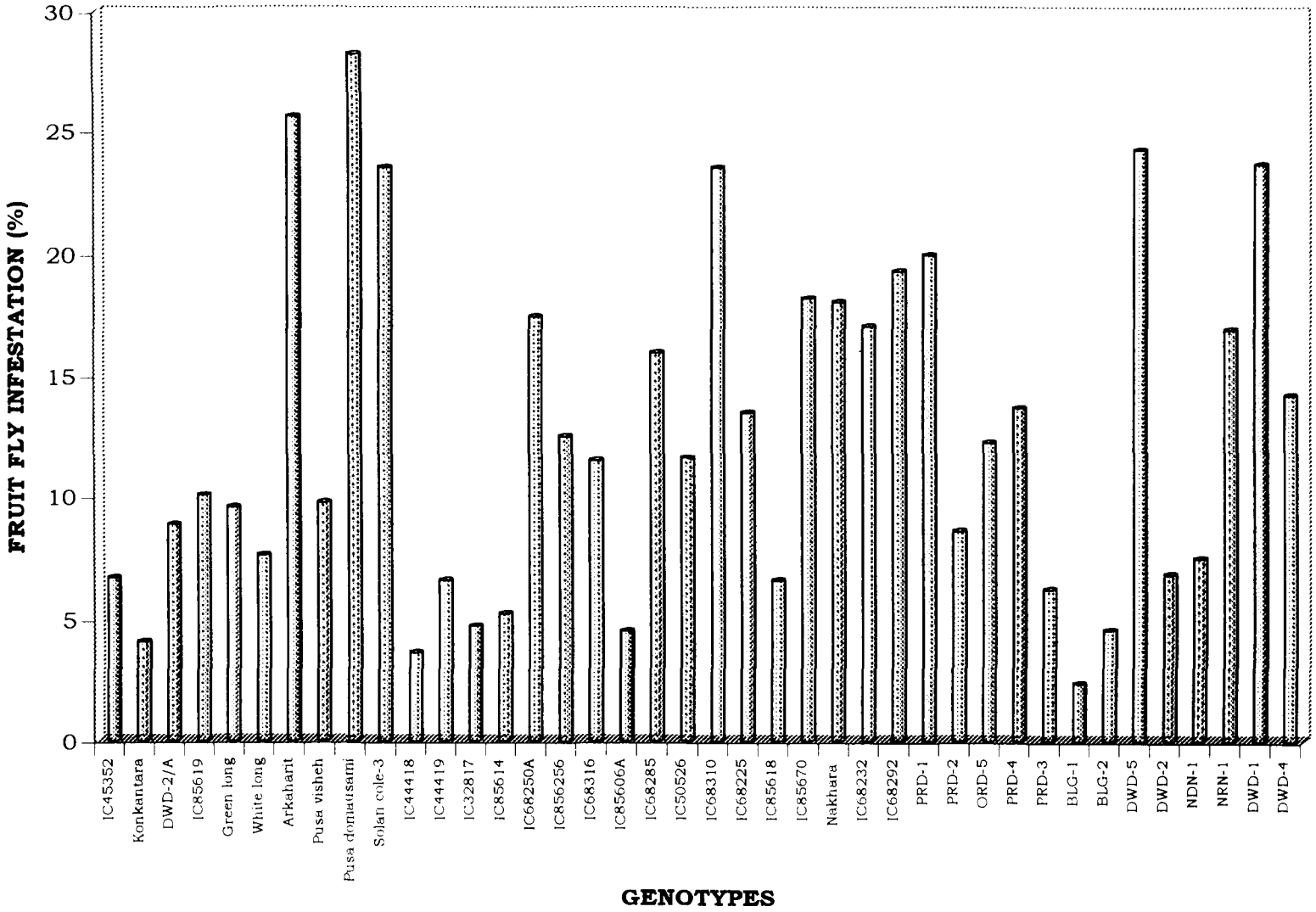


Fig. 5. Percentage fruit fly infestation in bitter gourd genotypes.

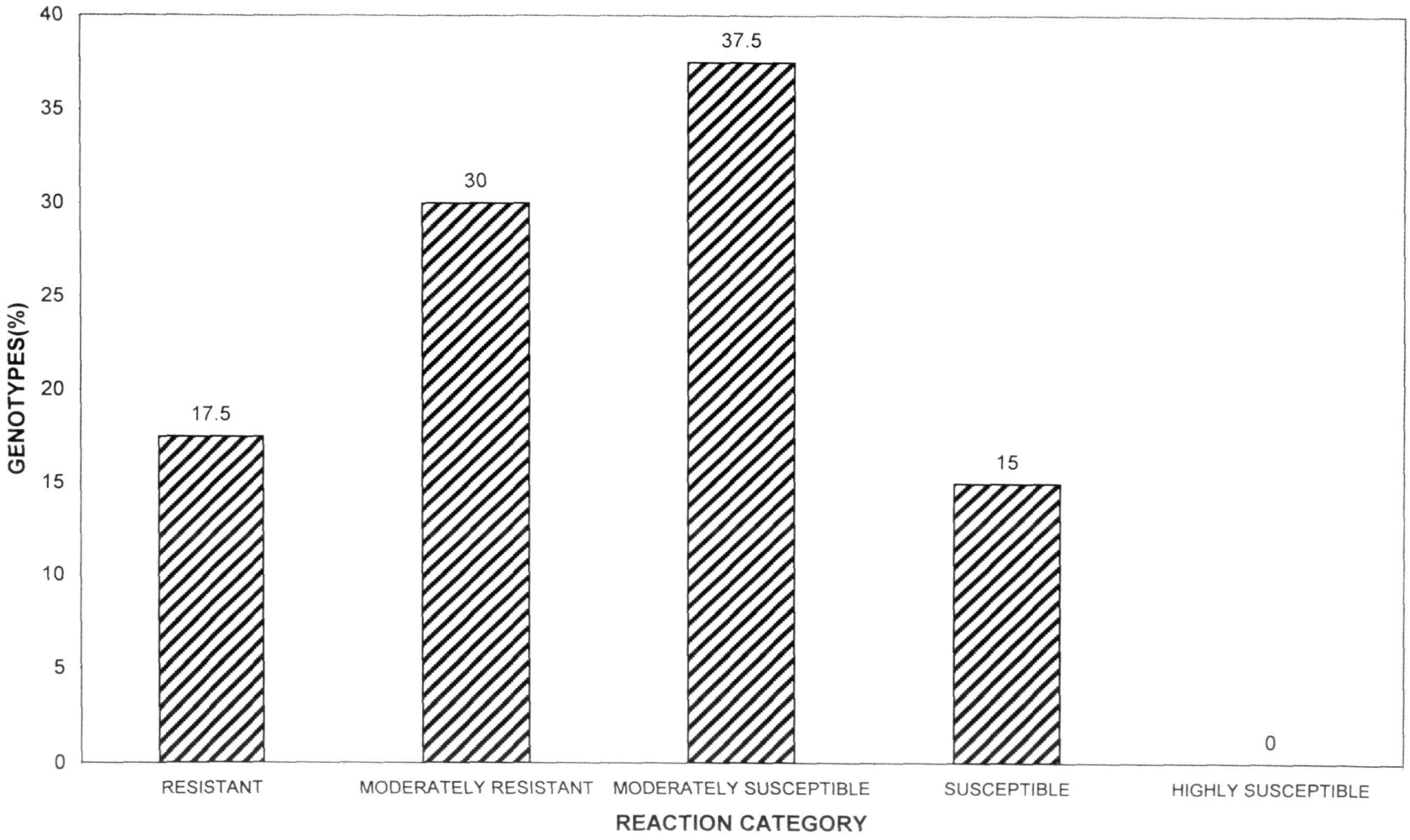


Fig. 6. Frequency Distribution of Fruitfly Infestation in 40 Bittergoud Genotypes

in 40 bitter gourd genotypes is shown in Fig. 7. None of the genotypes were free from disease incidence. The frequency distribution of downy mildew incidence in the 40 genotypes is shown in Fig. 8. It was observed that 50 per cent of genotypes were moderately susceptible, 20 per cent were highly susceptible and another 10 per cent were susceptible. Thus, 80 per cent of genotypes fell under different categories of susceptibility. Only 5 per cent of the genotypes (2 out of 40 genotypes) were resistant. While another 15 per cent were moderately resistant to the disease. Genotypes, White long and BLG-1 were found to be resistant, but based on yield and its components and disease resistant BLG-1 was most promising. Similar studies have been reported by Reddy *et al.* (1995) and Thakur *et al.* (1996) in bitter gourd, Jamadar and Desai (1999) and Thammaiah *et al.* (1999) in ridge gourd.

5.6 SUPERIOR GENOTYPES FOR ECONOMIC TRAITS

It was evident from the study that there was considerable degree of variability for fruit yield and its component characters along with resistance to fruit fly and downy mildew incidence. A few of the most promising genotypes for yield were BLG-1, DWD-2, NRN-1, IC68316, IC44418, IC32817, IC85614 and PRD-2. Looking to the other component characters like early flowering, fruit length, number of fruits per plant, fruit weight, resistance to fruit fly and

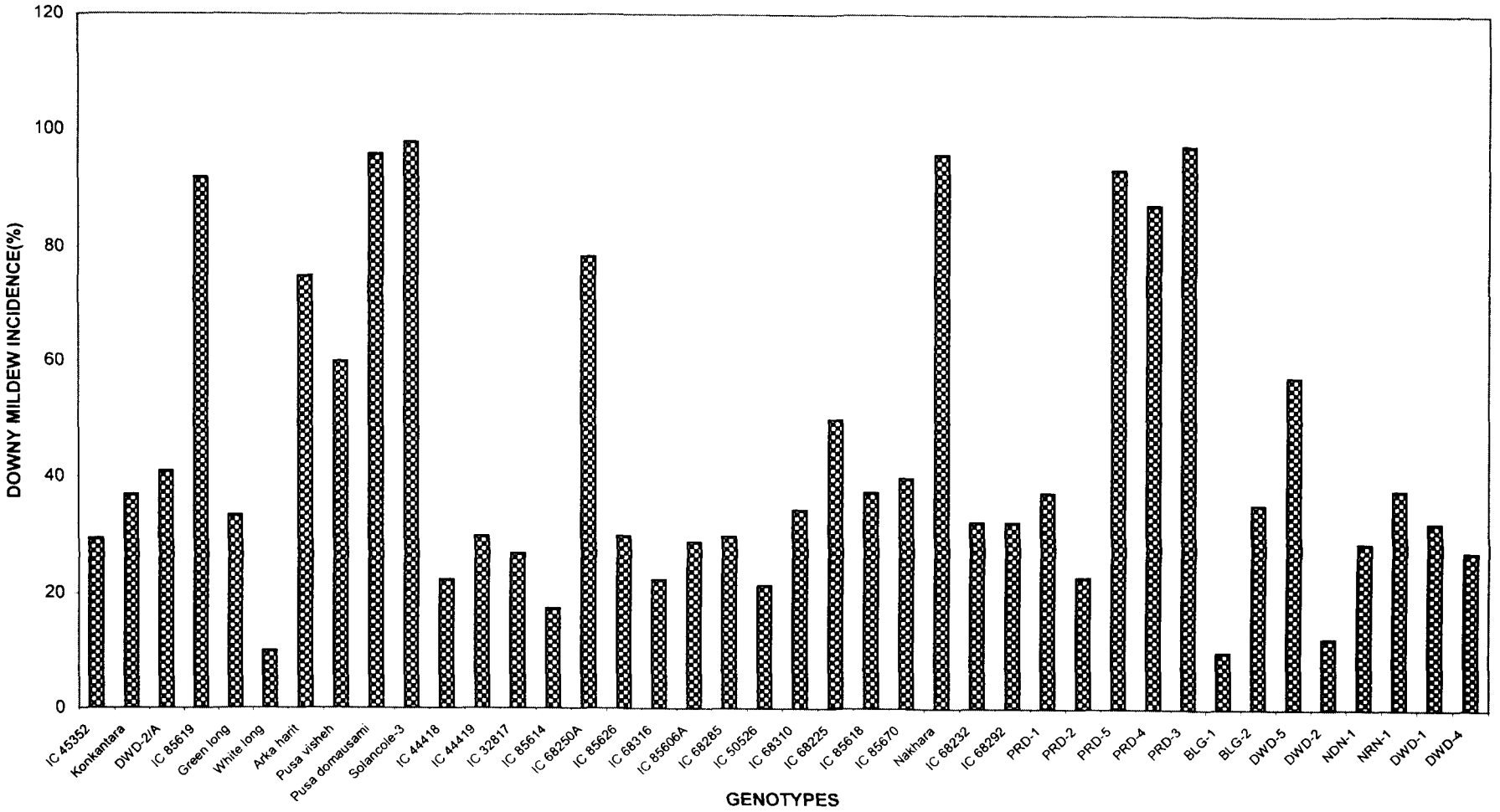


Fig 7. Percent Downy mildew incidence in bitter gourd genotypes

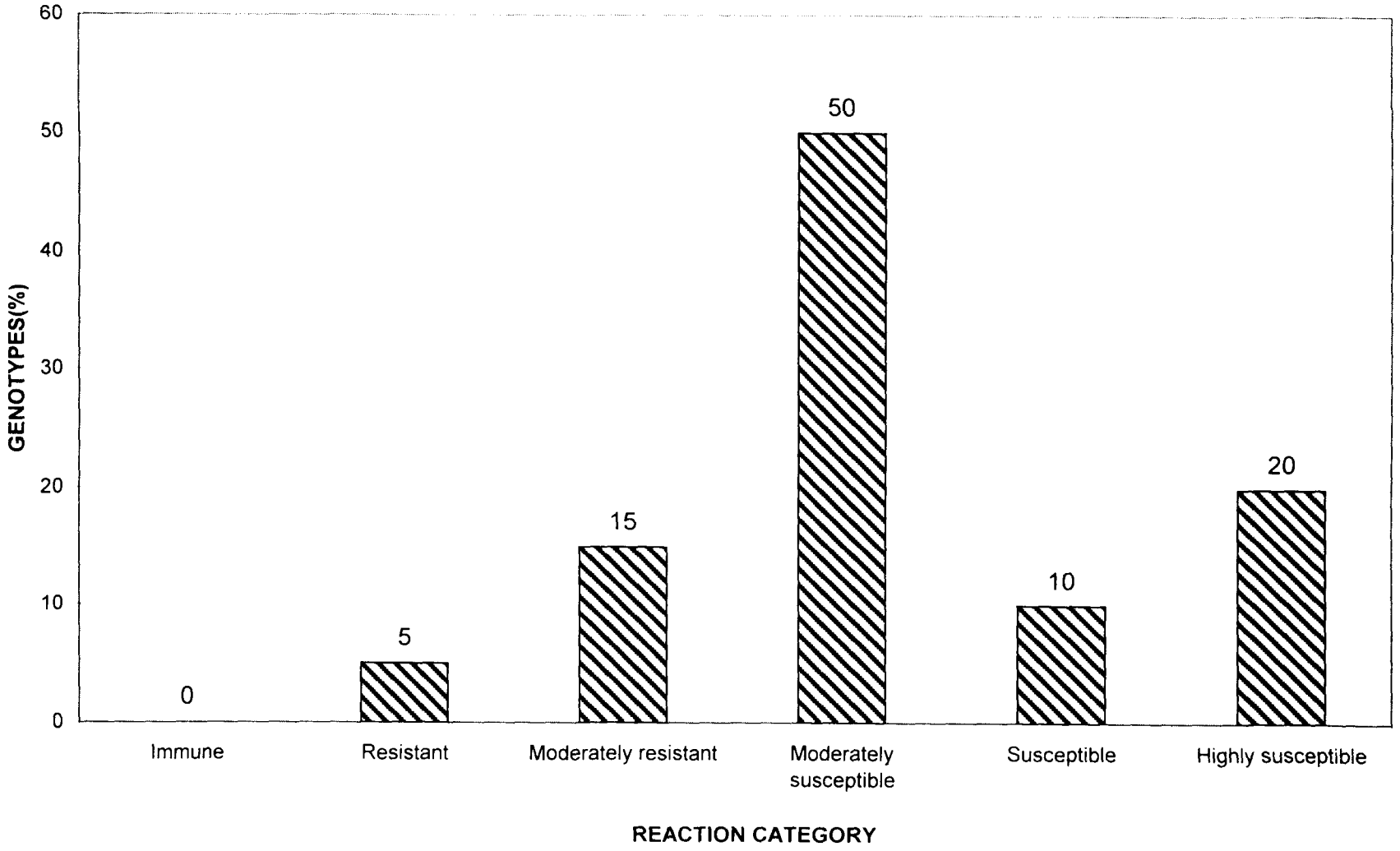


Fig . 8. Frequency Distribution of Downy Mildew Incidence in Bittergourd Genotypes

downy mildew incidence only five of the genotypes presented in Table 16 viz., BLG-1, DWD-2, PRD-2, IC44418 and IC85614, qualify to be of commercial value as most of the superior characters are shared in common.

5.7 FUTURE LINE OF WORK

1. The high yielding genotypes (BLG-1, PRD-2, NRN-1, IC44418, DWD-2, IC32817, IC85614, IC68316) could be tested over different locations and seasons for their stability before release for cultivation.

2. The genotypes, which were identified as field resistant to fruit fly infestation and downy mildew incidence, could be subjected to artificial inoculation to confirm their stability.

3. The genotypes belonging to divergent clusters i.e., BLG-1, DWD-2 and NDN-1 could be used in heterosis breeding programme.

4. Multiple hybridization could be practiced for combining most of the desirable horticultural traits with high yields and resistance to pest and disease.

5. All the genotypes could be evaluated for their suitability for canning and dehydration.

Table 16. The best genotypes for economic traits.

Characters	Genotypes
1. Early flowering (< 45 days to flowering)	IC44419, Greenlong, IC85614, IC85670, IC68310, Konkantara, DWD-2/A, Arka Harit
2. Fruit length (>= 17 cm)	DWD-2, PRD-2, NRN-1, IC85614, Pusa do mausami, IC85619, Greenlong, BLG-2
3. Number of fruits per plant. (> 27 fruits)	BLG-1, DWD-2, NRN-1, IC68225, IC68285, IC44418, IC32817, IC85606A, IC44419, DWD-2/A
4. Fruit weight (>80 g)	PRD-3, BLG-1, PRD-4, IC68250A, IC68316, DWD-2, DWD-5, PRD-2, Pusa do mausami, IC85619, Whitelong
5. Total yield per plant (>2 kg)	BLG-1, DWD-2, NRN-1, IC68316, IC44418, IC32817, IC85614, PRD-2
6. Resistance to fruit fly (<7% fruits damaged)	BLG-1, BLG-2, IC444418, Konkan tara, IC32817, IC44419, IC85618, PRD-3, IC85606A, IC85614
7. Resistance to downy mildew (<25% leaf area infected)	BLG-1, Whitelong, IC85614, DWD-21, IC50526, IC44418, IC68316, PRD-2

Summary

VI. SUMMARY

Genetic variability and diversity studies in 40 bitter gourd genotypes was carried out at Olericulture unit, Department of Horticulture, College of Agriculture, Dharwad on inceptisols during 2001 (August-December). The present study was undertaken to elicit information on the nature of variability in bitter gourd genotypes; correlation and path analysis studies of component characters with yield and to screen the genotypes against major pest and disease. The salient findings are summarized below.

The analysis of variance revealed significant differences among genotypes for all characters studied except days to opening of first female flower and days to first harvest. The phenotypic coefficient of variability was more than genotypic coefficient of variability for all characters under study. Phenotypic and genotypic coefficients of variation were low for characters like internodal length, days to first female flower opening, days to first harvest, size of cavity and flesh thickness. Yield per plant recorded both high GCV and PCV (58.10 and 54.22%, respectively). Remaining characters have recorded moderate to high coefficient of variability.

Heritability estimates were high for vine length, number of nodes per vine, number of leaves at 50 per cent flowering, flesh

thickness, number of seeds per fruit, number of fruits per plant, fruit yield per plant, fruit weight, fruit fly infestation and downy mildew incidence ranging from 71.0 per cent to 96.0 per cent. Most of the other characters except days to opening of first female flower and days to first harvest had moderate heritability. The result indicates that characters were least influenced by the environmental effect and were effectively transmitted to progeny.

The genetic advance over mean was low for characters like days to first female flower opening, days to first harvest, number of branches per plant and days to development of fruit, this situation arises when the variability for the character is low. Vine length, number of nodes per vine, internodal length, number of leaves at 50 per cent flowering stage, flesh thickness, number of seeds per fruit, number of fruits per plant, fruit yield per plant and fruit weight showed high genetic advance over mean with high heritability, indicating the operation of additive gene action for these traits. Simple selection schemes would suffice for these traits.

Fruit fly infestation and downy mildew incidence were also governed by additive gene action. Therefore, breeder should be cautious while selecting for other desirable traits.

For character association genotypic and phenotypic correlations were considered. In most cases genotypic correlations

were higher than phenotypic correlations indicating highly heritable nature of the characters. Yield per plant showed positive and significant correlation with number of leaves at 50 per cent flowering, number of seeds per fruit, fruit length, number of fruits per plant and fruit weight both at phenotypic and genotypic level. Since, the association is in desirable direction, selection for these traits may ultimately improve the yield. Fruit yield per plant and number of fruits per plant were highly significantly and negatively associated with fruit fly infestation and downy mildew incidence, indicating that pest and disease incidence adversely affected the fruit yield and number.

The path coefficient analysis for yield was carried out considering 11 component characters, both the genotypic and phenotypic path revealed that number of fruits per plant and fruit weight were the most influencing factors. Thus, these two characters deserve greater weightage during selection for yield.

The 40 bitter gourd genotypes were grouped into 10 clusters (based on D^2 values) which consisted of 16, 11, 1, 4, 2, 2, 1, 1, 1 and 1 genotypes, respectively in clusters, I, II, III, IV, V, VI, VII, VII, IX and IX. The clusters VI and IX were most divergent, thus the genotypes of these clusters could be used in hybridization programme to get higher heterotic hybrids. The maximum

contribution towards total genetic divergence was from number of leaves at 50 per cent flowering. Cluster mean analysis indicated that high yielding genotypes were congregated in clusters V and VI. The pest and disease resistant genotypes were grouped in clusters VI and VIII, respectively.

The genotypes Konkantara, BLG-1, BLG-2, IC44418, IC32817, IC85606A and IC85614 were resistant to fruit fly. In case of downy mildew disease, genotypes White long and BLG-1 were found to be resistant.

References

VII. REFERENCES

AGARWAL, M. L., SHARMA, D. D. AND RAHMAN, O., 1987, Melon fruit fly and its Control. *Indian Horticulture*, **32** : 10-11.

AL-JIBOURI, H. A., MILLER, P. A. AND ROBINSON, H. V., 1958, Genotypic and environmental variances and co-variances in an upland cotton cross of interspecific origin. *Agronomy Journal*, **50** : 633-636.

ANONYMOUS, 1990, Annual report. *Project Directorate on Vegetables*, ICAR, New Delhi.

ANONYMOUS, 2000, Horticultural Crop Statistics of Karnataka state at a glance (1999-2000). Directorate of Horticulture, Lalbagh, Bangalore, p. 66.

BADADE, D. S., WARADE, S. D. AND GAIKAWAD, S. K., 2001, Correlation studies in bitter gourd. *Journal of Maharahstra Agricultural Universities*, **26**(1) : 20-22.

BADADE, D. S., WARADE, S. D. AND GAIKWAD, S. K., 2001, Genetic divergence in bottle gourd. *Journal of Maharashtra Agricultural Universities*, **26**(2) : 137-139.

BAINS, S. S. AND JHOOTY, J. S., 1976, Host range and possibility of pathogenical races in *Pseudoperenospora cubensis* cause of downy mildew of muskmelon. *Indian Phytopathology*, **29** : 214-216.

*BISOGNIN, D. A. AND STORCK, L., 2000, Variance components and heritability estimation for fruit shape in bottle gourd (*Lagenaria siceraria* (Mol.) standl.). *Ciencia Rural*, **30**(4) : 593-597.

BORAH, S. R. AND DUTTA, S. K., 1997, Infestation of fruit fly in some curbitaceous vegetables. *Journal of the Agricultural Science Society of North East India*, **10**(1) : 128-131.

BOSE, T. K. AND SOM, M. C., 1990, *Vegetable Crops in India*, 1st reprint. Good Associates printers, Calcutta, pp. 148-150.

BURTON, G. W., 1952, Quantitative inheritance in pearlmillet. *Agronomy Journal*, **50** : 503.

BUTLER, E. J., 1918, *Fungi and Diseases in Plants*. Periodical expert book agency D-42, Vivek Vihar, Delhi, pp. 311-314.

CHARLES, D. R. AND SMITH, H. H., 1939, Distinguishing between two types of gene action in quantitative inheritance. *Genetics*, **24** : 34-38.

CHAUDHARI, S. M., KALE, P. N. AND DESAI, U. J., 1991, variability studies and scope of improvement in fruit yield in bitter gourd. *Journal of Maharashtra Agricultural Universities*, **16**(1) : 15-17.

COCHRAN, W. G. AND COX, G. M., 1959, *Experimental Designs 1st Ed.* Asia Publishing House, Bombay, pp. 95-145.

DEWEY, D. R. AND LU, K. H., 1959, A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal*, **51** : 515-518.

*EAST, E. M., 1916, Studies on size inheritance in *Nicotiana*. *Genetics*, **1** : 164-176.

FALCONER, D. S., 1981, *Introduction to Quantitative Genetics* 2nd Edition. Oliver and Boyd, Edinburgh, London, pp. 164-176.

FERNANDO, M. AND UDURAWANA, S. B., 1941, The relative resistance of some strains of bitter gourd to the cucurbit fruit fly. *Tropical Agriculturist*, **96** : 347.

FISHER, R. A., 1918, The correlation between relatives on the supposition of Mendelian inheritance. *Trans Royal Society*, Edinburgh, **52** : 399-443.

FISHER, R. A. AND YATES, F., 1963, *Statistical Tables for Biological, Agricultural and Medical Research.* Oliver and Boyd, Edinburgh, p. 66.

GIRISHA, K. N., 1989, Studies on biological control of powdery mildew pathogens with *Cladosporium* spp. *M. Sc. (Agri.) Thesis*, UAS, Bangalore.

GRAFIUS, J. E., 1959, Heterosis in barley. *Agronomy Journal*, **51** : 551-554.

GUPTA, J. N. AND VERMA, A. N., 1978, Screening of different cucurbit crops for the attack of the melon fruit fly, *Dacus cucurbitae* coquillett (Diptera : *Tephritidae*). *Haryana Journal of Horticultural Science*, **7** : 78-82.

HARLAND, S. C., 1939, *The Genetics of Cotton.* Jonathan Cape, London, p. 132.

*HAWALADER, M. S. H., HAQUE, M. M. AND ISLAM, M. S., 1999, Variability, correlation and path analysis in bottle gourd. *Bangladesh Journal of Scientific and Industrial Research*, **34**(1) : 50-54.

INDIRESH, B. T., 1979, Studies on genotypic and phenotypic variability in bitter gourd (*Momordica charanta* L.). *M. Sc. (Agri.)* Thesis, University of Agricultural Sciences, Bangalore.

JACKSON, M. L., 1967, *Soil Chemical Analysis*. Prentice Hall of India, Pvt. Ltd., New Delhi, pp. 38-82.

JAMADAR, M. M. AND DESAI, S. A., 1999, Reaction of Ridge gourd local cultivars against downy mildew caused by *Psuedoperonospora* cubensis (Berk. Et. Curt) Rostow. *Karnataka Journal of Agricultural Sciences*, **12**(1-4) : 204-205.

*JOHANNSEN, W. L., 1909, *Elements der Exateten Exblich Keitslehra Jena*, Gustan Fisher.

JOHNSON, H. W., ROBINSON, H. F. AND COMSTOCK, R. S., 1955, Estimates of genetic and environmental variability in soybean. *Agronomy Journal*, **41** : 314-318.

KADAM, P. Y. AND KALE, P. N., 1985, Genetic divergence in ridge gourd (*Luffa acutangularis* L. Roxb.). *Vegetable Science*, **12**(1) : 97-104.

KADAM, P. Y., AND KALE, P. N., 1987, Genetic variability in ridgegourd. *Journal of Maharashtra Agricultural Universities*, **12** : 242-243.

KUMAR, S. AND SINGH, S. P., 1998, Correlation and path coefficient analysis for certain metric traits in bottle gourd (*Lagenaria siceraria* (Mol.) Standl). *Vegetable Science*, **25**(1) : 40-42.

LAL, S. AND SRIVASTAVA, B. P., 1978, Genetic divergence in brinjal (*Solanum melongena* L.). *Vegetable Science*, **5** : 89-92.

LALL, B. S. AND SINHA, S. N., 1959, On the biology of melon fly, *Dacus cucurbitae* (coq) Diptera : *Trypetidae. Science and Culture*, **25** : 159-161.

LALL, B. S., AND SINHA, R. P., 1974, Reaction of different cucurbit varieties to invasion by melon fly *Dacus cucurbitae* (coq). *Proceeding Bihar Academy Agricultural Sciences*, **22/23** : 100-103.

LAWANDE, K. E. AND PATIL, A. V., 1989, Correlation studies in bitter gourd. *Journal of Maharashtra Agricultural Universities*, **14**(1) : 77-79.

LONGMAN, O., 1995, *Indian Medicinal Plants*, Volume 4, Orient Longman Publication Ltd., Madras.

MAHALANOBIS, P. C., 1936, On the generalized distance in statistics. In : *Proceedings of National Academy Science* (Indian), **12** : 49-55.

MAHRISHI, R. P. AND SIRADHANA, B. S., 1988, Studies on Downey mildew of cucurbits in Rajasthan : Incidence distribution host range and yield losses in musk melon. *Annals of Arid Zone*, **27**(1) : 71-74.

MANGAL, J. L., DIXIT, J., PANDITA, M. L. AND SIDHU, A. S., 1981, Genetic variability and correlation studies in bitter gourd (*Momordica charantia* L.). *Indian Journal of Horticulture*, **38** : 94-96.

MOHANTY, B. K., 2000, Studies on variability and selection parameters in pumpkin (*Cucurbita moschata* Duch. Ex. Poir.). *South Indian Horticulture*, **48**(1-6) : 111-113.

MOHANTY, B. K. AND MISHRA, R. S., 1999, Variation and genetic parameters of yield and its components in pumpkin. *Indian Journal of Horticulture*, **56**(4) : 337-342.

MUHR, C. R., DATTA, N. P. AND DOHANUE, R. L., 1965, *Soil Testing in India*. USAID, New Delhi, pp. 39-41.

MURTHY, G. S. AND PAVATE, M. V., 1962, Studies on quantitative inheritance in *Nicotina tobaccum* L. varietal classification and selection by multivariate analysis. *Indian Journal of Genetics and Plant Breeding*, **22** : 68.

NAIR, K. R. AND MUKHERJI, K. H., 1960, Classification of natural and plantation teak (*Tactona grandis*) grown at different localities of India and Burma with respect to its mechanical and physiological properties. *Sankhya*, **22** : 1-20.

*NELSON, AND EHLE, H., 1909, *Kreuzung, unter, sunchungen on Hafer and weizonjunds.* University of Asseter, N. F., Alfalfa, 2 Ed., 5, Nr., **2** : 1-22.

PAL, A. B. AND VANI, A., 1986, Studies on association between economic traits in gourds, *Indian Journal of Horticulture*, **43** : 270-273.

PANSE, V. G. AND SUKHATME, P. V., 1967, *Statistical methods for agricultural workers.* Indian Council of Agricultural Research, New Delhi, p. 145.

PANWAR, J. S., SINGH, H. N., PRASAD, R. AND SRIVASTAVA, J. P., 1977, Genetic variability and heritability studies in sponge gourd (*Luffa cylindrica*). *Haryana Journal of Horticultural Science*, **6**(3-4) : 170-174.

PARHI, G., MISHRA, H. N. AND TRIPATHY, P., 1993, Genetic divergence in bitter gourd (*Momordica charantia* L.). *South Indian Horticulture*, **41**(6) : 344-349.

PHOOKAN, A. K. AND GOGOI, R., 1995, Occurrence of downy mildew on bitter gourd in Assam. *Indian Journal of Mycology and Plant Pathology*, **25** (3) : 331.

PIPER, C. S., 1996, *Soil and Plant Analysis*, Hans Publishers, Bombay, pp. 1-368.

POWERS, L., 1942, The nature of the series of environmental variances and the estimation of genetic variances and the geometric means of crosses involving species of *Lycopersicon*. *Genetics*, **27** : 561-575.

PRASAD, V. S. R. K. AND SINGH, D. P., 1997, Genetic divergence in Parwal (*Trichosanthes dioica* Roxb.). *Indian Journal of Plant Genetic Resources*, **10**(1) : 91-96.

PRASAD, V. S. R. K., SINGH, D. P., AND SINGH, R. P., 1993, Biological divergence in the land races of Indian cucumber (*Cucumis sativus* L.). *Indian Journal of Horticulture*, 50(1) : 57-63.

RAJPUT, J. C., PARANJAPE, S. P. AND JAMADAGNI, B. M., 1995, Correlation and path analysis studies for fruit yield in bitter gourd. *Journal of Maharashtra Agricultural Universities*, **20**(3) : 377-379.

RAJPUT, J. C., PARANJAPE, S. P. AND JAMADAGNI, B. M., 1996, Variability, heritability and scope of improvement for yield components in bitter gourd (*Momordica charantia* L.). *Annals of Agricultural Research*, **17**(1) : 90-93.

RAM, D., 2001, Non-hierarchical euclidean cluster analysis in pointed gourd (*Trichosanthes dioica* Roxb.). *Indian Journal of Horticulture*, **58**(3) : 264-268.

RAMACHANDRAN, C., 1978, Genetic variability correlation studies and path coefficient analysis in bitter gourd (*Momordica charantia* L.). *M. Sc. (Hort.) Thesis*, Kerala Agricultural University, Trichur.

RAMACHANDRAN, C. AND GOPALKRISHNAN, P. K., 1979, Correlation and regression studies in bitter gourd. *Indian Journal of Agricultural Science*, **49**(11) : 850-854.

RAO, B. N., RAO, P. V. AND REDDY, T. B., 1999, Correlation and path coefficient studies in ridge gourd (*Luffa acutangula* (L.) Roxb.). *International Journal of Tropical Agriculture*, **17**(1-4) : 119-124.

RAO, C. R., 1952, *Advanced Statistical Methods in Biometrical Research*. John Wiley and sons, New York, pp. 357-369.

REDDY, B. S., THAMMAIAH, N., PATIL, R. V. AND NANDIHALLI, B. S., 1995, Studies on the performance of bitter gourd genotypes. *Advances in Agricultural Research in India*, **4** : 103-108.

SACHAN, J. K. S. AND SHARMA, J. R., 1971, Multivariate analysis of genetic divergence in tomato. *Indian Journal of Genetics*, **31**(1) : 86-93.

SAHNI, G. P., SINGH, R. K. AND SAHA, B. C., 1987, Genotypic and phenotypic variability in ridge gourd. *Indian Journal of Agricultural Science*, **57** (9) : 666-668.

SARKAR, S. K., MAITY, T. K. AND SOM, M. G., 1999, Correlation and path-coefficient studies in pointed gourd (*Trichosanthes dioica* Roxb.). *Indian Journal of Horticulture*, **56**(3) : 252-255.

SARNAIK, D. A., VERMA, S. K. AND SHARMA, G. L., 1999, Character association in lvy-gourd (*Coccinia grandis*). *Annals of Agricultural Research*, **26**(4) : 436-438.

SARNAIK, D. A., VERMA, S. K. AND SHARMA, G. L., 1999, Evaluation of lvy gourd (*Coccinia grandis*) germplasm. *Vegetable Science*, **26**(1) : 58-60.

SHAHA, S. R., KALE, P. N., NAVALE, P. A., 1999, Path analysis in ridge gourd. *Journal of Maharashtra Agricultural Universities*, **24**(2) : 197-198.

SHIVARKAR, D. T. AND DUMBRE, R. B., 1985, Bionomics and control of melon fruit fly. *Journal of Maharashtra Agricultural Universities*, **10** : 298-300.

SIDHU, A. S. AND BRAR, J. S., 1985, Genetic divergence and hybrid performance in water melon. *Indian Journal of Agricultural Sciences*, **55** (7) : 459-61.

SINGH, A. AND SIGNH, H. N., 1976, Genetic divergence in chilli. *Indian Journal of Genetics and Plant Breeding*, **36** : 425-430.

SINGH, A. K., SINGH, R. D. AND SINGH, J. P., 1993, Correlation and path coefficient analysis in pointed gourd. *Indian Journal of Horticulture*, **50** : 68-72.

SINGH, H. N., SRIVASTAVA, J. P. AND PRASAD, R., 1977, Genetic variability and correlation studies in bitter gourd. *Indian Journal of Agricultural Science*, **47** : 604.

SINGH, R. K. AND CHAUDHARY, B. D., 1977, *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani Publishers, New Delhi.

SINGH, R. R., MISHRA, G. M. AND JHA, R. N., 1987, Interrelationship between yield and its components in parwal. *South Indian Horticulture*, **35**(3) : 245-246.

SINGH, R. S., 1987, *Diseases of Vegetable Crops*. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, pp. 178-179.

SINGH, S. AND, LAL, T., 2000, Assessment of genetic divergence in Melon (*Cucumis melo* L.).*Journal of Research Punjab Agricultural University*, **37**(1-2) : 36-41.

SINGH, S. P., SINGH, N. K. AND MAURYA, I. B., 1996, Genetic variability and correlation studies in bottle gourd (*Lagenaria siceraria* (Molina) standl). *PKV-Research Journal*, **20**(1) : 88-89.

SIVASUBRAMANIAN, S. AND MENON, M., 1973, Heterosis and inbreeding depression in rice. *Madras Agricultural Journal*, **60** : 1139.

SRINIVASAN, P. M., 1959, Guard your bitter gourd against the fruit fly. *Indian Farming*, **9**(9) : 8.

SRIVASTAVA, V. K. AND SRIVASTAVA, L. S., 1976, Genetic parameters, correlation coefficients and path coefficient analysis in bitter gourd (*Momordica charantia* L.). *Indian Journal of Horticulture*, **33** : 66-70.

*SU, C. Y., 1986, Seasonal population fluctuations of *Dacus cucurbitae* in Southern Taiwan. *Plant Protection Bulletin of Taiwan*, **28** : 171-178.

SUBBAIAH, B. V. AND ASIJA, G. L., 1956, A rapid procedure for the estimation of available nitrogen in soils. *Current Science*, **25** : 259-260.

TEWATIA, A. S. AND DHANKHAR, B. S., 1996, Inheritance of resistance to melon fruit fly (*Batocera cucurbitae*) in bitter gourd (*Momordica charantia*). *Indian Journal of Agricultural Sciences*, **66** : 617-620.

TEWATIA, A. S., DHANKHAR, B. S. AND SINGH, R., 1998, Evaluation of bitter gourd (*Momordica charantia* L.) cultivars for resistance to melon fruit fly (*Batocera cucurbitae* coquillett). *Haryana Journal of Horticultural Science*, **27** (4) : 266-271.

THAKUR, J. C., KHATTRA, A. S. AND BRAR, K. S., 1992, Comparative resistance to fruit fly in bitter gourd. *Haryana Journal of Horticultural Sciences*, **21**(3-4) : 285-288.

THAKUR, J. C., KHATTRA, A. S. AND BRAR, K. S., 1994, Influence of genotypes and environment on the fruit fly infection in bitter gourd. *Vegetable Science*, **21**(1) : 85-88.

THAKUR, J. C., KHATTRA, A. S. AND BRAR, K. S., 1996, Correlation studies between economic traits fruit fly infestation and yield in bitter gourd. *Punjab Vegetable grower*, **31** : 37-40.

THAKUR, J. C., KHATTRA, A. S. AND DHANJU, K. C., 1996, Evaluation of bitter gourd genotypes against diseases and their correlation with other quantitative characters. *Punjab Vegetable Grower*, **31** : 25-28.

THAMMAIAH, N., REDDY, B. S., PATIL, R. V., KULKARNI, M. S. AND HARALAPUR, S. I., 1999, Varietal screening of ridge gourd genotypes against downy mildew. *South Indian Horticulture*, **47**(1-6) : 315-316.

VARALAKSHMI, B., RAO, P. V. AND REDDY, Y. N., 1995, Genetic variability and heritability in ridge gourd (*Luffa acutangula*). *Indian Journal of Agricultural Science*, **65**(8) : 608-610.

VARALAKSHMI, B., REDDY, N. Y. AND REDDY, B. M. M., 1994, Genetic divergence in ridge gourd (*Luffa acutangularis* Roxb. (L.)). *Journal of Genetics and Breeding*, **48** : 131-134.

WAHAB, A. M. AND GOPALAKRISHNAN, P. K., 1993, Genetic divergence in bitter gourd (*Momordica charantia* L.). *South Indian Horticulture*, **41**(4) : 232-234.

WALKLEY AND BLACK, 1947, An examination of the Degtjareff method for determining organic matter and a proposed modification of chromic acid titration method. *Soil Science*, **63** : 251-256.

WRIGHT, S., 1921, Correlation and Causation. *Journal of Agricultural Research*, **20** : 557-587.

*XIE-WEN HUA, XIE-DASEN, XIE-W. H, XIE-D. S., 1999, Studies on the resistance of different cultivars of ridge gourd to downy mildew. *Journal of South China Agricultural University*, **20**(2) : 28-31.

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* Originals not seen

Appendices

Appendix I. Monthly meteorological data for the year 2001 and average of past 51 years (1950-2000) of MRS, UAS, Dharwad.

Months	Rainfall (mm)		Temperature (°C)				Mean relative humidity (%)	
	2001	1950-2000	Mean Maximum		Mean Minimum			
			2001	1950-2000	2001	1950-2000	2001	1950-2000
Jan.	0.00	0.10	29.90	29.21	15.00	14.11	55.00	63.90
Feb.	0.00	0.00	34.00	34.61	16.80	15.95	50.00	51.25
Mar.	0.00	7.37	35.30	35.76	18.50	18.78	45.00	56.92
April	52.10	47.90	35.70	37.10	22.00	21.32	55.00	78.28
May	23.10	84.61	34.80	36.59	21.50	21.45	59.00	67.16
June	32.50	113.10	30.30	29.48	21.30	21.20	75.00	82.00
July	33.10	153.11	26.80	27.04	21.10	20.95	81.00	87.88
Aug.	58.10	98.67	27.20	27.02	20.90	20.63	81.00	86.83
Sept.	53.60	104.97	30.10	28.74	20.20	20.17	72.00	82.86
Oct.	17.00	135.39	30.10	30.10	19.90	19.27	65.00	77.04
Nov.	0.00	33.75	31.00	29.39	17.90	15.41	55.00	68.68
Dec.	0.00	5.76	29.60	29.15	13.70	13.41	55.00	64.58
Total	269.60	784.73						

Appendix II. Physical and chemical properties of soil from experimental site.

Particulars	Value obtained	Method adopted
A. PHYSICAL PROPERTIES		
1. Mechanical analysis		
a. Clay (%)	35.20	International Pipette Method (Piper, 1966)
b. Silt (%)	7.60	International Pipette Method (Piper, 1966)
c. Fine sand (%)	29.20	International Pipette Method (Piper, 1966)
d. Coarse sand (%)	28.00	International Pipette Method (Piper, 1966)
B. CHEMICAL PROPERTIES		
Organic carbon (%)	0.46	Chromic acid Wet Oxidation method (Walkley and Black, 1947)
Available N (kg/ha)	233.00	Modified kjeldhal's method (Jackson, 1967)
Available P (kg/ha)	31.00	Bray's method (Jackson, 1967)
Available K (kg/ha)	296.00	Flame photometer (Muhr et al., 1965)
PH	6.70	pH meter (Jackson, 1967)

LEGEND

VL	Vine length
NOB	No. of branches
NON	No. of nodes per vine
IL	Internodal length
DFF	Days to opening of first female flower
NFF	Node number of first female flower
NOL	No. of leaves at 50% flowering
DFH	Days to first harvest
DDF	Days to development of fruit
PLV	Productive length of vine
FG	Fruit girth
SC	Size of cavity
FT	Flesh thickness
NOS	No. of seeds per fruit
FL	Fruit length
NOF	No. of fruits per plant
FY	Total yield per plant
FW	Fruit weight
FFI	Fruit fly infestation
DMI	Downy mildew incidence

APPENDIX III. Mean performance of Bitter gourd genotypes for different characters

Genotypes	Characters																			
	VL	NOB	NON	IL	DFF	NFF	NOL	DFH	DDF	PLV	FG	SC	FT	NOS	FL	NOF	FY	FW	FFI	DMI
IC 45352	126.75	5.5	19.5	7.85	53.5	3.5	430.5	73	19.5	224.5	4.15	2.49	0.62	29.5	15.25	23	1.53	78.72	6.7	29.5
Konkantara	218.25	4.5	28.15	7.15	44.5	9.65	291.5	58.5	14	225	4.72	2.87	0.72	23.6	13.73	24	1.31	54.35	4.1	37
DWD-2/A	262	3.5	35.65	6.88	43.5	12.8	267.5	58	14.5	283	4.16	2.49	0.6	27.5	15	27.5	1.09	49.35	8.85	41
Ic 85619	122.65	4.5	22	6.35	56.5	10	411.5	73	14.5	140	3.66	2.45	0.6	26.5	17.3	15	1.18	82.25	10.05	92
Green long	218	3.5	26.5	7.91	42.5	5.5	303	59.5	17	327	4	2.25	0.58	26.5	17	20.5	1.61	79.25	9.55	33.5
White long	247.65	3	31.65	6.93	52.25	11.25	410.5	66.75	16.5	328	3.26	1.95	0.38	21.5	16.15	17.5	1.44	80.8	7.6	10
Arka Harit	121.5	4	25.8	4.52	43.5	6.5	308.5	57.15	13.65	147.65	3.27	2.35	0.31	13.75	6.95	18.5	0.5	21.65	25.6	75
Pusa Visheh	146.23	4	23	6.3	52.5	10.5	478.5	63.5	11	209.5	4.69	2.08	0.69	28	14.3	14	0.87	68.35	9.75	60
PDM	165.8	5.5	26	7.11	47.5	5	440	59.5	12	241.5	3.52	1.35	0.58	31	18.95	19	1.48	87.35	28.25	96
Solancole-3	90.4	3.5	15	6.67	53.5	8.5	204	67	13.5	130.5	3.56	2	0.43	21.5	15.55	12.5	0.89	74.9	23.5	98
IC 44418	143.5	4.5	22.85	7.54	46.5	10	235.5	58.1	13.1	241	3	2	0.4	18	11.15	35.5	2.51	76.8	3.65	22.5
IC 44419	181	3.5	35.25	5.05	41.5	5	205.5	55.5	14	190.75	3.83	2.33	0.42	17	12.35	34.5	1.19	41.2	6.6	30
IC 32817	271.3	4	36.65	7.57	53	9	276	67.5	14.5	267	4.31	2.55	0.52	13.25	13.8	29.5	2.05	61.25	4.75	27
IC 85614	170.35	4	21.1	7.65	43	10.5	336	63	20	307	3.44	2.2	0.61	24.5	19.45	27	2.07	72	5.25	17.5
IC 68250A	176.15	5.15	18.65	7.46	53.3	7.15	219.5	65.8	12.5	244	3.77	2.28	0.73	37.5	15.75	18.5	1.57	109.65	17.5	78.5
IC 85626	259.1	5	38.15	6.22	47	9.8	281.5	61.55	14.25	212.75	3.45	2.08	0.6	23.8	16.4	20.5	1.05	69.25	12.5	30
IC 68316	126.58	3.5	19.45	10.02	52.5	10.65	301.5	64.75	12.75	277.5	4.47	3.33	0.73	27.5	12.75	26.5	2.1	89.05	11.5	22.5
IC85606A	217.5	4	28	6.36	51.5	15	271.5	64	12.5	237.5	3.17	1.95	0.59	13.5	14.75	29.5	1.13	46.2	4.55	29
IC 68285	21.5	4	29	7.43	47.25	10.5	279	62.25	15	272.5	3.78	2.3	0.6	27	14.49	44.5	1.8	48.25	16	30
IC 50526	168.5	4	27.5	5.18	61.5	6.5	203	78.5	17	245.5	2.68	1.75	0.42	12	10.28	17	0.54	35.5	11.6	21.5
IC 68310	203	4.5	27.5	5.54	43.25	10.45	255	58.45	15.2	331.5	3.78	2.15	0.62	15	15.8	15	0.75	54.3	23.5	34.5
IC 68225	248.5	4	36.5	7.53	49	11	237	64.5	15.5	315.5	4.39	2.7	0.6	18.5	14.4	33.5	1.19	45	13.5	50
IC 85618	257.8	3.5	35	6.87	53	10.5	256	65.5	12.5	259.5	4	2	0.38	19	16.83	25.5	1.12	43.25	6.6	37.5
IC 85670	213.75	3.75	28.5	7.67	43	13.5	238.5	56.25	13.25	193.5	4.7	3.35	0.6	17.5	13.6	20.5	0.97	49.85	18.25	40
Nakhara	132.65	3.5	21.5	6.07	51	4	192.5	68.5	17.5	181.5	3.22	2.35	0.59	23	10.4	10.5	0.39	49.2	18.1	96
IC 68232	207	4.5	35	7.43	48.5	11	231.5	61.5	13	271.5	3.12	2.05	0.41	11.5	13.75	13.5	0.54	52.6	17.1	32.5
IC 68292	177	3.5	27.5	5.45	50.1	11	227.5	64.6	14.5	277.5	2.45	2.15	0.58	13	10.85	10	0.5	57.5	19.35	32.5
PRD-1	219.55	5.15	20	7.53	54	5.8	278.5	68.3	14.3	254	3.62	2.05	0.78	23	16.2	22	1.63	78.3	20	37.5
PRD-2	108.9	3.5	12	8.19	58.5	13	387	69	10.5	235.5	3.88	2.05	0.78	19	24.31	26.5	2.09	85.9	8.6	23
PRD-5	146.43	4.75	20.9	6.8	52.25	7.5	461.5	65	12.75	190	4.09	2.53	0.59	27	13.73	14	0.97	74.1	12.25	93.5
PRD-4	144.71	5.4	19.55	7.12	50.1	7	485.5	65.35	15.25	202.5	4.53	3.05	0.89	30	15.9	10	0.73	92.7	13.7	87.5
PRD-3	142.62	5	21	5.82	50.75	6.75	253	67.25	16.5	140	4.95	3.5	0.68	31.5	14.43	15.5	1.46	103.35	6.25	97.5
BLG-1	174	4.75	20	9.32	53	12	473.5	68.5	15.5	291.5	3.62	2.25	0.5	32.5	15.8	40	3.74	97.7	2.4	10
BLG-2	221	4.5	28.65	7.48	52.25	13	459	65.25	13	269.5	3.76	2.18	0.52	20.5	17.85	22	0.98	51.05	4.6	35.5
DWD-5	163.38	3	19.5	8.15	56	11	450	66.5	10.5	218.5	4.3	2.8	0.59	26	15.7	19	1.52	83.25	24.25	57.5
DWD-2	155.9	2.5	16.5	7.55	55.5	14.5	518.5	68	12.5	292	4.57	2.45	0.53	29	24.8	35	3.03	82.15	6.85	12.5
NDN-1	132	3.5	22.5	5.85	60	12	189	70	10	366.5	2.76	1.7	0.52	22.5	10.9	15.5	0.43	25.4	7.5	29
NRN-1	179.8	5.75	24.75	7.14	55.25	15.3	381	70.25	15	232.5	3.56	2	0.52	20	18.4	35.5	2.62	74.3	17	38
DWD-1	148.65	3	23.15	6	61	15	421	75	14	261	3.3	2.2	0.6	18	12.35	12	0.46	54.3	23.65	32.5
DWD-4	147.75	3	20.35	6.65	60	13	366.5	74	14	230.5	3.15	2.4	0.52	21	12.15	8.5	0.49	60.75	14.25	27.5

GENETIC VARIABILITY STUDIES IN BITTER GOURD (*Momordica charantia* L.)

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ABSTRACT

Bitter gourd is an important cucurbitaceous vegetable with good nutritive value and medicinal importance. The present study was undertaken to elicit information on the nature of variability in bitter gourd genotypes, correlation and path analysis studies of component characters with yield and to screen the genotypes against major pest and disease.

The analysis of variance revealed significant differences among genotypes for all characters studied except days to opening of first female flower and days to first harvest. The phenotypic coefficient of variability was more than genotypic coefficient of variability for all characters under study.

Most of the important characters showed high genetic advance over mean with high heritability, indicating the influence of additive gene action for these traits, which could be improved by simple selection procedure.

Correlation studies revealed that yield per plant was positively and highly significantly correlated with number of leaves at 50 per cent flowering, number of seeds per fruit, fruit length, number of fruits per plant and fruit weight both at phenotypic and genotypic level. Hence, selection for these traits may help in improvement of yield. The path coefficient analysis for yield indicated that number of fruits per plant and fruit weight were the most important factors influencing the yield, thereby deserving greater weightage during selection for yield.

The 40 bitter gourd genotypes were grouped into 10 clusters based on D^2 values. The clusters VI and IX were most divergent, thus the genotypes of these clusters could be used in hybridization programme to get higher heterotic hybrids.

From the study high yielding genotypes such as BLG-1,PRD-2,NRN-1,IC44418,DWD-2,IC32817,IC85614,IC68316, promising line with respect to resistance to fruit fly (BLG-1,IC44418,IC32817,IC85614), and downy mildew resistant genotypes *viz.* White long and BLG-1 could be screened. These genotypes can be further utilized as such or in hybrid combinations. The genotype BLG-1 was most promising with respect to yield and resistance to pest and disease.