GENETIC VARIABILITY, CORRELATION STUDIES AND PATH COEFFICIENT ANALYSIS IN BITTER GOURD

(Momordica charantia L.)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "GENETIC VARIABILITY, CORRELATION STUDIES AND PATH COEFFICIENT ANALYSIS IN BITTER GOURD (*Momordica charantia* L.)" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara,
17th, August, 1978.

(C.Ramachandran)

CERTIFICATE

Certified that this thesis is a record of research work done independently by Shri.C.Ramachandran under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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CERTIFICATE

We, the undersigned, members of the advisory committee of Shri.C.Ramachandran, a candidate for the degree of Master of Science in Horticulture with major in Horticulture (Olericulture), agree that the thesis entitled "GENETIC VARIABILITY, CORRELATION STUDIES AND PATH COEFFICIENT ANALYSIS IN BITTER GOURD (Momordica charantia L.)" may be submitted by Shri.C.Ramachandran in partial fulfilment of the requirement for the degree.

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INTRODUCTION

INTRODUCTION

Bitter gourd (*Momordica charantia* L.) is one of the important cucurbitaceous vegetables grown extensively throughout India for its bitter fruits. It is believed to have originated in the tropical regions of the Old World and is widely distributed in India, China, Malaysia and Tropical Africa. The importance of this vegetable has long been well recognised due to its high nutritive values and precious medicinal properties.

Bitter gourd ranks first among the cucurbits with regard to the nutritive values of fruits and can very well be compared with any other vegetable. The large and small fruited varieties contain 4.2 g and 9.8 g of carbohydrates, 1.6 g and 2.1 g of protein, 88 mg and 96 mg of vitamin C, 210 I.U. of vitamin A each, and 1.8 mg and 9.4 mg of iron, respectively in 100 g of edible portion of fruits (Choudhury, 1967). Although the fruits are bitter, they are wholesome and are esteemed as a vegetable when tender. They are consumed in various preparations like pickles, curries, fries, etc.

The fruits are reported to have some medicinal properties also. They are used as tonic, stomachic, stimulant, laxative and alterative and have long been used as a folk remedy for diabetes mellitus(Nadkarni, 1927). The fruits contain two alkaloids, one of them being 'momordicine' and the bitter principles are different from 'cucurbitacines' which occur in other genera of cucurbitaceae (Anon., 1962).

In spite of the economic importance of this vegetable in India, the availability of high yielding, superior quality varieties is limited, which necessitates a need-based crop improvement programme. Again, there is an imperative need of developing varieties suited to the agro-climatic conditions of Kerala. Hence, the present investigations were undertaken, utilising the high amount of diversity noticed among the bitter gourd types in Kerala, which have been collected and maintained in the College of Horticulture, Kerala Agricultural University, Vellanikkara.

Selection is an intrinsic part of all crop improvement programmes and is as old as cultivation itself. For effective selection, information on the extent of genetic variability present in a breeding population is essential in order to identify superior genotypes for different characters. In selecting a plant or a type, one should be reasonably sure that there is a good chance of the superiority of the selection being inherited by the progenies. This is due to the fact that a sizeable part of the phenotypic variation is caused by environmental factors. Confidence in this line could be had only if there is some means of evaluating the phenotypic expression of different characters in terms of their genotypic worth. It is in this direction that the biometrical methods applied to crop improvement programmes have played a dominant role. Now, it is possible to partition the total variability into heritable and non-heritable components with the aid of suitable genetic parameters such as genotypic coefficient of variation, heritability and genetic advance which serve as the basis for selection.

The development of biometrical genetics has also revealed that, most of the economical characters are being controlled by polygenes. Yield in bitter gourd, as in other crops, is a polygenic character which depends on a number of fitness characters (Srivastava and Srivastava, 1976) and, therefore, direct selection for yield is often misleading and inappropriate. 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.

The correlation coefficients between important and non-important characters may also reveal that some of the latter are useful as indicators of one or more of the former. Also, the correlations between morphological and biochemical characters will be useful in visual selection for biochemical traits.

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. This is attributed to the interdependence of contributory characters which is often found affecting their direct influence on yield. The path coefficient analysis suggested by Wright (1921) and first adapted in plants by Dewey and Lu (1959) has been employed in many vegetables in order to overcome the unreliability of correlation coefficients. This technique is a study of cause and effect relationship which involves effective partitioning the correlation coefficients into measures of direct and indirect effects on yield.

For selecting the high yielding genotypes based on the phenotypic performance, a selection index is desirable. In order to formulate a selection index, multiple regression analysis suggested by Goulden (1952) has been used in many crops. With the regression function thus fitted, it is possible to ascertain the extent of contribution of each character in a group and also to predict the yield possible by utilising the function.

Information on the genetic variability, association analysis, path coefficient analysis and multiple regression analysis is inadequate in bitter gourd. Hence, the evaluation of available germplasm in this regard is highly necessary and the present investigations were undertaken taking into consideration, the following objectives.

i) To identify genotypes which are superior for yield and other economic characters by the analysis of variance technique.

ii) To find out the extent of genetic variability available for different characters by estimating genotypic coefficient of variation, heritability and genetic advance.

iii) To study the association between yield and its components and also among themselves by estimating phenotypic, genotypic and environmental correlation coefficients.

iv) To determine the direct and indirect effects of each component on fruit yield by utilising path coefficient analysis.

v) To formulate a reliable selection index by the multiple regression analysis.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In this review, an attempt is made to outline the important works carried out on the biometrical aspects of yield and yield components in various vegetables, which would substantiate the present study. The available literature is reviewed under the following headings:

1. Variability studies
2. Correlation studies
3. Path coefficient analysis
4. Selection index

1. VARIABILITY STUDIES

Many have studied the extent of variability in various crops by estimating the genetic parameters like phenotypic coefficient of variation, genotypic coefficient of variation, heritability, genetic advance and genetic gain.

Thakur and Nandpuri (1974) carried out variability studies in watermelon and they reported that the highest estimates of genotypic coefficient of variation and expected genetic advance were exhibited by number of seeds per kg of fruit weight while the lowest values for these parameters were shown by days to first picking. Heritability was maximum for 100-seed weight (84.97 per cent) and was minimum for branches per plant (25.59 per cent).

Miller and Quisenberry (1976) reported that genetic variance was primarily additive for early flowering in cucumber. However, partial dominance for early flowering and low nodal position of the first female flower was also noted. They have stated that, days to opening of the first female flower was controlled by relatively few genes and heritability for this trait was moderately high. Singh et al. (1976) found that the additive component of variance was high for days for opening of the first female flower, maturity, fruit number per vine and total soluble solids, whereas dominance was evident for fruit weight, flesh thickness and total yield in muskmelon.

Srivastava and Srivastava (1976) obtained the highest genotypic coefficient of variation (37.45), heritability (99.31 per cent) and genetic gain(71.73 per cent) for number of fruits per plant and lowest genotypic coefficient of variation (11.47), heritability (49.93 per cent) and genetic gain (16.73 per cent) for number of male flowers per plant in ten lines of bitter gourd. High heritability in conjunction with high genetic gain was also observed in weight of fruit, yield per plant and length of fruit which might be attributed to the action of additive genes. Characters such as number of lateral branches per plant, number of female flowers per plant and days taken to appear first female flower, which showed high values of heritability, but very low values of genetic gain, might be attributed to the non-additive gene effects.

Thakur and Choudhury (1977) estimated the genetic variability in ridge gourd and they obtained high estimates of heritability in girth of fruit, length of fruit and number of fruits per plant. The latter two characters were also reported to have high expected genetic gain estimates.

Srivastava and Sachan (1973) stated that the genotypic and environmental coefficients of variation were the highest for number of fruits per bunch and lowest for peduncle length in tomato. Broad sense heritability was highest for total soluble solids. But heritability and expected genetic advance were reported to be high in weight per fruit. Parthasarathy et al. (1976) have observed a wide range of variability for all characters studied in tomato. They estimated high heritability for all characters except stem girth and the highest value was recorded in size of fruit (97.69 per cent). Expected genetic advance was low for yield and number of primary branches, while it was maximum for average fruit weight (124.33g). However, the genetic gain was found to be quite high in yield, size of fruit and average fruit weight. Singh et al. (1977) stated that the heritability and genetic advance were relatively high for yield per plant, fruit width and number of locules per fruit in tomato.

A wide range of phenotypic variability for yield per plant, fruit length and plant height was observed among the 45 varieties of brinjal studied by Mehrotra and Dixit (1973). They also obtained high estimates of heritability and genetic advance as percentage of mean for number of branches per plant, plant height and bottom girth of fruit. Srivastava and Sachan (1973) reported that, the variability was maximum for fruits per plant and minimum for days to fruiting among the 25 varieties of brinjal tested. Genotypic coefficient of variation was reported to be highest for fruits per plant (77.39), while it was lowest for branches per plant (5.88). Fruits per plant also had high heritability (98.24 per cent) and high genetic gain (73.35 per cent). Days to first picking was reported to have the lowest heritability of 52.24 per cent. Singh *et al.* (1974) reported that the genotypic coefficient of variation and genetic gain were high for fruit weight, fruit length and yield per plant in brinjal. They also observed high heritability estimates for all characters except in fruit weight (7.59 per cent). Days to flower, number of primary branches, plant height and number of secondary branches had low genetic gain coupled with high heritability which was suggested to be due to non-additive gene effects. The results obtained by Mishra and Roy (1976) in brinjal had indicated that the genotypic coefficient of variation was high for average weight of fruit (42.21), number of fruits per plant (38.29) and yield per plant (27.57), which was supported by relatively higher heritability values for these traits. They also obtained the highest genetic advance as percentage of mean for yield per plant (98.5 per cent).

In a collection of 12 varieties of chilli, Ramanujam and Thirumalachar (1967) made estimates of various genetic parameters. A considerable degree of phenotypic as well as genotypic variability was observed for placental content, amount of capsaicin and percentage of capsaicin in whole dry fruit, indicating polygenic nature of inheritance. These characters were also reported to exhibit high heritability exceeding 90 per cent. Both dry and wet yield had low heritability value, which was explained to be due to the influence of environment. The variability studies carried out in chilli by Nandpuri et al. (1971) have shown high heritability for days to flowering, fruit number, days to maturity and single plant yield. Maximum genetic advance was estimated in the case of number of fruits per plant followed by number of branches, yield and plant height and they have concluded that high heritability need not be associated with high genetic gain.

Kirti Singh et al. (1972) reported that the 20 strains of chilli, they evaluated differed significantly for ten characters. They obtained high phenotypic and genotypic coefficients of variation in primary and tertiary branches, fruit number, size, fresh weight and yield. Fruit size also exhibited high expected genetic advance and maximum heritability.

Many other workers have studied the extent of variability in chillies and reported contrasting results. Arya and Saini (1976) observed high heritability and low genetic gain in the case of fruit yield per plant. But fruit yield had high genetic gain according to the reports of Awasthi et al. (1976), Arya and Saini (1977 a), Arya and Saini (1977 b) and Hiremath and Mathapati (1977). Fruit length was also observed to have low heritability by Hiremath and Mathapati (1977). However, Ramalingam and Murugarajendran (1977) have reported that the fruit length had high heritability as well as high genetic gain. Other characters which exhibited parallelism in the high estimates of heritability and genetic advance were number of fruits per plant, number of branches per plant, weight of fruit, size of fruit, rind thickness and number of seeds per fruit (Arya and Saini, 1977 b; Hiremath and Mathapati, 1977; and Ramalingam and Murugarajendran, 1977).

Kirti Singh et al. (1974) made estimates of various genetic parameters in a collection of 30 strains of bhindi. Phenotypic and genotypic coefficients of variation showed the maximum values for diameter of fruit, while heritability was maximum in vitamin C content. Yield exhibited low value of 33.06 per cent for heritability. Genetic gain was highest for fruit diameter, followed by crude fibre content, total sugars, vitamin C content of fruit and marketable fruit yield per plant. Variability studies carried out by different workers have shown that days to flower in bhindi had high heritability in the broad sense (Lal et al., 1977 and Rao et al., 1977). Lal et al. (1977) also reported that the fruit length and fruit thickness had high heritability, but the genetic gain was highest for number of branches per plant. Yield was observed to have the lowest genotypic coefficient of variation and heritability. In contrast to this, Rao et al. (1977) suggested that the yield per plant had the highest values of heritability and genetic gain.

In cowpea, Singh and Mehndiratta (1969) found that the number of pods per plant had the highest genotypic coefficient of variation (52.52 per cent) whereas the heritability estimate showed high values for 100-seed weight (95.89 per cent), days to flowering (88.79 per cent), pod length (80.45 per cent) and days to maturity (78.29 per cent). Expected genetic advance was appreciable for number of branches, 100-grain weight, pod number, pod length and yield. Borida et al. (1973), while working with cowpea, reported that the 100-seed weight exhibited the highest heritability followed by number of days to flowering and pod length. They also observed the highest genotypic coefficient of variation and genetic advance with pod number per plant. Lakshmi and Goud (1977) reported that the genotypic coefficient of variation was higher for plant height, grain yield, number of pods per plant and 100-grain weight. They also observed high heritability accompanied by high genetic advance as percentage of mean in the case of plant height, 100-seed weight and length of pod. Number of pods per plant and grain yield per plant were also reported to have comparatively low heritability and high genetic advance as percentage of mean.

Seth et al. (1972) found high genotypic coefficient of variation for average pod length and green pod yield per plant in french bean. Number of primary branches and green pod yield per plant had high heritability and high genetic gain estimate showing additive gene effect, while average pod length had high heritability and low genetic advance showing non-additive gene effect. Pande *et al.* (1975) found that in french bean, plant height, secondary branches and pod weight had high genetic variability, but the genetic advance was siseable for plant height (32.86 per cent), secondary branches (29.78 per cent) and pod yield (26.27 per cent). Sharma *et al.* (1977) have revealed that genetic gain was low for days taken to flowering and days taken to first picking.

Sanghi et al. (1964) estimated genotypic and phenotypic variability in cluster bean and observed high values of genotypic coefficient of variation for plant height, number of branches, 100-seed weight and reaction to blight. High heritability combined with high genetic advance was also shown by plant height, branches per plant, pod length, number of seeds per pod, 100-seed weight and reaction to blight, whereas yield and number of pods per plant showed low heritability. Sohoo *et al.* (1971) obtained high values of genotypic coefficient of variation, heritability and expected genetic advance in branches per plant, pods per plant and plant height in cluster bean. Tikka et al. (1974) studied the extent of variation in a collection of 30 cluster bean varieties and observed a good amount of genetic variability in pods per plant, grain yield and days to flower. Tripathi and Lal (1975) have revealed that high values of variance components and coefficients of variation were associated with clusters per plant, pod length, pod width and yield per plant in cluster bean. All characters were found to be highly heritable, the heritability ranging from 48.9 per cent for number of seeds per pod to 98.3 per cent for pod length. Pod length, pod width and yield per plant also had high estimates of genetic advance.

Johnson et al. (1955 a) estimated genetic and environmental variability existing in F4 and F5 generations of soybean and they concluded that the heritability estimates along with the genetic gain would be usually more useful than heritability values alone, in predicting the resultant effects of selecting the best individuals. Anand and Torrie (1963) reported that in soybean, heritability estimates were low for seed yield, pods per plant and seeds per pod and were high for 100-seed weight, lodging, height, flowering, fruiting and maturity. According to Khurana and

Sadhu (1972), high values of genotypic coefficient of variation, heritability and expected genetic advance have been found associated with branches per plant, pods per plant and plant height in soybean. Malhotra (1973) obtained the highest genotypic coefficient of variation and genetic gain for number of pods per plant and seed yield, but the heritability was maximum for number of seeds per pod in soybean. Yadav __et al__. (1974) reported that the phenotypic and genotypic variances were high for plant height, branch length and fodder yield, moderate for branch number, stem girth and days taken to flower and low for node number, in soybean. High estimates of heritability along with those for genetic advance as percentage of mean were also observed in branch length and leaf area, while those for days taken to flower, node number and plant height were moderate to high.

Teehan __et al__. (1969) suggested that the broad sense heritability and expected genetic advance were high for characters such as pods per node, length of pod, girth of pod and weight per pod in garden pea. The genetic gain for yield per plant was also moderate.

Srivastava *et al.* (1972) estimated high heritability values for days to flowering (84.48 per cent), pod length (73.29 per cent) and pod width (65.70 per cent) in peas, but the genetic advance was highest for number of pods per plant (25.61 per cent). Srivastava and Sachan (1974) suggested that pods per plant in peas, showed the maximum genotypic coefficient of variation whereas high heritability in conjunction with high genetic advance as percentage of mean was noted in the case of branches per plant and grains per pod. The investigations by Saini *et al.* (1976) have revealed that a good amount of phenotypic and genotypic variability was present for all characters, maximum being in yield per plant and minimum for number of pods per axil. Yield per plant and grain weight of fifteen pods also exhibited high heritability estimates in conjunction with high genetic advance. Tikka and Asawa (1977) suggested that the genotypic coefficient of variation and heritability were high for plant height, pods per plant and seed yield in peas.

Katiyar *et al.* (1974) while estimating the various genetic parameters in mustard, stated that yield per plant, days to first flower and plant height had high genotypic coefficient of variation and expected genetic advance. Heritability values were found high for yield per plant, days to flower and number of primary branches, moderate for days from flowering to maturity, but low for the number of secondary branches.

2. CORRELATION STUDIES

Information on the association of plant characters to ultimate yield and also on the intercorrelations is available in many vegetables.

Carlsson (1962) reported that length of fruit was positively correlated with the average weight of fruit in cucumber. Long-fruited varieties were generally observed to have a poorer fruit set than those with short fruits. Molokojedova (1962) stated that the correlations between fruit yield (weight and number) and the proportion of marketable fruits were positive and significant in cucumber. Ramalao (1975) observed that the number of pistillate flowers was positively correlated phenotypically and genotypically with fruit number, but negatively with fruit weight, length and fruit set in cucumber. The occurance of pistillate flowers on the main stem was also found to be negatively correlated with number of fruits, fruit weight, fruit length and total fruit yield.

Thamburaj (1973) reported that the number of seeds per pod, pod weight and pod length were significantly and positively correlated with yield per plant in ridge gourd.

Srivastava and Srivastava (1976) stated that the genotypic correlation coefficients were higher than phenotypic correlation coefficients among different pairs of characters in bitter gourd. Yield per plant was found to be positively associated with number of female flowers (r_g = 0.8684), number of fruits (r_g = 0.8611) and number of lateral branches (r_g = 0.5873). Number of female flowers and number of lateral branches were also found to exhibit positive association with number of fruits per plant. They also reported that the days to first female flower showed negative correlations with number of fruits per plant and number of female flowers per plant, but positive correlation with weight of fruit. Weight of fruit had negative genotypic association with number of fruits per plant.

Kalyanasundaram (1976) obtained significant positive correlations of fruit weight and diameter, size and flesh thickness in muskmelon. Total soluble solids was reported to have negative correlations with fruit weight and number of seeds per fruit.

The correlation studies by Srivastava and Sachan (1973) in tomato had shown that number of fruits per plant was correlated with yield per plant. Barooah and Mohan (1976) obtained significant negative association between fruit size and ascorbic acid content in tomato (-0.22). Verma et al. (1976) reported that total soluble solids had negative association with fruit size index (-0.296) and positive association with number of fruits per plant (0.562). Singh and Mital (1976) established that the fruit weight, locule number and fruit girth were the important characters in increasing the yield in tomato. They also found that smaller and late fruits contained more total soluble solids than large and early fruits. Positive association was also observed between fruit length and fruit girth. Nandpuri et al. (1976) and Singh et al. (1977) found positive association between yield per plant and number of fruits per plant in tomato.

Nandpuri *et al*. (1976) also reported that the yield per plant was negatively correlated with average fruit size and plant height. Plant height was also found negatively associated with number of fruits per plant.

Baha-Eldin *et al*. (1968) reported that the early flowering habit had positive association with high yielding ability, high number of fruits per plant and long fruit shape in brinjal. Nsowah (1970) studied the association of characters in brinjal and found significant association among days to floral initiation, days to flower opening and days to maturity. Fruit number had negative correlation with average weight of first matured fruit, but positive correlation with total fruit weight.

Yield in chilli has been shown to be positively correlated with number, length, width and 100-seed weight of berries by Singh and Singh (1970). According to Kirti Singh *et al*. (1972) yield per plant had positive association with plant height, number of branches, fruit number and fruit weight in chilli. Fruit number in turn was found to have positive association with fruit weight, branch number, plant height and days to flowering. Arya and Saini (1976) revealed that fruit size contributed to a greater extent, towards fruit yield in chilli. They also found that the days to flower, capsaicin content and number of branches were dependent characters. Hiremath and Mathapati (1977) established that yield in chilli was positively associated with number of branches. They also observed negative correlations between number of fruits per plant and length of fruit and between number of branches and seeds per fruit.

Association analysis in bhindi by Kirti Singh et al. (1974) revealed that yield had negative correlation with days to flowering (r_p = 0.3704, r_g = 0.3714). They also obtained positive correlations between yield per plant and flower number, number of branches, plant height and fruit number per plant both at phenotypic and genotypic levels. Fruit number was also found to exhibit positive association with number of flowers, plant height and number of branches. Srivastava and

Sachan (1975) obtained significant positive association between branches per plant and number of fruits and between plant height and length of fruit. Yield per plant was strongly and positively correlated with number of fruits per plant and number of branches per plant according to the reports of Srivastava and Sachan (1975), and Roy and Chhonkar (1976).

In cowpea, grain yield has been reported to exhibit significant positive association with number of pods per plant (Singh and Mehndiratta, 1969; Doku, 1970; and Borida et al., 1973). Grain yield was also positively correlated with pod length and number of seeds per pod according to the reports of Borida et al. (1973). Kumar et al. (1976 found that the pod yield in cowpea was positively associated with branches per plant (0.561), pods per plant (0.844), pod length (0.532), thickness of pod (0.576), days to flowering (0.613) and days taken to maturity (0.518).

The correlation coefficients worked out in french bean by Pande et al. (1975) have revealed that the pod yield was strongly and positively correlated with plant height, primary branches, pod weight, pod length and pods per plant and it was negatively correlated with days to flower. Sharma et al. (1977) concluded that vegetable yield and earliness in french bean were mainly contributed by number of nodes bearing pod, plant height and number of branches per plant.

Investigations in cluster bean by many workers have shown that yield per plant was highly and positively correlated with pods per plant, clusters per plant, branches per plant and pod length. (Sanghi and Sharma, 1964; Solanki et al., 1975; and Tikka, 1975). Pod number was also found to be correlated with pod length by Tikka (1975).

Johnson et al. (1955 b) attempted to correlate the different characters in soybean and they concluded that selection for a long fruiting period, lateness, resistance to lodging and shattering, low protein and high oil content would be effective in increasing the yield in soybean. Anand and Torrie (1963) worked out significant and positive genotypic correlations between yield and number of pods per plant, and seeds per pod in soybean. Tang (1963), after a critical study of the characters, stated that plant height, node number, branch number and pod number were found correlated with seed yield. Several others had established that the yield in soybean had positive correlation with number of pods per plant, plant height and number of branches and among themselves (Kaw and Menon, 1972; Khurana and Sadhu, 1972; Singh and Singh, 1974; Srivastava et al., 1976; and Choudhury et al., 1977). Yield was also found positively correlated with days to flowering by Singh and Singh (1974), Srivastava et al. (1976) and Choudhury et al. (1977).

Association analysis of peas by Kumar et al. (1965) revealed that the correlation coefficient between yield and number of branches and between length of pod and weight of pod were positive and significant. Teehan et al. (1969) suggested that pod yield in pea was highly and positively correlated with girth of pod (0.745), weight of pod (0.677) and pods per plant (0.625). Singh and Singh (1970) established that yield per plant had positive correlation with branches per plant and pods per plant in pea. They also estimated positive correlation coefficients between days to flowering and days to maturity and between pod length and seeds per pod. Srivastava et al. (1975) and Tikka and Asawa (1977) have also shown that yield per plant in pea had significant positive association with length of pod and pods per plant.

Choudhuri (1967) carried out correlation studies in mustard and reported that yield was highly and positively correlated with number of pods per plant (0.849) and number of primary branches (0.711). The environmental correlations between yield and the yield contributing characters were also significant. Shivahare et al. (1975) stated that seed yield of Indian mustard had a positive genotypic correlation with plant height (0.6710), number of primary branches (0.5730) and days to flower (0.4120).

3. PATH COEFFICIENT ANALYSIS

Recently some investigators have employed path coefficient analysis in certain vegetables, the results of which are summarised below:

Srivastava and Srivastava (1976) carried out path analysis in bitter gourd and reported that number of female flowers per plant had the maximum direct effect on yield followed by number of fruits per plant and number of lateral branches per plant. The indirect effects of other characters towards yield were mainly through number of lateral branches, number of female flowers and number of fruits per plant. Number of fruits per plant also had high indirect contribution towards yield through weight of fruit.

Nandpuri et al. (1976) analysed the path values in tomato and observed that only the average number of fruits per plant had high direct positive effect and high indirect effect through plant height on the fruit yield. The direct effect of plant height and indirect effect through number of fruits per plant were also negative. Singh and Mital (1976) reported that locule number, fruit girth, number of primary branches and fruit weight in early pickings had a high direct positive effect on yield in tomato. They also noticed negative direct effects in the case of fruit length, fruit shape index, number of fruits per plant and fruit weight towards early yields in tomato.

In chilli, Singh and Singh (1974) obtained maximum direct effect for number of branches. Days to flower and days to maturity, in addition to their direct effects, were found to influence the yield through number of branches. Plant height and fruit number had also influenced the yield mainly through number of branches per plant. Lee (1976) and Korla and Rastogi (1977) estimated the path coefficients in chilli and reported that the number of fruits per plant had high direct influence on yield. Korla and Rastogi (1977) also revealed that the weight of fruit, plant height and length of fruit had appreciable direct effects. The indirect effects of fruit length through number of fruits and plant height were found negative.

Path coefficient analysis by Rao *et al.* (1977) has shown that number of pods per plant exerted the highest direct effect on yield in bhindi. They obtained positive and low direct effects in the case of plant height and number of seeds per pod.

Shettar _et al_. (1975) employing the path analysis in french bean, suggested that the number of pods per plant had high direct influence on yield. The direct influence of pod length was moderate, while the indirect effect of pod length through pod number was low.

Path coefficient analysis by Tikka (1975) in cluster bean has shown that the positive correlations of pod number and pod length on seed yield were due to their indirect effects through clusters per plant and grains per pod. In fact the direct effect of pod length was negative.

Lal and Fazul Haque (1971) reported that 100-seed weight and number of pods per plant had very low direct positive effect on seed yield in soybean and all other characters except 100-seed weight had sufficiently high positive indirect effects on seed yield through number of pods. Sengupta and Kataria (1971) analysed the path coefficients in soybean and found very small direct effects of pods per plant and clusters per plant towards yield. The high residual effect (0.541) in their investigation was suggested to be due to sampling error and many other characters which were not taken into account. Kaw and Menon (1972), after a critical study of the path analysis in soybean suggested that the number of pods and days to maturity contributed the most, both directly and indirectly towards yield per plant. Days to 50 per cent flowering had sizeable negative effects on yield both directly and indirectly.

Singh and Singh (1970) used path analysis in pea and reported that branch number, pods per plant, seeds per pod and 100-seed weight were the important yield contributors as indicated by the direct and indirect effects. Srivastava et al. (1975) using the path analysis in pea suggested that number of pods per plant, pod length and number of seeds per pod could be effectively utilised in selecting high yielding genotypes, since they had high direct effects. Tikka and Asawa (1975) pointed out that maximum weightage should be given to seed size and pods per plant, while making selection for yield in peas, as shown by the path coefficients.

4. <u>SELECTION INDEX</u>

The multiple regression analysis has been used in many vegetables for formulating the selection index. The results are reviewed below briefly.

Hazel and Lush (1942) has suggested that an index of selection which gives proper weight to each trait is more efficient than selection for one trait at a time.

Thamburaj (1973) carried out multiple regression analysis in ridge gourd and reported that pod weight and number of seeds per pod had a significant effect on yield per plant.

In tomato, Nandpuri <u>et al</u>. (1976) have revealed that the number of fruits per plant, days taken to maturity and plant height measured 48.80 per cent of the total variation in yield. An index including the average fruit size in addition to the above components was found to increase the efficiency to 51.29 per cent.

Lee (1976) stated that plant height, diameter of stem, number of fruits per plant and fruit weight were the important characters for yield prediction in chilli.

Kirti Singh et al. (1974) attempted to predict the yield in bhindi and found that it was primarily dependent on weight of fruit, number of fruits per plant and number of female flowers per plant. The estimate of coefficient of determination was 0.83. Roy and Chhonkar (1976) stated that the number of fruits per plant and branches per plant had significant contribution towards yield in bhindi and the prediction power of the regression equation was 87.10 per cent of fruit yield.

Kumar et al. (1976) analysed the regression values in cowpea and showed that the clusters per plant, pods per plant and 100-seed weight were the important characters in determining the pod yield.

Pande et al. (1975) have revealed that the yield in french bean was primarily dependent on plant height, days to flower, primary branches, pod length and pods per plant. The estimate of coefficient of determination was 0.741, indicating that about 74 per cent of total variability in yield could be accounted for, if selection was based on these characters.

Sanghi and Sharma (1964) suggested that about 64 per cent of the variability in yield of cluster bean was observed to be due to clusters per plant, pods per plant and 100-seed weight while 90 per cent of the variability in yield was accounted for, by the variables such as clusters per plant, pods per plant and branches per plant.

Anand and Torrie (1963) reported that the number of pods per plant and seeds per pod were more important than seed weight for predicting the yield in soybean. Choudhury et al. (1977) with a study of multiple regression analysis, suggested that number of pods per plant and test weight were the predictors of yield in soybean and the prediction power of the equation was 74.5 per cent of the observed yield.

MATERIALS AND METHODS

MATERIALS AND METHODS

A field experiment for the analysis of genetic variability, correlation studies and path coefficient analysis in bitter gourd (*Momordica charantia* L.) was conducted during 1977-78 (October-February). The trial was conducted in the fields of the Instructional Farm of the College of Horticulture, Kerala Agricultural University, Vellanikkara.

MATERIALS

Twenty five diverse bitter gourd types, collected from different parts of the Kerala State (Cannanore, Calicut and Trichur) and maintained in the Department of Olericulture, College of Horticulture, Vellanikkara were used for the study. These types had been selected based on the visual morphological characters of fruit given in Table 1.

METHODS

1. Lay out of experiment

The experiment was laid out in randomised block design with three replications. Each replication consisted of twenty five plots, one for each bitter gourd type and the number of plants per plot was three. To enable accurate individual observations, a spacing of 3 M between rows and 2.5 M between plants was given.

Table 1. Morphological fruit characters of different bitter gourd types

Type	Colour	Length	Girth in the middle
B.G.1	Green, light green at the tip	Medium long	Broad
B.G.2	Whitish green	Medium long	Broad
B.G.3	White	Medium long	Narrow
B.G.4	White	Medium long	Broad
B.G.5	Whitish green	Medium long	Narrow
B.G.6	Whitish green	Long	Broad
B.G.7	Dark green	Medium long	Broad
B.G.8	White	Medium long	Broad
B.G.9	Whitish green	Short	Broad
B.G.10	White	Medium long	Narrow
B.G.11	Whitish green	Very short	Broad
B.G.12	Dark green, light green at the tip	Medium long	Narrow
B.G.13	Dark green	Short	Narrow
B.G.14	White	Short	Narrow
B.G.15	Whitish green	Long	Narrow
B.G.16	White	Medium long	Narrow
B.G.17	Green	Medium long	Narrow
B.G.18	White	Medium long	Broad
B.G.19	Whitish green	Medium long	Broad
B.G.20	Green	Long	Broad
B.G.21	Green, light green at the tip	Long	Broad
B.G.22	Green	Medium long	Narrow
B.G.23	Green	Very long	Broad
B.G.24	White	Medium long	Broad
B.G.25	White	Long	Narrow in the middle and broad at the tip.

(Continued)

Table 1. (contd.)

Type	Spines	Ridges
B.G.1	Present, not prominent	Present, discontinuous
B.G.2	Absent	Present, discontinuous
B.G.3	Present, prominent	Absent
B.G.4	Present, highly prominent	Absent
B.G.5	Absent	Present, continuous
B.G.6	Absent	Present, discontinuous
B.G.7	Present, prominent	Absent
B.G.8	Present, not prominent	Absent
B.G.9	Present, prominent	Absent
B.G.10	Present, prominent	Absent
B.G.11	Present, prominent	Absent
B.G.12	Present, not prominent	Absent
B.G.13	Present, not prominent	Absent
B.G.14	Present, not prominent	Absent
B.G.15	Present, not prominent	Present, discontinuous
B.G.16	Absent	Present, discontinuous
B.G.17	Present, not prominent	Absent
B.G.18	Absent	Present, discontinuous
B.G.19	Present, prominent	Absent
B.G.20	Absent	Present, continuous
B.G.21	Present, not prominent	Present, discontinuous
B.G.22	Absent	Present, continuous
B.G.23	Present, prominent	Absent
B.G.24	Present, prominent	Absent
B.G.25	Absent	Present, continuous

2. Field culture

The twenty five types were selfed for two generations when apparent homozygosity was achieved. The seeds were then sown in prepared pits at the rate of four seeds per pit on 22-10-1977. After germination, only one seedling was retained per pit and the rest were removed.

Farm yard manure was basally applied at the rate of five tonnes per hectare. Inorganic fertilizers were applied at the rate of 56 kg N, 56 kg P and 56 kg K per hectare as ammonium sulphate, superphosphate and muriate of potash respectively, in three equal doses, one before sowing and later, at 15 days interval after germination as per the recommendations of Dhesi et al.(1966). Pot watering was practised on alternate days in the early stages. When the vines started trailing, basin irrigation was adopted on alternate days. The vines were trained individually on pandals erected at a height of about 1.85 metres. During the cropping period prophylatic plant protection measures were taken as per the recommendations. The harvest of the crop was completed on 26-2-1978.

A part of the experimental field showing the method of training, is presented in Plate I. Information regarding temperature, humidity and rainfall during the period of crop growth is given in Appendix I.

3. Observations

Data were collected on the following twenty one characters. Entire population was considered for all the characters except for floral characters and biochemical characters of fruit, in which case only the central plants of each bitter gourd type in every replication were chosen. Wherever entire plants were taken into account, average values were calculated for each plot for the statistical analysis.

3.1. Number of primary branches per plant

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

3.2. Length of main vine

The total length of the main vine was measured in metres when once cropping was completed.

3.3. Node at which the first female flower appeared

The node at which the first female flower appeared was counted from the cotyledon node and recorded.

3.4. Days for opening of the first female flower

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

3.5. Number of female flowers per plant

Total number of female flowers produced by each vine was counted during the entire cropping period.

3.6. Percentage of female flowers

The number of male flowers opened each day was also recorded. After collecting the data, percentage of female flowers over total number of flowers was worked out.

3.7. Days for picking maturity

Ten female flowers were tagged on the dates of their opening. After set, six fruits out of the tagged ones were chosen for observation. The number of days from the date of opening to the date of harvest was recorded and the mean worked out for all the plants.

3.8. Yield per plant

Fruits were harvested as and when they matured, the maturity for vegetable purpose being judged by visual observation. Total weight of the fruits harvested from each plant was calculated at the end of the period and yield recorded in kg per plant.

3.9. Number of fruits per plant

The number of fruits harvested was counted and total number of fruits produced by each plant was worked out.

During harvest, six fruits were randomly selected from each plant for recording the following measurements.

3.10. Weight of fruit

Weight of the six fruits were recorded in grams and the mean weight worked out.

3.11. Length of fruit

Length was measured from the stalk end to the tip in cm for the six fruits and averaged.

3.12. Girth of fruit

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

3.13. Flesh thickness

By using a micrometer the flesh thickness of the six fruits was estimated after cutting at the centre and data recorded in mm. The mean was then worked out.

3.14. Number of seeds per fruit

Total number of seeds contained in the six fruits was counted to get the mean.

3.15. 100-seed weight

Seeds were extracted separately for each plant, from ripe fruits, washed and dried uniformly. Hundred bold seeds were selected and the weight recorded in grams.

For estimating the following chemical constituents of fruit, one fruit per plant was harvested at random, on the 18th day of flower opening (that is the time of attaining commercial maturity) from the middle row of each replication.

3.16. Total soluble solids

The total soluble solids was estimated by using Abbe refractometer.

3.17. Vitamin C content

Samples from the middle portion of fresh fruits were used for the estimation of vitamin C content. The tissue was macerated in a pestle and mortar adding 2 per cent metaphosphoric acid-acetic acid stabilising extracting solution and vitamin C content was estimated volumetrically by the 2, 6 - dichlorophenol-indophenol visual titration method (A.O.A.C., 1960). The value was expressed in mg of vitamin C per 100 g of fruit on a wet weight basis.

3.18. Protein content

The rest of the fruit, after being used for vitamin C determination, was chopped into pieces and dried in an air-oven at 80°C till constant weight was obtained. The whole material was ground to pass through a 0.5 mm mesh in a Wiley mill.

Accurately 0.1 g of the sample was weighed and nitrogen content was estimated by macrokjeldahl method.

Protein content of the fruit was found out by multiplying the value of nitrogen by 6.25 and the protein content was expressed in grams per 100 g of fruit on dry weight basis (A.O.A.C., 1960).

3.19. Phosphorus content

A suitable quantity of 1 g of ground sample was digested in 1:2:9 $HClO_4:H_2SO_4:HNO_3$ mixture and made upto 100 ml with distilled water.

Phosphorus in a 10 ml aliquot of this extract was determined colorimetrically using the vanadomolybdo-phosphoric yellow colour method in nitric acid system (Jackson, 1973).

3.20. Potassium content

Potassium in an aliquot of the triple acid extract of the sample was determined using a flame photometer (Jackson, 1973).

3.21. Iron content

Iron content in 15 ml aliquot of the triple acid extract of the sample was determined colorimetrically using the O-phenanthroline red ferrous complex method (Jackson, 1973).

4. <u>Statistical analysis</u>

Data on different characters studied were subjected to statistical analysis.

The analysis of variance technique suggested by Fisher (1954) was employed for the estimation of various genetic parameters. The bitter gourd types were compared for different economic characters after estimating the various critical differences. The extent of association among characters, was measured by correlation coefficients. Path coefficient analysis was used for estimating the direct and indirect effects. Later, a prediction equation was fitted by the multiple regression technique.

4.1. <u>Phenotypic, genotypic and environmental variances</u>

Estimates of variance components were made by the following formulae as suggested by Burton (1951).

Phenotypic variance (Vp) = Vg + Ve

where (Vg) = Genotypic variance

Ve = Environmental variance

Genotypic variance $(Vg) = \frac{VT - VE}{N}$

where VT = Mean sum of squares due to treatments

VE = Mean sum of squares due to error

N = Number of replication

Environmental variance (Ve) = VE

where VE = Mean sum of squares due to error

4.2. <u>Phenotypic and genotypic coefficients of variation</u>

The phenotypic and genotypic coefficients of variation were calculated by the formulae suggested by Burton and Devane (1953).

Phenotypic coefficient of variation (PCV) $= \frac{\sqrt{Vp}}{\bar{X}} \times 100$

where Vp = Phenotypic variance

$\bar{X}$ = Mean of the character under study

Genotypic coefficient of variation (GCV) $= \frac{\sqrt{Vg}}{\bar{X}} \times 100$

where Vg = Genotypic variance

$\bar{X}$ = Mean of the character under study

4.3. Heritability

Heritability in the broad sense was estimated by the following formula as suggested by Burton and Devane (1953).

$$\text{Heritability} \quad (H) = \frac{Vg}{Vp} \times 100$$

where Vg = Genotypic variance

Vp = Phenotypic variance

4.4. Expected genetic advance

The expected genetic advance of the available germplasm was measured by using the formula suggested by Lush (1949) and Johnson *et al.*(1955 a) at 5 per cent selection intensity using the constant K as 2.06 given by Allard (1960).

$$\text{Expected genetic advance} \quad (Ga) = \frac{Vg}{\sqrt{Vp}} \times K$$

where Vg = Genotypic variance

Vp = Phenotypic variance

K = Selection differential

4.5. Genetic gain (Genetic advance as percentage of mean)

The method for the assessment of genetic advance as percentage of mean suggested by Johnson *et al.* (1955 a) was used.

Genetic gain (GG) = $\frac{Gs}{\bar{X}}$ x 100

where Gs = Expected genetic advance

$\bar{X}$ = Mean of the character under study

4.6. Phenotypic, genotypic and environmental correlation coefficients

The phenotypic, genotypic and environmental covariances were worked out in the same way as the variances were calculated. Mean product expectations of the covariance analyses are analogous to the mean square expectations of the analyses of variance. The different covariance estimates were calculated by the method suggested by Fisher (1954).

Phenotypic covariance between two characters 1 and 2 $(COVp_{12}) = COVg_{12} + COVe_{12}$

where $COVg_{12}$ = Genotypic covariance between characters 1 and 2

$COVe_{12}$ = Environmental covariance between characters 1 and 2

Genotypic covariance between two characters 1 and 2 $(COVg_{12}) = \frac{Mt_{12} - Me_{12}}{N}$

where Mt_{12} = Mean sum of product due to treatments between characters 1 and 2

Me_{12} = Mean sum of product due to error between characters 1 and 2

N = Number of replication

The phenotypic, genotypic and environmental correlation coefficients among the various characters were worked out in all possible combinations according to the formulae suggested by Johnson et al. (1955 b) and Al - Jibouri et al. (1958).

Phenotypic correlation coefficient between two characters 1 and 2 $(rp_{12}) = \frac{COVp_{12}}{\sqrt{(Vp_1)(Vp_2)}}$

where $COVp_{12}$ = Phenotypic covariance between characters 1 and 2

Vp_1 = Phenotypic variance of character 1

Vp_2 = Phenotypic variance of character 2

Genotypic correlation coefficient between two characters 1 and 2 $(rg_{12}) = \frac{COVg_{12}}{\sqrt{(Vg_1)(Vg_2)}}$

where $COVg_{12}$ = Genotypic covariance between characters 1 and 2

Vg_1 = Genotypic variance of character 1

Vg_2 = Genotypic variance of character 2

Environmental correlation coefficient between two characters 1 and 2 $(re_{12}) = \frac{COVe_{12}}{\sqrt{(Ve_1)(Ve_2)}}$

where $COVe_{12}$ = Environmental covariance between characters 1 and 2

Ve_1 = Environmental variance of character 1

Ve_2 = Environmental variance of character 2

4.7. Path coefficient analysis

Path coefficients are standardised regression coefficients. In path coefficient analysis the correlations among cause and effect are partitioned into direct and indirect effects of causal factors on an effect factor. The principles and techniques suggested by Wright (1921) and Li (1955) for cause and effect system were adopted for the analysis using the formula given by Dewey and Lu (1959). The characters having significant correlation with yield at one per cent level were selected and accordingly number of primary branches per plant, length of main vine, number of female flowers per plant, number of fruits per plant, weight of fruit and length of fruit were considered for the path coefficient analysis.

4.8. Multiple regression analysis

The characters having high direct contribution towards yield as revealed from path coefficient analysis, were selected for the formulation of selection index. Accordingly, length of main vine (X_2), number of fruits per plant (X_9) and weight of fruit (X_{10}) were taken into account. The partial regression coefficients of these characters with yield (Y) were worked out and a multiple liniar regression function, $Y = a + b_1 X_2 + b_2 X_9 + b_3 X_{10}$, was fitted according to the method given by Goulden (1952).

RESULTS

RESULTS

1. VARIABILITY STUDIES

Of the various parameters of quantitative variability, mean, range and the variation around the mean are the basic ones. The mean performances of twentyfive bitter gourd types in respect of yield and other quantitative characters are furnished in Table 2 and Fig. 1, 2 and 3. The analysis of variance carried out for the twenty one characters presented in Table 3 showed that the differences among the twenty five types for all the charactere were highly significant. The range, overall mean and standard error for different characters are given in Table 4. Table 5 contains the estimates of phenotypic, genotypic and environmental variances. In Table 6 and Fig. 4 and 5, the phenotypic and genotypic coefficients of variation, heritability, expected genetic advance and genetic gain for the different characters are furnished.

1.1. Number of primary branches per plant

The mean number of primary branches among the different bitter gourd types ranged from 18.00 to

Table 2. Mean values of twenty one quantitative characters in different bitter gourd types (from 1 to 5)

Types	No.of primary branches per plant	Length of main vine (metres)	Node at which the first female flower appeared	Days for opening of the first female flower	No.of female flowers per plant
	1	2	3	4	5
B.G.1	25.00	4.81	17.00	35.34	62.67
B.G.2	19.11	4.26	18.78	41.22	51.00
B.G.3	31.11	4.69	25.00	43.67	37.67
B.G.4	26.44	4.59	16.11	38.56	35.33
B.G.5	26.89	3.93	23.22	45.00	50.00
B.G.6	30.67	5.00	21.11	37.22	51.00
B.G.7	28.00	4.09	15.89	33.89	65.67
B.G.8	23.33	4.22	21.22	46.89	48.67
B.G.9	25.11	5.06	22.34	46.55	64.00
B.G.10	26.22	4.60	18.56	39.56	60.00
B.G.11	24.55	2.92	18.11	41.45	38.67
B.G.12	22.22	4.36	22.78	45.33	75.67
B.G.13	26.11	4.64	20.22	41.00	82.33
B.G.14	27.44	4.42	18.56	39.22	36.67
B.G.15	32.78	5.19	25.11	45.78	71.67
B.G.16	30.67	4.37	17.78	38.11	80.67
B.G.17	34.33	5.48	26.44	44.22	81.67
B.G.18	30.00	5.26	25.22	48.44	61.00
B.G.19	22.67	4.13	14.11	46.00	38.33
B.G.20	28.34	4.34	14.11	45.34	62.00
B.G.21	34.44	5.37	22.56	42.67	83.00
B.G.22	18.00	4.37	20.00	45.89	41.00
B.G.23	35.89	6.22	21.44	42.78	66.33
B.G.24	25.11	4.65	26.89	44.67	62.67
B.G.25	23.55	4.27	20.11	40.22	59.67

35.89 with a general mean of 27.12. Among the types studied, B.G. 23 recorded maximum number of branches (35.89), whereas B.G. 22 had the minimum number of branches (18.00) per plant. The differences among the types were highly significant. The estimated phenotypic, genotypic and environmental variances (Vp = 21.64, Vg = 20.81, Ve = 0.83) showed a predominant influence of genetic component in relation to environmental effect for this character. The phenotypic and genotypic coefficients of variation (PCV = 17.15 per cent, GCV = 16.82 per cent) also confirmed that the major part of variation was due to the genetic effects. Broad sense heritability was high (96.16 per cent) and the genetic gain was fairly good (33.98 per cent).

1.2. Length of main vine

The length of main vine ranged from 2.92 to 6.22 metres with a general mean of 4.61 metres. Maximum length of 6.22 metres was observed in the type B.G. 23 followed by B.G. 17 (5.48 m), B.G. 21 (5.37 m), B.G. 15 (5.19 m), while a minimum mean length of 2.92 m was recorded for B.G. 11. The

METROGLYPH SHOWING PLANT CHARACTERS IN DIFFERENT BITTER GOURD TYPES

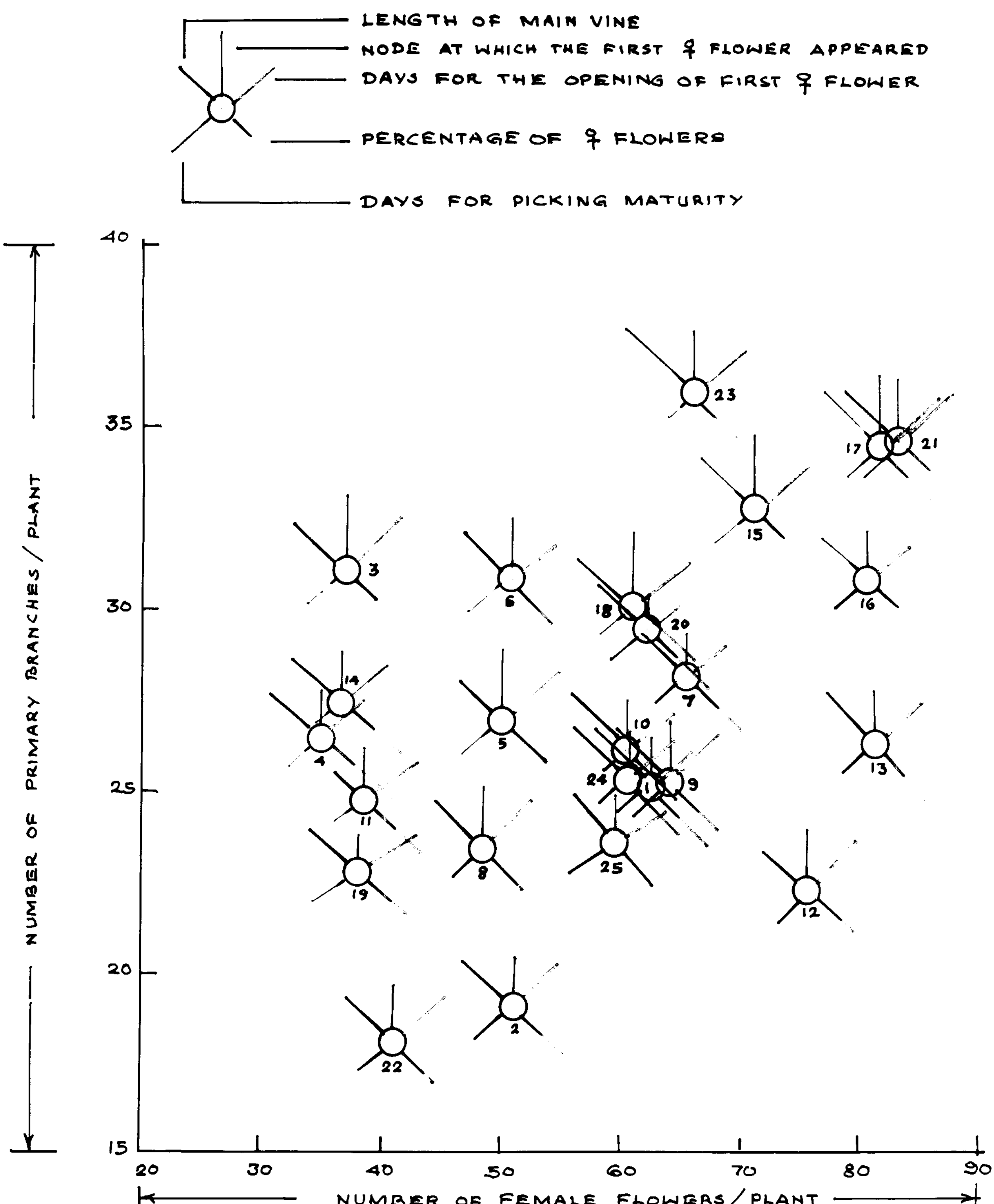


FIG: 1.

different variance estimates were comparatively very low with larger genetic component than environmental variance (Vp = 0.42, Vg = 0.39, Ve = 0.03). The phenotypic and genotypic coefficients of variation were 14.07 per cent and 13.51 per cent respectively, which showed that a greater part of variation was accounted by genetic causes. Heritability estimate recorded a high value of 92.18 per cent. Eventhough the expected genetic advance exhibited a low value of 1.23, the improvement possible for the character was found to be 26.73 per cent, as indicated by the estimate of genetic gain.

1.3. Node at which the first female flower appeared

The general mean of this character was 20.51, eventhough the values ranged from 14.11 to 26.89 among the different types tested. The type B.G. 24 had maximum number of nodes (26.89), whereas the types B.G. 19 and B.G. 20 recorded the minimum number of nodes (14.11) for the appearance of first female flower. The variance estimates have revealed that major part of variability for the character was contributed by genetic effect (Vp = 13.91, Vg = 13.07, Ve = 0.84). In general genotypic coefficient of variation was moderately high (17.63 per cent) with high heritability (93.97 per cent). The expected genetic advance showed a low value (7.22), but the genetic gain indicated a high percentage (35.21 per cent), noting the improvement feasible for the character.

1.4. Days for opening of the first female flower

The mean number of days for the opening of the first female flower ranged from 33.89 to 48.44 with a general mean of 42.36 days. Maximum number of days was recorded for the type B.G. 18 (48.44) and the minimum number of days was observed in B.G. 7 (33.89). Other early flowering types were B.G. 1 (35.34 days) and B.G. 6 (37.22 days). In general the variability was low (Vp = 14.90) with more amount of genetic component (Vg = 14.68) than the environmental variance (Ve = 0.22). The genotypic coefficient of variation recorded was only to the extent of 9.05 per cent. Heritability estimate was very high (98.5 per cent) and the expected genetic advance (7.83) and genetic gain (18.49 per cent) exhibited low values.

1.5. Number of female flowers per plant

Number of female flowers showed a wide range of variation from 35.33 to 83.00 flowers among the types, eventhough the general mean was 58.69 flowers per plant. Maximum number of female flowers was produced by the type B.G. 21 (83.00) which was followed by B.G. 13 (82.33), and B.G. 17 (81.67), while the minimum number of female flowers was produced by B.G. 4 (35.33). The variance estimates were high (Vp = 240.01, Vg = 236.15, Ve = 3.86) and the genotypic coefficient of variation was fairly good (26.18 per cent). The heritability percentage and expected genetic advance were high (H = 98.39 per cent, Gs = 31.40). The estimate of genetic gain revealed that by selecting five per cent superior plants from the available germplasm it was possible to get 53.5 per cent improvement for the character.

1.6. Percentage of female flowers per plant

Percentage of female flowers showed a narrow range of 2.74 to 6.56 with a general mean of 4.52.

Table 2a. Mean values of twenty one quantitative characters in different bitter gourd types (from 6 to 10)

Types	Percentage of female flowers	Days for picking maturity	Yield per plant (Kg)	No.of fruits per plant	Weight of fruit (g)
	6	7	8	9	10
B.G.1	4.65	15.44	5.23	54.22	155.39
B.G.2	4.55	15.17	5.04	46.11	182.21
B.G.3	2.74	16.94	3.26	32.89	170.36
B.G.4	6.56	14.22	3.50	33.67	183.15
B.G.5	4.06	17.28	2.92	29.78	136.93
B.G.6	3.49	18.00	5.22	42.78	200.75
B.G.7	4.91	13.44	4.41	53.22	163.92
B.G.8	3.71	13.17	3.93	41.22	156.97
B.G.9	4.21	14.94	6.73	53.11	166.53
B.G.10	4.56	12.39	7.47	51.22	187.72
B.G.11	5.23	11.89	2.53	31.22	122.36
B.G.12	4.07	14.06	5.67	66.66	159.36
B.G.13	4.99	13.06	3.36	73.22	115.41
B.G.14	5.38	14.17	2.69	29.89	127.55
B.G.15	4.34	15.89	7.58	61.33	188.14
B.G.16	5.05	14.28	4.58	73.33	157.97
B.G.17	4.67	13.22	5.67	70.22	154.65
B.G.18	5.03	13.28	5.03	50.56	192.90
B.G.19	4.21	17.22	3.04	31.00	191.65
B.G.20	5.67	15.45	6.02	48.00	199.68
B.G.21	4.95	16.39	7.75	73.67	209.07
B.G.22	3.71	13.67	3.78	31.11	156.43
B.G.23	3.96	12.83	10.87	55.22	234.98
B.G.24	4.60	14.39	5.15	51.56	180.84
B.G.25	3.72	16.44	3.04	28.56	185.74

The highest percentage of 6.56 was observed in B.G. 4 and the lowest (2.74) in B.G. 3. The variance estimates (Vp = 1.24, Vg = 1.19, Ve = 0.05) exhibited a predominant effect of genetic component. Similarly the phenotypic and genetypic coefficients of variation were very low (PCV = 9.11 per cent, GCV = 8.94 per cent). The heritability estimate was high (96.17 per cent), but the genetic gain showed a low value (18.06 per cent).

1.7. Days for picking maturity

The range observed for the character was from 11.89 to 18.00 days with a general mean of 14.69 days. The maximum number of days was taken by the type B.G.6 and the minimum number in B.G. 11 for the maturity of fruit. Other early maturing types were B.G. 10 (12.39 days), B.G. 23 (12.83 days), B.G. 13 (13.06 days), B.G. 8 (13.17 days), B.G. 17 (13.22 days) and B.G. 18 (13.28 days). The variance estimates observed for the character were low (Vp = 2.87, Vg = 2.78, Ve = 0.09) with a dominance of genotypic variance. Similarly the genotypic coefficient of variation was found to exhibit a low value of 11.35

per cent. Other genetic parameters like heritability, expected genetic advance and genetic gain estimated were 96.81 per cent, 3.38 and 23.01 per cent, respectively.

1.8. Yield per plant

The general mean of the available population was found to be 4.98 kg of fruits per plant. However yield showed a wide variation, ranging from 2.53 to 10.87 kg per plant. The highest yield was produced by the type B.G. 23 (10.87 kg) which was followed by B.G. 21 (7.75 kg), B.G. 15 (7.58 kg), B.G. 10 (7.47 kg), B.G. 9 (6.73 kg), B.G. 20 (6.02 kg) and the lowest yield was recorded in B.G. 11 (2.53 kg). The variance estimates indicated a profound influence of genetic component than the environmental effect in the total phenotypic variance. The phenotypic and genotypic coefficients of variation were the highest(PCV = 39.88 per cent, GCV = 39.82 per cent) among the different characters studied. Similarly the broad sense heritability exhibited very high percentage (99.74 per cent). Although the expected genetic

Fig.2. Metroglyph showing fruit and seed characters

Numbers from 1 to 25 in the figure represent bitter gourd types from B.G.1 to B.G.25, respectively

METROGLYPH SHOWING FRUIT AND SEED CHARACTERS

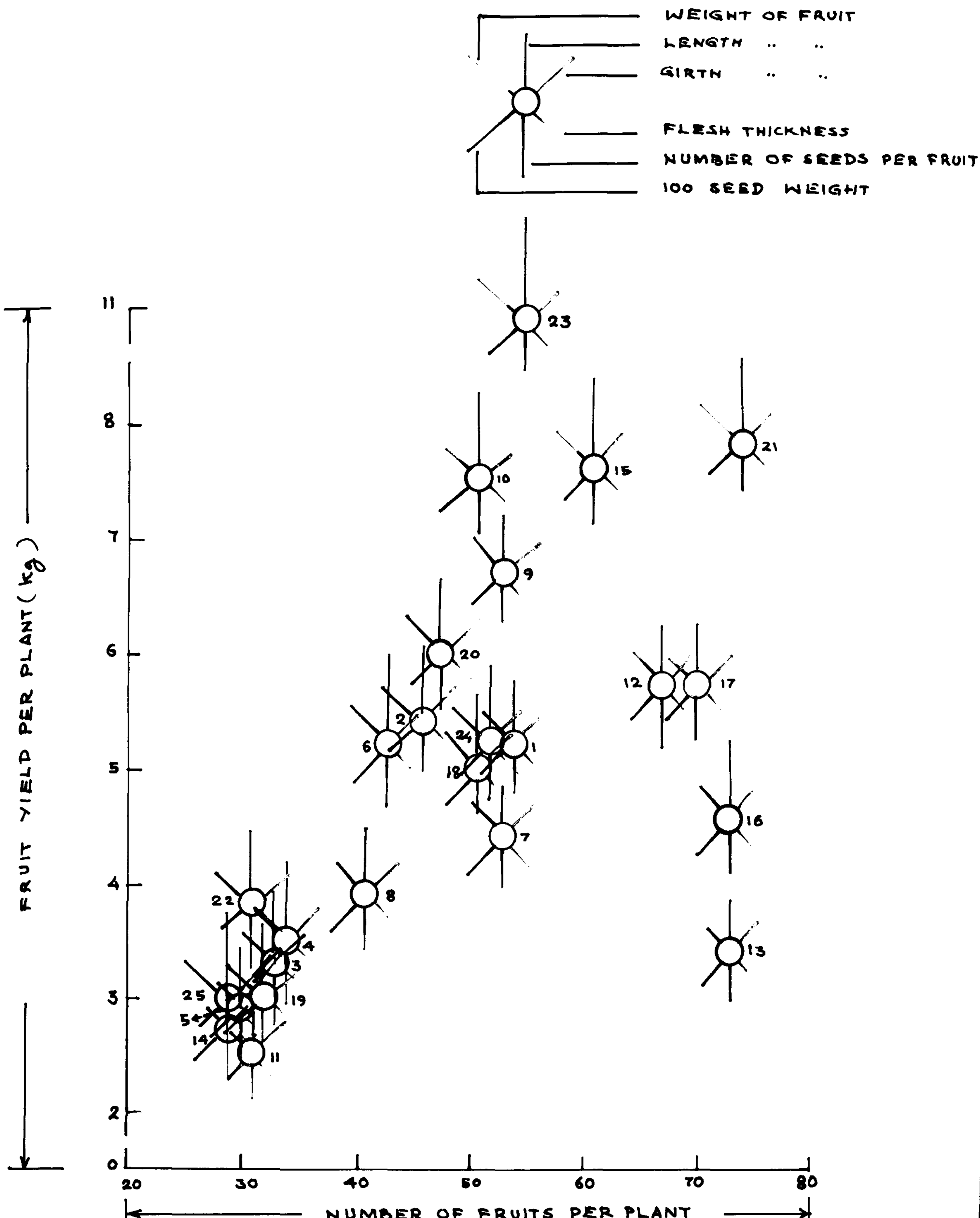


FIG: 2

advance was low (4.08) the genetic gain had the highest estimate of 81.93 per cent among the different traits.

1.9. <u>Number of fruits per plant</u>

The range of variation observed in this character was from 28.56 to 73.67 with a general mean of 48.55. Maximum number of 73.67 fruits was produced by the type B.G. 21 which was closely followed by B.G. 16 (73.33), B.G. 13 (73.22), B.G. 17 (70.22), B.G. 12 (66.66), B.G. 15 (61.33) and B.G. 23 (55.22), while the minimum number of fruits was produced by the type B.G. 25 (28.56). A high amount of variability was observed for the character as shown by the different variance estimates (Vp = 230.60, Vg = 230.14, Ve = 0.46). The phenotypic and genotypic coefficients of variation showed the same trend with high estimates (PCV = 31.28 per cent, GCV = 31.25 per cent). The estimated heritability showed the highest percentage (99.80 per cent) among the various characters and the expected genetic advance recorded a moderately high value of 31.22. The genetic gain had a high value of 64.30 per cent, indicating the possibility of improvement at five per cent selection pressure.

1.10. <u>Weight of fruit</u>

Mean weight of fruit ranged from 115.41 g to 234.98 g. Type B.G. 23 recorded the highest average fruit weight of 234.98 g while the lowest average fruit weight of 115.41 g was recorded for the type B.G. 12. Other bitter gourd types like B.G. 21 (209.07 g), B.G. 6 (200.75 g), B.G. 20 (199.68 g) and B.G. 18 (192.90 g) also had appreciably high average fruit weight. The phenotypic, genotypic and environmental variances were 835.90, 776.86 and 59.04, respectively. The phenotypic and genotypic coefficients of variation (PCV = 16.89 per cent, GCV = 16.28 per cent) showed that a major part of the variation was due to genetic effect. The heritability and expected genetic gain were comparatively high (H = 92.94 per cent, Ge = 55.35). The estimate of genetic advance as percentage of mean was found to be moderately good (32.33 per cent).

1.11. <u>Length of fruit</u>

Mean length of fruit exhibited a range, 16.93

Table 2b. Mean values of twenty one quantitative characters in different bitter gourd types (from 11 to 15)

Types	Length of fruit (cm)	Girth of fruit (cm)	Flesh thickness (mm)	No. of seeds per fruit	100-seed weight (g)
	11	12	13	14	15
B.G.1	22.88	16.29	5.81	28.79	22.79
B.G.2	25.55	16.39	6.77	26.11	20.78
B.G.3	28.35	13.99	6.01	30.00	24.53
B.G.4	27.66	16.76	6.84	31.68	25.15
B.G.5	21.60	14.06	4.73	28.86	17.82
B.G.6	31.09	15.42	5.97	31.66	24.75
B.G.7	22.87	15.99	6.58	29.59	24.08
B.G.8	24.72	16.13	5.93	30.92	23.70
B.G.9	19.70	17.91	7.31	26.31	24.74
B.G.10	29.81	14.87	5.93	29.94	25.36
B.G.11	16.93	15.03	5.09	27.79	21.16
B.G.12	22.77	14.85	6.31	33.35	22.56
B.G.13	17.99	14.74	4.69	26.11	23.41
B.G.14	21.24	14.58	5.15	31.27	23.70
B.G.15	31.14	15.13	5.85	29.65	24.41
B.G.16	27.80	14.53	5.94	30.74	23.38
B.G.17	21.86	15.74	6.09	30.35	23.92
B.G.18	26.41	15.97	7.52	32.05	22.81
B.G.19	29.49	12.98	5.87	30.87	20.66
B.G.20	26.92	17.69	7.52	32.27	23.93
B.G.21	30.55	15.65	6.68	27.20	23.50
B.G.22	26.25	14.68	7.01	31.15	21.64
B.G.23	38.78	16.04	5.98	27.43	23.93
B.G.24	28.02	14.82	6.74	30.31	23.34
B.G.25	27.96	15.13	5.93	28.00	22.89

to 38.78 cm among the different types with a general mean of 25.92 cm. B.G. 23 produced the longest fruit (38.78 cm) whereas the shortest fruits(16.93 cm) were produced by the type B.G. 11. Other types producing appreciably long fruits were B.G. 15 (31.14 cm), B.G. 6 (31.09 cm), B.G. 21 (30.55 cm) and B.G. 10 (29.81 cm). The phenotypic, genotypic and environmental variances showed that the genetic component was more than the environmental variance(Vp = 23.92, Vg = 22.97, Ve = 0.95). However the phenotypic and genotypic coefficients of variation were 18.87 per cent and 18.49 per cent, respectively. The heritability (96.01 per cent) and genetic gain (37.32 per cent) were found to be fairly promising.

1.12. Girth of fruit

Mean girth of fruit ranged from 12.98 cm to 17.91 cm and the overall mean was 15.41 cm. The maximum average girth was recorded in B.G. 9 (17.91 cm), while the minimum was observed in the type B.G. 19 (12.98 cm). The variance estimates exhibited very low values (Vp = 1.43, Vg = 1.19, Ve = 0.25). Similarly the phenotypic and genotypic coefficients of variation were also low (PCV = 7.77 per cent, GCV = 7.07 per cent). The heritability recorded moderate estimate (82.90 per cent) while the expected genetic advance (2.04), and genetic gain (13.26 per cent) were of low magnitude.

1.13. Flesh thickness

Flesh thickness showed a narrow range of 4.69 to 7.52 mm, with a general mean of 6.17 mm. The types B.G. 18 and B.G. 20 were found to have the thickest flesh while the least thickness of flesh was observed in the type B.G. 13. The variance estimates have shown that a greater part of variation was contributed by the genetic component. The phenotypic and genotypic coefficients of variation were found to be low (PCV = 12.88 per cent, GCV = 12.36 per cent). High heritability (92.05 per cent) coupled with low genetic gain (24.42 per cent) was recorded in the available material for flesh thickness.

1.14. Number of seeds per fruit

Mean number of seeds per fruit was found to range from 26.11 to 33.35 with a general mean of 29.70. B.G. 12 contained the maximum number of seeds in the fruit while the minimum number was observed in the fruits of B.G. 13. The estimates of variances and coefficients of variation were low and also indicated a predominant influence of environment over genes for this character (Vp = 6.65, Vg = 2.89, Ve = 3.77). Among the different traits studied, the heritability was found to have the lowest estimate of 43.37 per cent for the number of seeds per fruit. Similarly the expected genetic advance (2.30) and genetic gain (7.76 per cent) were observed to have lowest estimates.

1.15. Hundred seed weight

The range of variation was from 17.82 to 25.36 g with a general mean of 23.56 g for the 100-seed weight. The highest 100-seed weight was recorded in the type B.G. 10 and the lowest by the type B.G. 5. The various variance components and coefficients of variation were found to have low estimates. The heritability percentage was moderate (70.79 per cent) and the genetic gain was only to the extent of 11.82 per cent.

1.16. Total soluble solids

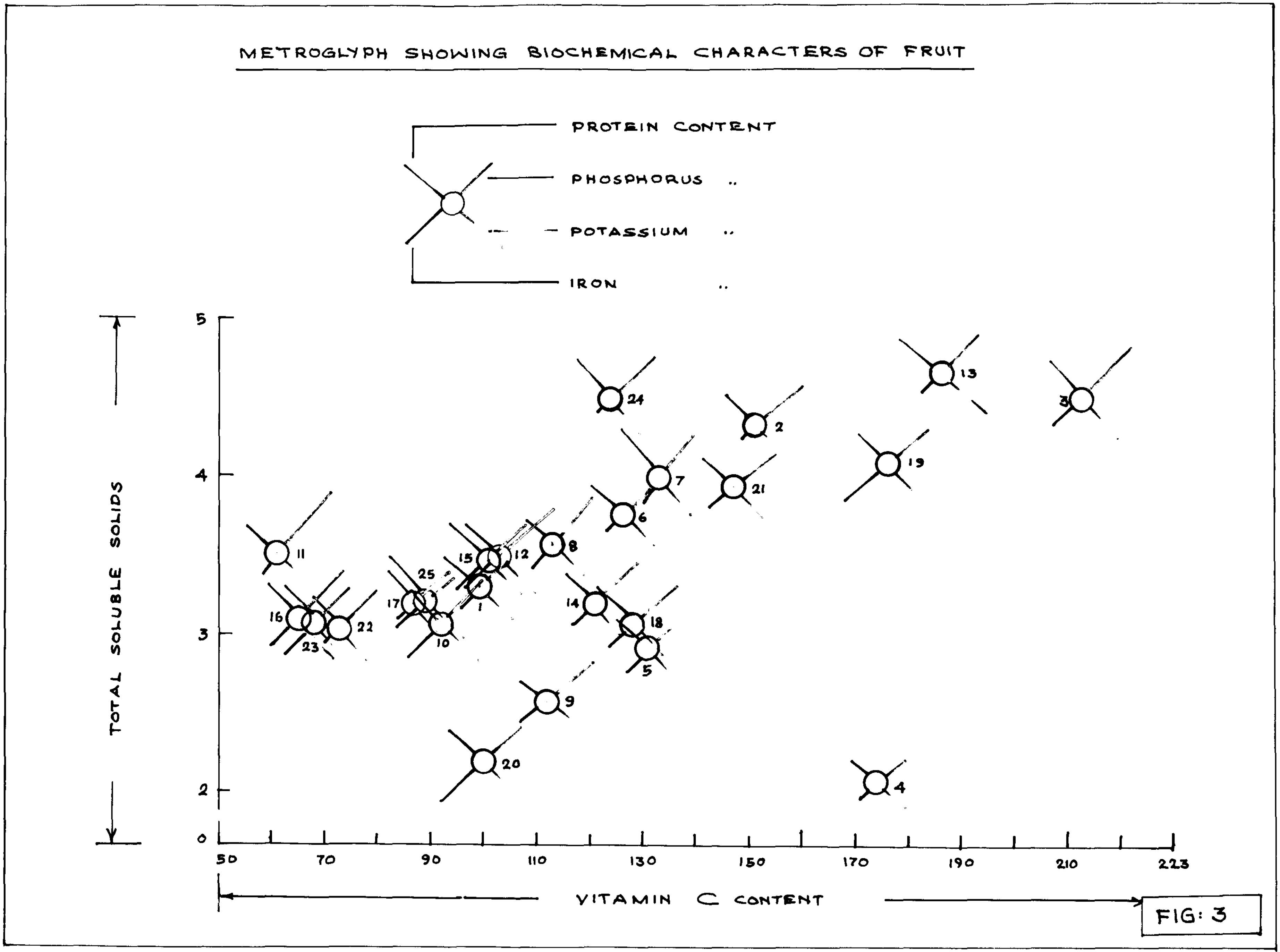
This biochemical trait had a general mean of

Table 2c. Mean values of twenty one quantitative characters in different bitter gourd types (from 16 to 21)

Types	Total soluble solids	Vitamin C content (mg/100g)	Protein content (g/100g)	Phosphorus content (mg/100g)	Potassium content (mg/100g)	Iron content (mg/100g)
	16	17	18	19	20	21
B.G.1	3.32	99.52	18.12	360.83	366.00	10.37
B.G.2	4.33	150.94	16.52	487.50	376.00	7.83
B.G.3	4.55	223.02	16.96	550.67	436.00	13.54
B.G.4	2.07	174.21	14.70	275.00	303.00	7.51
B.G.5	2.93	130.90	15.48	250.00	274.00	12.27
B.G.6	3.75	125.87	16.07	330.00	348.67	8.34
B.G.7	4.00	133.32	22.79	432.50	383.33	12.38
B.G.8	3.58	113.37	14.28	454.17	379.00	14.07
B.G.9	2.57	102.12	14.26	247.50	357.67	11.64
B.G.10	3.07	92.68	19.35	428.33	382.00	18.40
B.G.11	3.50	60.71	17.28	439.17	379.00	10.89
B.G.12	3.50	93.33	19.94	528.33	390.67	16.07
B.G.13	4.70	186.29	20.16	398.33	428.00	9.31
B.G.14	3.20	121.64	15.08	421.67	312.00	11.74
B.G.15	3.52	101.48	20.34	405.00	365.00	17.56
B.G.16	3.10	65.53	18.57	485.83	391.00	14.60
B.G.17	3.20	87.92	15.80	344.17	315.33	7.19
B.G.18	3.07	128.53	18.62	423.33	368.00	11.21
B.G.19	4.10	166.69	16.72	395.83	296.67	21.58
B.G.20	2.20	100.10	17.99	319.50	334.67	12.59
B.G.21	3.95	147.59	16.73	383.33	338.00	14.28
B.G.22	3.03	73.09	15.98	356.67	334.33	10.05
B.G.23	3.08	65.77	18.79	377.50	346.00	9.20
B.G.24	4.50	124.30	20.81	439.17	342.00	6.77
B.G.25	3.20	78.43	23.93	282.50	400.00	13.22

Fig.3. Metroglyph showing biochemical characters of fruit

Numbers from 1 to 25 in the figure represent bitter gourd types from B.G.1 to B.G.25, respectively



METROGLYPH SHOWING BIOCHEMICAL CHARACTERS OF FRUIT
PROTEIN CONTENT
PHOSPHORUS ..
POTASSIUM ..
IRON ..
TOTAL SOLUBLE SOLIDS
VITAMIN C CONTENT
0
2
3
4
5
50
70
90
110
130
150
170
190
210
223
1
2
3
4
5
6
7
8
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23
24
25

FIG: 3

Table 3. Analysis of variance for 21 characters in 25 bitter gourd types (Mean square values)

	Character	Replication (d.f.=2)	Types (d.f.=24)	Error (d.f.=48)	F value for types	C.D. P=0.05	C.D. P=0.01
1.	Number of primary branches	1.93	63.25	0.83	76.15**	1.50	2.01
2.	Length of main vine (metres)	0.01	1.20	0.03	36.37**	0.30	0.40
3.	Node at which the first female flower appeared	0.08	40.06	0.84	47.71**	1.50	2.02
4.	Days for opening of the first female flower	0.57	44.27	0.22	198.68**	0.77	1.04
5.	Number of female flowers per plant	0.65	712.30	3.86	184.53**	3.23	4.33
6.	Percentage of female flowers	0.07	3.63	0.05	76.33**	0.36	0.48
7.	Days for picking maturity	0.08	8.43	0.09	92.04**	0.50	0.67
8.	Yield per plant (kg)	0.03	11.80	0.01	1168.62**	0.16	0.22
9.	Number of fruits per plant	0.41	690.88	0.46	1489.22**	1.12	1.50
10.	Weight of fruit (g)	76.9[illegible]	2389.62	59.04	40.48**	12.61	16.91
11.	Length of fruit (cm)	0.41	69.86	0.95	73.20**	1.60	2.15
12.	Girth of fruit (cm)	1.96	3.81	0.23	15.54**	0.81	1.09
13.	Flesh thickness (mm)	0.09	1.79	0.05	35.66**	0.37	0.49
14.	Number of seeds per fruit	6.86	12.43	3.77	3.30**	3.19	4.27
15.	100-seed weight (g)	0.17	8.52	1.03	8.27**	1.67	2.23
16.	Total soluble solids	0.09	1.40	0.09	15.28**	0.50	0.67
17.	Vitamin C content (mg per 100 g)	1.80	4938.17	5.83	847.65**	3.96	5.31
18.	Protein content (g per 100 g)	4.48	19.41	3.49	5.57**	3.06	4.11
19.	Phosphorus content (mg per 100 g)	828.73	19463.16	341.39	57.01**	30.32	40.65
20.	Potassium content (mg per 100 g)	6.25	4663.92	52.02	89.66**	11.84	15.87
21.	Iron content (mg)per 100 g)	0.82	40.69	3.95	10.31**	3.26	4.37

** Significant at 1 per cent level

3.44 with a narrow range of variation from 2.07 to 4.70. Maximum total soluble solids were estimated in the fruits of B.G. 13, whereas B.G. 4 had the least total soluble solids. Other types such as B.G. 3, B.G. 24 and B.G. 2 also had significantly higher total soluble solids in their fruits. Total soluble solids had the least variance estimates among the different traits studied (Vp = 0.53, Vg = 0.44, Ve = 0.09) and the phenotypic and genotypic coefficients of variation were 21.11 per cent and 19.19 per cent, respectively. The heritability (82.64 per cent) and genetic gain (35.94 per cent) were moderately high.

1.17. Vitamin C content

The vitamin C content in the fruits ranged from 60.71 to 223.02 mg per 100 g of fruit eventhough the general mean was 117.90 mg. Vitamin C content was maximum in B.G. 3, whereas the minimum quantity was observed in the fruits of B.G. 11. However, the bitter gourd typee like B.G. 13, B.G. 4, B.G. 19, B.G. 2, B.G. 21, B.G. 5, B.G. 18 and B.G. 6 recorded significantly higher vitamin C content in their

Table 4. Range, mean and standard error of the characters

	Character	Range	Mean	Standard error
1.	Number of primary branches	18.00-35.89	27.12	0.11
2.	Length of main vine (metres)	2.92-6.22	4.61	0.02
3.	Node at which the first female flower appeared	14.11-26.89	20.51	0.11
4.	Days for opening of the first female flower	33.89-48.44	42.36	0.05
5.	Number of female flowers	35.33-83.00	58.69	0.23
6.	Percentage of female flowers	2.74-6.56	4.52	0.02
7.	Days for picking maturity	11.89-18.00	14.69	0.04
8.	Yield per plant (kg)	2.53-10.87	4.98	0.01
9.	Number of fruits per plant	28.56-73.67	48.55	0.08
10.	Weight of fruit (g)	115.41-234.98	171.23	0.09
11.	Length of fruit (cm)	16.93-38.78	25.92	0.11
12.	Girth of fruit (cm)	12.98-17.91	15.[illegible]1	0.06
13.	Flesh thickness (mm)	4.69-7.52	6.17	0.02
14.	Number of seeds per fruit	26.11-33.35	29.70	0.22
15.	100-seed weight (g)	17.82-25.36	23.16	0.12
16.	Total soluble solids	2.07-4.70	3.44	0.03
17.	Vitamin C content (mg/100 g)	60.71-22[illegible].02	117.90	0.28
18.	Protein content (g/100 g)	14.26-23.93	17.81	0.22
19.	Phosphorus content (mg/100 g)	247.50-550.67	392.68	2.13
20.	Potassium content (mg/100 g)	274.00-436.00	357.85	0.83
21.	Iron content (mg/100 g)	6.77-21.58	12.10	0.23

fruits. The variability observed was fairly high with more genetic effect (Vp = 1649.94, Vg = 1644.12, Ve = 5.83). The phenotypic and genotypic coefficients of variation were also appreciably high (PCV = 34.45 per cent, GCV = 34.39 per cent). The heritability (99.65 per cent), expected genetic advance (83.38) and genetic gain (70.72 per cent) were also very high.

1.18. Protein content

The protein content was observed to range from 14.26 to 23.93 g with a general mean of 17.81 g. Maximum protein content was observed in the type B.G. 25 (23.93 g), which was followed by the types B.G. 7 (22.79 g), B.G. 24 (20.81 g) and B.G. 15 (20.34 g), and the minimum content was estimated in the type B.G. 9 (14.26 g). The estimatee of phenotypic, genotypic and environmental variances (Vp = 8.77, Vg = 5.31, Ve = 3.49) showed that a good per cent of variation was contributed by the genetic factors. The genotypic coefficient of variation was only 12.94 per cent and the heritability was moderate (60.55 per cent). The genetic advance (3.69) and genetic gain (20.74 per cent) showed comparatively lower estimates.

1.19. Phosphorus content

The quantity of phosphorus in the fruits ranged from 247.50 to 550.67 mg among the different bitter gourd types, eventhough the general mean was only 392.68 mg per 100 g of dried fruit material. Maximum phosphorus was analysed in B.G. 3 whereas the least phosphorus content was noted in B.G. 9. The variance estimates were the highest among all biochemical characters ($Vp = 6715.31$, $Vg = 6373.92$, $Ve = 341.39$), indicating the high amount of genetic variability. The phenotypic and genotypic coefficients of variation were moderate (PCV = 20.87 per cent, GCV = 20.33 per cent). The heritability percentage and expected genetic advance were high (H = 94.92 per cent, Gs = 160.23). The genetic gain recorded a moderately high estimate of 40.80 per cent.

1.20. Potassium content

The content of potassium in the fruits of different types ranged from 274.00 to 436 mg per 100 g of dried fruit material and the overall mean was

Table 5. Phenotypic, genotypic and environmental variances for different characters

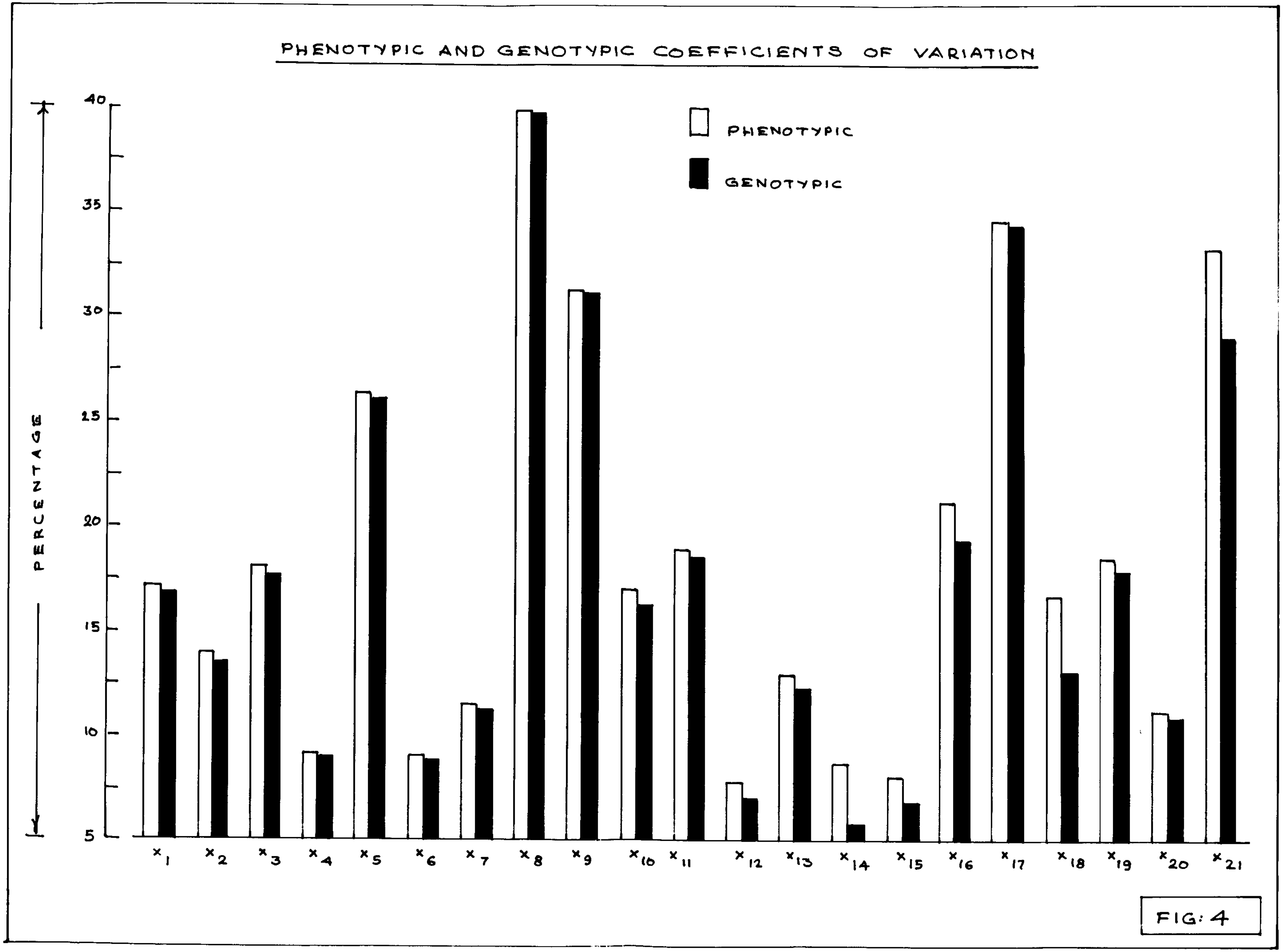
	Character	Phenotypic variance (Vp)	Genotypic variance (Vg)	Environmental variance (Ve)
1.	Number of primary branches	21.64	20.81	0.83
2.	Length of main vine	0.42	0.39	0.03
3.	Node at which the first female flower appeared	13.91	13.07	0.84
4.	Days for opening of the first female flower	14.90	14.68	0.22
5.	Number of female flowers	240.01	236.15	3.86
6.	Percentage of female flowers	1.24	1.19	0.05
7.	Days for picking maturity	2.87	2.78	0.09
8.	Yield per plant	3.94	3.93	0.01
9.	Number of fruits per plant	230.60	230.14	0.46
10.	Weight of fruit	835.90	776.86	59.04
11.	Length of fruit	23.92	22.97	0.95
12.	Girth of fruit	1.43	1.19	0.25
13.	Flesh thickness	0.63	0.58	0.05
14.	Number of seeds per fruit	6.65	2.89	3.77
15.	100-seed weight	3.53	2.50	1.09
16.	Total soluble solids	0.53	0.44	0.09
17.	Vitamin C content	1649.94	1644.12	5.83
18.	Protein content	8.77	5.31	3.49
19.	Phosphorus content	6715.31	6373.92	341.39
20.	Potassium content	1589.32	1537.30	52.02
21.	Iron content	16.20	12.25	3.95

Table 6. Phenotypic and genotypic coefficients of variation, heritability, expected genetic advance and genetic gain for different characters

	Character	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	Heritability (%)	Expected genetic advance (Ga)	Genetic gain (GG)
1.	Number of primary branches	17.15	16.82	96.16	9.22	33.98
2.	Length of the main vine	14.07	13.51	92.18	1.23	26.73
3.	Node at which the first female flower appeared	18.19	17.63	93.97	7.22	35.21
4.	Days for opening of the first female flower	9.11	9.05	98.51	7.83	18.49
5.	Number of female flowers	26.40	26.18	98.39	31.40	53.50
6.	Percentage of female flowers	9.11	8.94	96.17	2.21	18.06
7.	Days for picking maturity	11.54	11.35	96.81	3.38	23.01
8.	Yield per plant	39.88	39.82	99.74	4.08	81.93
9.	Number of fruits per plant	31.28	31.25	99.80	31.22	64.30
10.	Weight of fruit	16.89	16.28	92.94	55.35	32.33
11.	Length of fruit	18.87	18.49	96.01	9.67	37.32
12.	Girth of fruit	7.77	7.07	82.90	2.04	13.26
13.	Flesh thickness	12.88	12.36	92.05	1.51	24.42
14.	Number of seeds per fruit	8.69	5.72	43.37	2.30	7.76
15.	100-seed weight	8.11	6.82	70.79	2.71	11.82
16.	Total soluble solids	21.11	19.19	82.64	1.21	35.94
17.	Vitamin C content	34.45	34.39	99.65	83.38	70.72
18.	Protein content	16.62	12.94	60.55	3.69	20.74
19.	Phosphorus content	20.87	20.33	94.92	160.23	40.80
20.	Potassium content	11.14	10.96	96.73	74.44	22.20
21.	Iron content	33.25	28.92	75.64	6.27	51.81

Fig.4. Phenotypic and genotypic coefficients of variation

X_1 - Number of primary branches per plant
X_2 - Length of main vine
X_3 - Node at which the first female flower appeared
X_4 - Days for opening of the first female flower
X_5 - Number of female flowers per plant
X_6 - Percentage of female flower per plant
X_7 - Days for picking maturity
X_8 - Yield per plant
X_9 - Number of fruits per plant
X_{10} - Weight of fruit
X_{11} - Length of fruit
X_{12} - Girth of fruit
X_{13} - Flesh thickness
X_{14} - Number of seeds per fruit
X_{15} - 100-seed weight
X_{16} - Total soluble solids
X_{17} - Vitamin C content
X_{18} - Protein content
X_{19} - Phosphorus content
X_{20} - Potassium content
X_{21} - Iron content



PHENOTYPIC AND GENOTYPIC COEFFICIENTS OF VARIATION
PHENOTYPIC
GENOTYPIC
PERCENTAGE
40
35
30
25
20
15
10
5
x_1 x_2 x_3 x_4 x_5 x_6 x_7 x_8 x_9 x_{10} x_{11} x_{12} x_{13} x_{14} x_{15} x_{16} x_{17} x_{18} x_{19} x_{20} x_{21}

FIG: 4

357.85 mg. The highest potassium content was recorded in the type B.G. 3, while the lowest estimate was recorded in B.G. 5. The different variance estimates were also high (Vp = 1589.32, Vg = 1537.30, Ve = 52.02). But the phenotypic and genotypic coefficients of variation were low (PCV = 11.14 per cent, GCV = 10.96 per cent). The heritability and genetic advance were 96.73 per cent and 74.44, respectively. But the genetic gain was only 22.20 per cent.

1.21. Iron content

Iron content was found to range from 6.77 to 21.58 mg with a general mean of 12.10 mg per 100 g of dried fruit material. Maximum iron content of 21.58 mg was observed in the type B.G. 19 which was followed by B.G. 10 (18.40 mg), B.G. 15 (17.56 mg), B.G. 12 (16.07 mg) and the lowest content of 6.77 mg was observed in B.G. 24. The estimates of variance exhibited low values at phenotypic, genotypic and environmental levels (Vp = 16.20, Vg = 12.25, Ve = 3.95). The phenotypic and genotypic coefficients of variation were moderately good (PCV = 33.25 per cent, GCV = 28.92 per cent). The

Fig.5. Heritability and expected genetic gain

X_1 - Number of primary branches per plant
X_2 - Length of main vine
X_3 - Node at which the first female flower appeared
X_4 - Days for opening of the first female flowers
X_5 - Number of female flowers per plant
X_6 - Percentage of female flowers per plant
X_7 - Days for picking maturity
X_8 - Yield per plant
X_9 - Number of fruits per plant
X_{10} - Weight of fruit
X_{11} - Length of fruit
X_{12} - Girth of fruit
X_{13} - Flesh thickness
X_{14} - Number of seeds per fruit
X_{15} - 100-seed weight
X_{16} - Total soluble solids
X_{17} - Vitamin C content
X_{18} - Protein content
X_{19} - Phosphorus content
X_{20} - Potassium content
X_{21} - Iron content

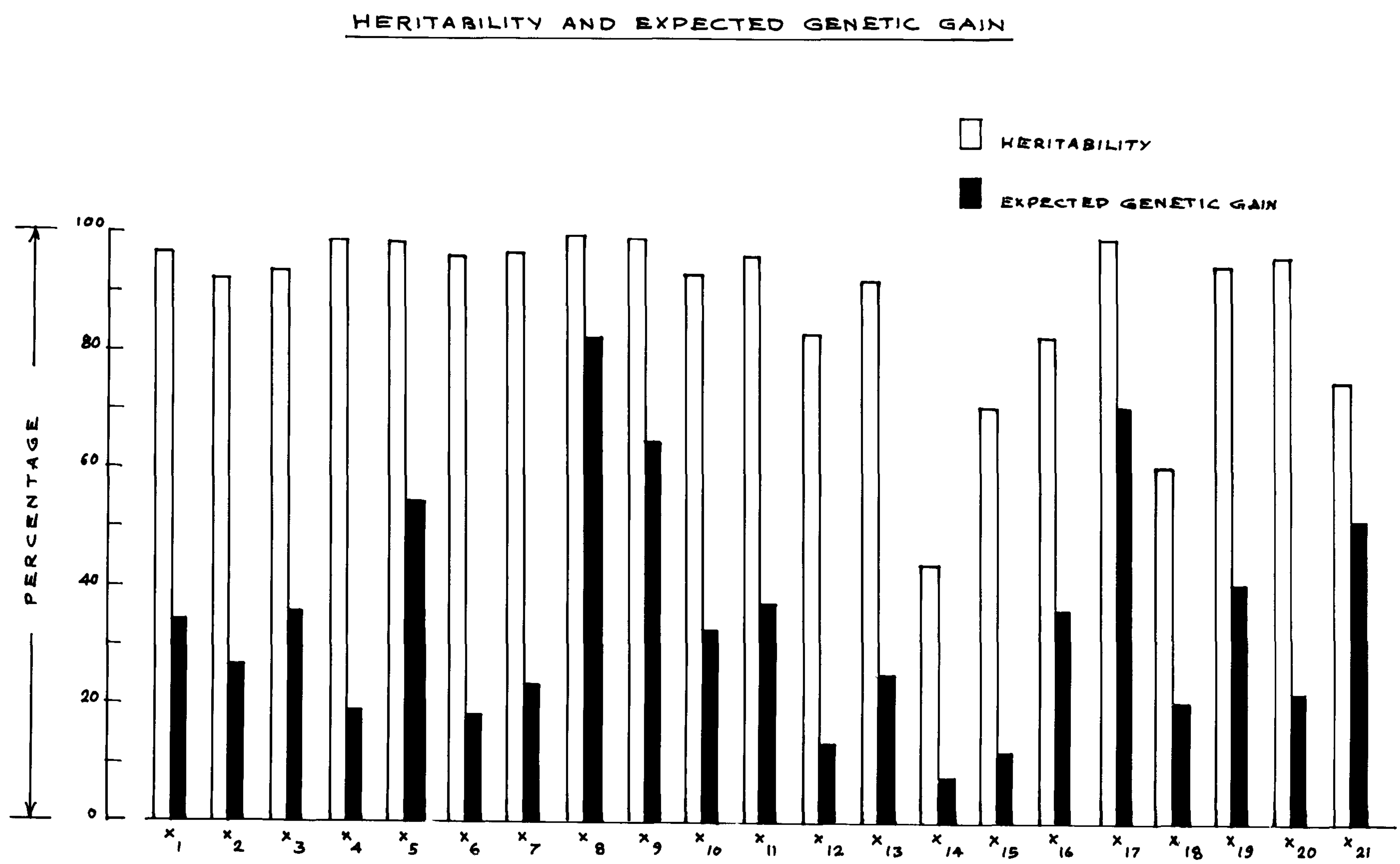

HERITABILITY AND EXPECTED GENETIC GAIN
HERITABILITY
EXPECTED GENETIC GAIN
PERCENTAGE
100
80
60
40
20
0
x1
x2
x3
x4
x5
x6
x7
x8
x9
x10
x11
x12
x13
x14
x15
x16
x17
x18
x19
x20
x21

FIG: 5

heritability and genetic gain showed moderately high estimates of 75.64 per cent and 51.81 per cent, respectively.

Plates II and II a represent the characters of fruit in different bitter gourd types. In plates III, IV, V, VI, VII and VIII, the general field performances of some of the bitter gourd types, showing variability in the bearing habit are given.

2. CORRELATION STUDIES

In order to find out the various components of fruit yield and their extent of association with yield and among themselves, the phenotypic, genotypic and environmental correlation coefficients were analysed. The results are presented in Tables 7, 8 and 9, respectively. In Fig. 6, the correlation coefficients between yield and all other characters are given.

2.1. Phenotypic and genotypic correlations

Generally, the phenotypic and genotypic correlation coefficients were of the same magnitude. The genotypic correlation coefficients were slightly higher than the phenotypic correlation coefficients

Table 7. Phenotypic correlation coefficients (r_p) for different pairs of characters

	Character	X_2	X_3	X_4	X_5	X_6	X_7
X_1	Number of primary branches	+0.6396**	+0.3368	-0.0704	+0.4295*	+0.0659	+0.0672
X_2	Length of main vine		+0.4314*	+0.1386	+0.4572*	-0.0996	+0.0361
X_3	Node at which the first female flower appeared			+0.4776*	+0.3005	-0.3829	+0.0172
X_4	Days for opening of the first female flower				-0.0131	-0.2420	+0.0126
X_5	Number of female flowers					+0.1421	-0.1514
X_6	Percentage of female flowers						-0.4047*
X_7	Days for picking maturity						
X_8	Yield						
X_9	Number of fruits						
X_{10}	Weight of fruit						
X_{11}	Length of fruit						
X_{12}	Girth of fruit						
X_{13}	Flesh thickness						
X_{14}	Number of seeds per fruit						
X_{15}	100-seed weight						
X_{16}	Total soluble solids						
X_{17}	Vitamin C content						
X_{18}	Protein content						
X_{19}	Phosphorus content						
X_{20}	Potassium content						
X_{21}	Iron content						

* Significant at 5 per cent level

** Significant at 1 per cent level

(Continued)

Table 7 (contd.)

	Character	X_8	X_9	X_{10}	X_{11}	X_{12}
X_1	Number of primary branches	+0.5111**	+0.4448*	+0.3758	+0.4141*	+0.0909
X_2	Length of main vine	+0.7345**	+0.4826*	+0.5709**	+0.5423**	+0.2809
X_3	Node at which the first female flower appeared	+0.2289	+0.2589	+0.0379	+0.0587	-0.0861
X_4	Days for opening of the first female flower	+0.1146	-0.0453	+0.1199	+0.0374	-0.0279
X_5	Number of female flowers	+0.5369**	+0.9275**	+0.1026	+0.0299	+0.1848
X_6	Percentage of female flowers	-0.0233	+0.2118	-0.1311	-0.2592	+0.3396
X_7	Days for picking maturity	-0.1302	-0.2405	+0.2671	+0.2636	-0.1931
X_8	Yield		+0.5611**	+0.6640**	+0.5846**	+0.3864
X_9	Number of fruits			+0.0881	+0.0323	+0.2004
X_{10}	Weight of fruit				+0.8578**	+0.2468
X_{11}	Length of fruit					-0.0504
X_{12}	Girth of fruit					
X_{13}	Flesh thickness					
X_{14}	Number of seeds per fruit					
X_{15}	100-seed weight					
X_{16}	Total soluble solids					
X_{17}	Vitamin C content					
X_{18}	Protein content					
X_{19}	Phosphorus content					
X_{20}	Potassium content					
X_{21}	Iron content					

* Significant at 5 per cent level

** Significant at 1 per cent level

(Continued)

Table 7. (contd.)

	Character	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
X_1	Number of primary branches	-0.0441	+0.0043	+0.3956*	-0.0755	+0.1322
X_2	Length of main vine	+0.2654	-0.1375	+0.4548*	-0.0593	+0.0091
X_3	Node at which the first female flower appeared	+0.0278	-0.0408	-0.0432	+0.2446	+0.0301
X_4	Days for opening of the first female flower	+0.2739	+0.1078	-0.2262	-0.0612	-0.0091
X_5	Number of female flowers	+0.0601	-0.1647	+0.1785	+0.0947	-0.2447
X_6	Percentage of female flowers	+0.1508	+0.0300	+0.0909	-0.3627	-0.0617
X_7	Days for picking maturity	-0.0313	-0.0194	-0.2036	+0.1295	+0.3862
X_8	Yield	+0.3199	-0.1325	+0.3705	-0.1507	-0.3270
X_9	Number of fruits	+0.0969	-0.1199	+0.2957	+0.1572	-0.1238
X_{10}	Weight of fruit	+0.5232**	+0.0496	+0.2915	-0.1050	-0.0282
X_{11}	Length of fruit	+0.2763	+0.1660	+0.2534	-0.0457	-0.0307
X_{12}	Girth of fruit	+0.6323**	+0.2619	+0.2741	-0.4323*	-0.1610
X_{13}	Flesh thickness		+0.2259	+0.2684	-0.3468	-0.0373
X_{14}	Number of seeds per fruit			+0.0931	-0.3309	-0.0551
X_{15}	100-seed weight				-0.0161	+0.0366
X_{16}	Total soluble solids					+0.4495*
X_{17}	Vitamin C content					
X_{18}	Protein content					
X_{19}	Phosphorus content					
X_{20}	Potassium content					
X_{21}	Iron content					

*Significant at 5 per cent level
**Significant at 1 per cent level

(Continued)

Table 7. (contd.)

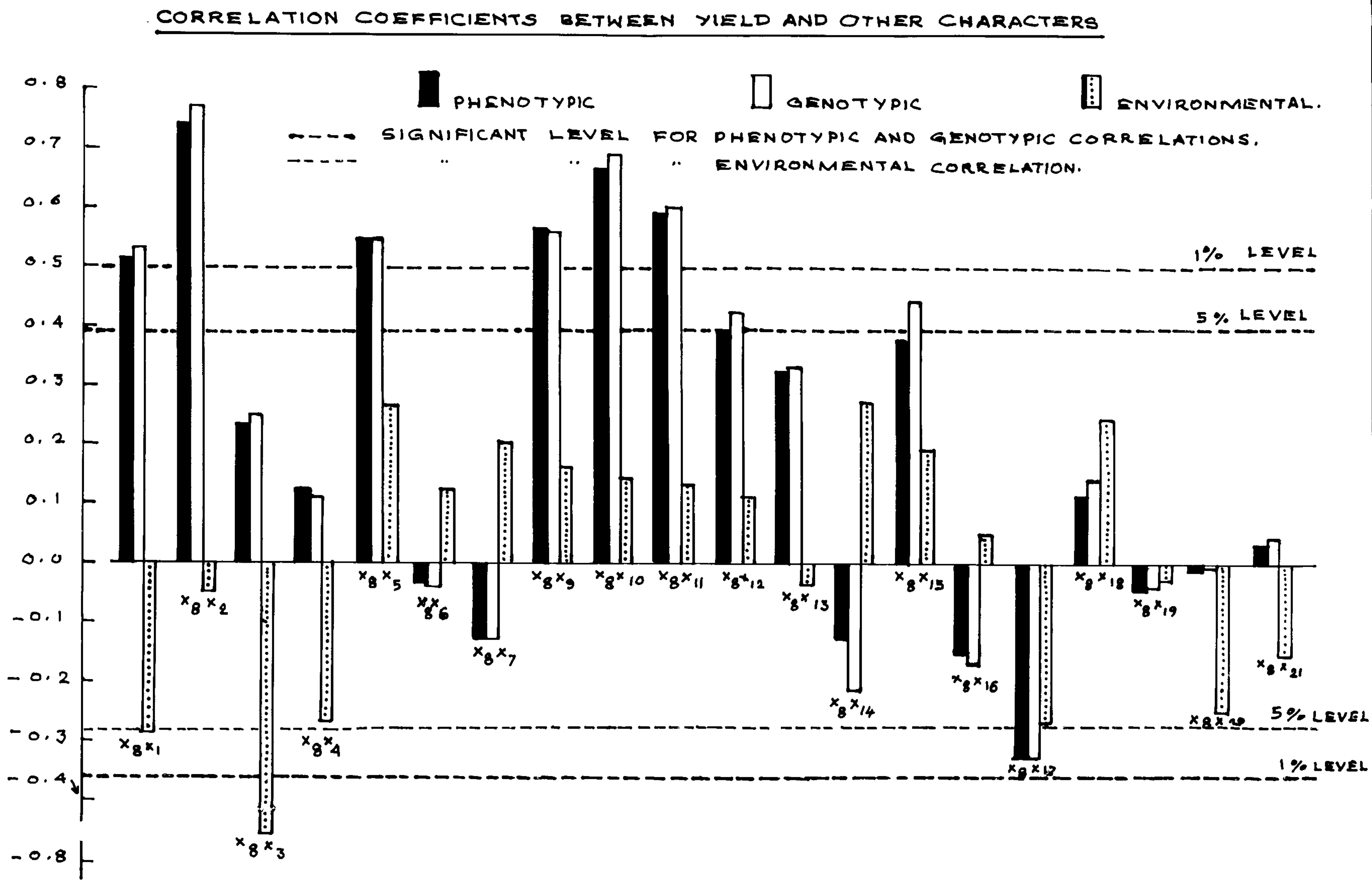
	Character	X_{18}	X_{19}	X_{20}	X_{21}
X_1	Number of primary branches	-0.0256	-0.0536	-0.0525	-0.0362
X_2	Length of main vine	-0.0490	-0.1345	-0.0695	-0.1584
X_3	Node at which the first female flower appeared	+0.0455	+0.1149	+0.0978	-0.2038
X_4	Days for opening of the first female flower	-0.2167	-0.0036	-0.1759	+0.1744
X_5	Number of female flowers	+0.3977*	+0.0403	+0.2773	+0.0068
X_6	Percentage of female flowers	-0.0359	-0.1736	-0.2858	-0.1979
X_7	Days for picking maturity	-0.0979	-0.2574	-0.2192	+0.1948
X_8	Yield	+0.1112	-0.0357	-0.0045	+0.0300
X_9	Number of fruits	+0.2186	+0.2156	+0.2836	-0.0081
X_{10}	Weight of fruit	+0.1006	-0.1070	-0.1241	+0.0981
X_{11}	Length of fruit	+0.1694	+0.0292	-0.0936	+0.1567
X_{12}	Girth of fruit	-0.1012	-0.3388	+0.0055	-0.3919*
X_{13}	Flesh thickness	-0.0506	-0.0748	-0.0599	-0.0830
X_{14}	Number of seeds per fruit	-0.0036	+0.1316	-0.1741	+0.0945
X_{15}	100-seed weight	+0.2493	+0.0352	+0.1736	-0.0026
X_{16}	Total soluble solids	+0.2654	+0.5376**	+0.4116*	+0.0486
X_{17}	Vitamin C content	-0.1469	+0.1575	+0.0751	-0.0068
X_{18}	Protein content		+0.1745	+0.3654	+0.0930
X_{19}	Phosphorus content			+0.5522**	+0.2288
X_{20}	Potassium content				+0.0811
X_{21}	Iron content				x

* Significant at 5 per cent level
** Significant at 1 per cent level

in most cases indicating a strong inherent association of characters under study; but a probable influence of environment on the expression.

2.1.1. <u>Correlation between yield and yield components</u>

The length of the main vine exhibited the highest, positive significant association with yield per plant both at phenotypic and genotypic levels (r_p = +0.7345, r_g = +0.7652), followed by weight of fruit (r_p = +0.6640, r_g = +0.6877), length of fruit (r_p = +0.5846, r_g = +0.5961), number of fruits per plant (r_p = +0.5611, r_g = +0.5620), number of female flowers per plant (r_p = +0.5369, r_g = +0.5403), and number of primary branches per plant (r_p = +0.5111, r_g = +0.5248). Genotypic correlation coefficients were positive and significant between yield and 100-seed weight (r_g = +0.4348), and between yield and girth of fruit (r_g = +0.4223). Phenotypic and genotypic correlations between yield per plant and (i) node at which the first female flower appeared (ii) days for opening of the first female flower (iii) flesh thickness (iv) protein content and (v) iron content were positive; but not significant.


CORRELATION COEFFICIENTS BETWEEN YIELD AND OTHER CHARACTERS
PHENOTYPIC
GENOTYPIC
ENVIRONMENTAL.
SIGNIFICANT LEVEL FOR PHENOTYPIC AND GENOTYPIC CORRELATIONS.
" " " ENVIRONMENTAL CORRELATION.
1% LEVEL
5% LEVEL
5% LEVEL
1% LEVEL
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.8
x_8x_1
x_8x_2
x_8x_3
x_8x_4
x_8x_5
x_8x_6
x_8x_7
x_8x_9
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x_8x_{15}
x_8x_{16}
x_8x_{17}
x_8x_{18}
x_8x_{19}
x_8x_{20}
x_8x_{21}

FIG: 6

The correlation coefficients between yield and (i) percentage of female flowers (ii) days for picking maturity (iii) number of seeds per fruit (iv) total soluble solids (v) vitamin C content (vi) phosphorus content and (vii) potassium content were negative; but not significant.

2.1.2. <u>Intercorrelation among yield components</u>

Highly significant positive phenotypic and genotypic correlations were observed between number of primary branches and length of the main vine (r_p = +0.6396, r_g = +0.6567). The correlations were positive and significant at five per cent level between number of primary branches and (i) number of female flowers (ii) number of fruits per plant (iii) length of fruit and (iv) 100-seed weight. Length of main vine showed highly significant positive association with weight of fruit (r_p = +0.5709, r_g = +0.6004) and length of fruit (r_p = +0.5423, r_g = +0.5753). The genotypic correlation between length of main vine and 100-seed weight was highly significant eventhough the phenotypic correlation was significant only at five per cent probability. Positive phenotypic and genotypic correlations,

Table 8. Genotypic correlation coefficients (r_g) for different pairs of characters

	Character	X_2	X_3	X_4	X_5	X_6	X_7
X_1	Number of primary branches	+0.6567**	+0.3519	-0.0710	+0.4413*	+0.0578	+0.0734
X_2	Length of main vine		+0.4756*	+0.1420	+0.4786*	-0.1165	+0.0481
X_3	Node at which the first female flower appeared			+0.4906*	+0.3128	+0.4010*	+0.0320
X_4	Days for opening of the first female flower				-0.0173	-0.2524	+0.0138
X_5	Number of female flowers					+0.1206	-0.1558
X_6	Percentage of female flowers						-0.4073*
X_7	Days for picking maturity						
X_8	Yield						
X_9	Number of fruits						
X_{10}	Weight of fruit						
X_{11}	Length of fruit						
X_{12}	Girth of fruit						
X_{13}	Flesh thickness						
X_{14}	Number seeds per fruit						
X_{15}	100-seed weight						
X_{16}	Total soluble solids						
X_{17}	Vitamin C content						
X_{18}	Protein content						
X_{19}	Phosphorus content						
X_{20}	Potassium content						
X_{21}	Iron content						

* Significant at 5 per cent level

** Significant at 1 per cent level

(Continued)

Table 8. (contd.)

	Character	X_8	X_9	X_{10}	X_{11}	X_{12}
X_1	Number of primary branches	+0.5248**	+0.4488*	+0.3665	+0.4063*	+0.0792
X_2	Length of main vine	+0.7652**	+0.5058**	+0.6004**	+0.5753**	+0.2892
X_3	Node at which the first female flower appeared	+0.2462	+0.2676	+0.0297	+0.0686	-0.1256
X_4	Days for opening of the first female flower	+0.1139	-0.0450	+0.1218	+0.0421	-0.0292
X_5	Number of female flowers	+0.5403**	+0.9365**	+0.1168	+0.0352	+0.2093
X_6	Percentage of female flowers	-0.0251	+0.2185	-0.1352	-0.2637	+0.3894*
X_7	Days for picking maturity	-0.1344	-0.2437	+0.2912	+0.2754	-0.2036
X_8	Yield		+0.5620**	+0.6877**	+0.5961**	+0.4223*
X_9	Number of fruits			+0.0912	+0.0332	+0.2187
X_{10}	Weight of fruit				+0.9004**	+0.2929
X_{11}	Length of fruit					-0.0541
X_{12}	Girth of fruit					
X_{13}	Flesh thickness					
X_{14}	Number of seeds per fruit					
X_{15}	100-seed weight					
X_{16}	Total soluble solids					
X_{17}	Vitamin C content					
X_{18}	Protein content					
X_{19}	Phosphorus content					
X_{20}	Potassium content					
X_{21}	Iron content					

* Significant at 5 per cent level

** Significant at 1 per cent level

(Continued)

Table 8. (contd.)

	Character	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
X_1	Number of primary branches	-0.0591	-0.0291	+0.4569*	-0.0736	+0.1501
X_2	Length of main vine	+0.2998	-0.1962	+0.5180**	-0.1076	+0.0089
X_3	Node at which the first female flower appeared	+0.0049	-0.0238	+0.0700	+0.2551	+0.0290
X_4	Days for opening of the first female flower	+0.2746	+0.1985	-0.2537	-0.0823	-0.0315
X_5	Number of female flowers	+0.0377	-0.2626	+0.2401	+0.1079	-0.2499
X_6	Percentage of female flowers	+0.1605	+0.0913	+0.1411	-0.4076	-0.0641
X_7	Days for picking maturity	-0.0077	-0.0304	-0.2082	+0.1444	+0.3945*
X_8	Yield	+0.3343	-0.2168	+0.4348*	-0.1617	-0.3272
X_9	Number of fruits	+0.1044	-0.1873	+0.3561	+0.1709	-0.1239
X_{10}	Weight of fruit	+0.5706**	+0.0728	+0.3387	-0.1487	-0.0231
X_{11}	Length of fruit	+0.2531	+0.1373	+0.2531	-0.2532	-0.0306
X_{12}	Girth of fruit	+0.5913**	+0.0188	+0.4883*	-0.5202**	-0.1936
X_{13}	Flesh thickness		-0.2788	+0.3331	-0.2862	-0.0357
X_{14}	Number of seeds per fruit			+0.2129	-0.2851	-0.0681
X_{15}	100-seed weight				-0.1111	+0.0389
X_{16}	Total soluble solids					+0.5011**
X_{17}	Vitamin C content					
X_{18}	Protein content					
X_{19}	Phosphorus content					
X_{20}	Potassium content					
X_{21}	Iron content					

* Significant at 5 per cent

** Significant at 1 per cent

(Continued)

Table 8. (contd.)

	Character	X_{18}	X_{19}	X_{20}	X_{21}
X_1	Number of primary branches	-0.0622	-0.0452	-0.0549	-0.0416
X_2	Length of main vine	+0.0091	-0.1543	-0.0692	-0.2041
X_3	Node at which the first female flower appeared	-0.0075	+0.1221	+0.1081	-0.2330
X_4	Days for opening of the first female flower	-0.2960	-0.0075	-0.1798	+0.2154
X_5	Number of female flowers	+0.4671*	+0.0465	+0.2777	+0.0173
X_6	Percentage of female flowers	-0.0358	-0.1838	-0.2958	-0.2333
X_7	Days for picking maturity	-0.1031	-0.2636	-0.2303	+0.2035
X_8	Yield	+0.1332	-0.0369	-0.0022	+0.0393
X_9	Number of fruits	+0.2856	+0.2203	+0.2868	-0.0109
X_{10}	Weight of fruit	+0.1768	-0.1066	-0.1332	+0.1266
X_{11}	Length of fruit	+0.1588	+0.0445	-0.0932	+0.2000
X_{12}	Girth of fruit	-0.1859	-0.3893*	-0.0020	-0.4320*
X_{13}	Flesh thickness	-0.0248	-0.0807	-0.0671	-0.1712
X_{14}	Number of seeds per fruit	-0.1605	+0.2081	-0.2979	+0.2830
X_{15}	100-seeds weight	+0.2435	+0.0746	+0.1759	+0.0883
X_{16}	Total soluble solids	+0.3062	+0.6303**	+0.4669*	+0.0249
X_{17}	Vitamin C content	-0.1846	+0.1603	+0.0795	-0.0065
X_{18}	Protein content		+0.2334	+0.5888**	+0.1261
X_{19}	Phosphorus content			+0.5784**	+0.2542
X_{20}	Potassium content				+0.0985
X_{21}	Iron content				x

* Significant at 5 per cent level
** Significant at 1 per cent level

significant at five per cent level, were also observed between length of main vine and (i) node at which the first female flower appeared and (ii) number of female flowers per plant.

Node at which the first female flower appeared had positive significant association with days for opening of the first female flower and negative, significant genotypic correlation with percentage of female flowers. Number of female flowers per plant was found to exhibit highly significant positive correlations with number of fruits per plant (r_p = +0.9275, r_g = +0.9365). The phenotypic and genotypic correlations were positive and significant between number of female flowers and protein content. Percentage of female flowers had negative significant association with days for picking maturity and total soluble solids. The genotypic correlation between percentage of female flowers and girth of fruit was found to be positive and significant.

ays for picking maturity exhibited positive and significant genotypic association with vitamin C content. Number of fruits per plant, one of the important contributors of yield, showed positive but insignificant correlations with almost all characters except number of seeds per fruit and Vitamin C content where negative correlations were observed. Weight of fruit showed highly significant, positive association with length of fruit (r_p = +0.8578, r_g = +0.9004) and with flesh thickness (r_p = +0.5232, r_g = +0.5706). Highly significant, positive association was also observed between girth of fruit and flesh thickness (r_p = +0.6323, r_g = +0.5913). The genotypic correlation coefficient only was highly significant and negative between girth of fruit and total soluble solids (r_g = -0.5202), whereas the phenotypic correlation was significant only at five per cent level. The genotypic correlation was positive and significant between girth of fruit and 100-seed weight whereas it was negative and significant between girth of fruit and phosphorus content. Girth of fruit also showed negative and significant phenotypic and genotypic correlations with iron content.

The study of intercorrelations among biochemical traits have showed that the total soluble solids had highly significant positive correlations with phosphorus content in the fruit (r_p = +0.5376, r_g = +0.6303). Positive genotypic correlation observed between total soluble solids and vitamin C content was highly significant (G = +0.5011), but the phenotypic correlation was only significant at five per cent level. Total soluble solids also had significant association with potassium content. Highly significant, positive, genotypic correlation (r_g = +0.5838) was also observed between protein and phosphorus contents in the fruit. Phosphorus content in turn was found to exhibit highly significant, positive association both at phenotypic and genotypic levels with potassium content (r_p = +0.5522, r_g = +0.5784).

2.2. Environmental correlation

In the present study number of primary branches showed highly significant, positive, environmental correlations with length of main vine (r_e = +0.3879), weight of fruit (r_e = +0.5632) and length of fruit (r_e = +0.6004), indicating that the environment favourable for number of primary branches may also be

Table 9. Environmental correlation coefficients (r_e) between different pairs of characters

	Character	X_2	X_3	X_4	X_5	X_6	X_7
X_1	Number of primary branches	+0.3879**	+0.0481	-0.0536	+0.0084	+0.2675	-0.1021
X_2	Length of main vine		-0.1630	+0.0968	+0.0419	+0.1844	-0.1877
X_3	Node at which the first female flower appeared			+0.1873	-0.0094	-0.0339	-0.3023*
X_4	Days for opening of the first female flower				+0.2512	+0.1541	-0.0403
X_5	Number of female flowers					+0.4281**	+0.0264
X_6	Percentage of female flowers						-0.3364*
X_7	Days for picking maturity						
X_8	Yield						
X_9	Number of fruits						
X_{10}	Weight of fruit						
X_{11}	Length of fruit						
X_{12}	Girth of fruit						
X_{13}	Flesh thickness						
X_{14}	Number of seeds per fruit						
X_{15}	100-seed weight						
X_{16}	Total soluble solids						
X_{17}	Vitamin C content						
X_{18}	Protein content						
X_{19}	Phosphorus content						
X_{20}	Potassium content						
X_{21}	Iron content						

* Significant at 5 per cent level

** Significant at 1 per cent level

(Continued)

Table 9. (contd.)

	Character	X_8	X_9	X_{10}	X_{11}	X_{12}
X_1	Number of primary branches	-0.2868*	+0.5906**	+0.5632**	+0.6004**	+0.2490
X_2	Length of main vine	+0.0488	-0.2048	+0.2045	+0.0186	+0.2417
X_3	Node at which the first female flower appeared	-0.7569**	-0.0239	+0.1547	-0.1311	+0.2433
X_4	Days for opening of the first female flower	+0.2699	-0.1171	+0.1046	-0.1433	-0.0280
X_5	Number of female flowers	+0.2549	-0.0853	-0.2698	-0.1649	-0.0792
X_6	Percentage of female flowers	+0.1225	-0.2559	-0.0638	-0.1488	-0.0992
X_7	Days for picking maturity	+0.2081	-0.1183	-0.1911	-0.0530	-0.1461
X_8	Yield		+0.1637	+0.1380	+0.1294	+0.1105
X_9	Number of fruits			+0.0217	-0.0223	+0.0770
X_{10}	Weight of fruit				+0.1378	-0.0939
X_{11}	Length of fruit					-0.0242
X_{12}	Girth of fruit					
X_{13}	Flesh thickness					
X_{14}	Number of seeds per fruit					
X_{15}	100-seed weight					
X_{16}	Total soluble solids					
X_{17}	Vitamin C content					
X_{18}	Protein content					
X_{19}	Phosphorus content					
X_{20}	Potassium content					
X_{21}	Iron content					

* Significant at 5 per cent level

** Significant at 1 per cent level

(Continued)

Table 9. (contd.)

	Character	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
X_1	Number of primary branches	+0.2087	+0.1572	+0.1762	-0.1216	+0.0430
X_2	Length of main vine	-0.1373	+0.4114**	+0.2401	+0.2970*	+0.0349
X_3	Node at which the first female flower appeared	+0.3336*	-0.1386	-0.1044	+0.1939	+0.1430
X_4	Days for opening of the first female flower	+0.3608**	-0.2383	-0.2162	+0.2561	+0.6144**
X_5	Number of female flowers	+0.6761**	+0.0712	-0.3197*	-0.0515	+0.3712**
X_6	Percentage of female flowers	-0.0017	-0.1971	-0.2414	+0.0089	+0.0891
X_7	Days for picking maturity	-0.4759**	-0.0018	-0.3243*	+0.0029	-0.1194
X_8	Yield	-0.0263	+0.2647	+0.1884	+0.0525	-0.2723
X_9	Number of fruits	-0.2524	+0.0963	-0.1490	+0.1031	-0.1015
X_{10}	Weight of fruit	-0.0614	+0.2542	+0.1165	+0.2280	-0.3785**
X_{11}	Length of fruit	+0.6788**	+0.5154**	+0.4146**	-0.3103*	-0.0640
X_{12}	Girth of fruit	+0.9917**	+0.8054**	-0.4468**	+0.0099	+0.8311**
X_{13}	Flesh thickness		+0.2341	+0.0034	-0.8268**	-0.1895
X_{14}	Number of seeds per fruit			-0.0610	-0.5112**	-0.2315
X_{15}	100-seed weight				+0.3060*	+0.1240
X_{16}	Total soluble solids					-0.2083
X_{17}	Vitamin C content					
X_{18}	Protein content					
X_{19}	Phosphorus content					
X_{20}	Potassium content					
X_{21}	Iron content					

* Significant at 5 per cent level
** Significant at 1 per cent level

(Continued)

Table 9. (contd.)

	Character	X_{18}	X_{19}	X_{20}	X_{21}
X_1	Number of primary branches	-0.1772	-0.2377	+0.0142	-0.0077
X_2	Length of main vine	-0.2171	+0.1568	-0.0825	+0.0871
X_3	Node at which the first female flower appeared	+0.3311*	-0.0074	-0.1178	-0.0604
X_4	Days for opening of the first female flower	+0.1545	+0.1308	-0.0161	-0.1916
X_5	Number of female flowers	+0.4648**	-0.1614	+0.2765	-0.1293
X_6	Percentage of female flowers	-0.0702	+0.0449	-0.0134	+0.0106
X_7	Days for picking maturity	-0.1686	-0.1189	+0.1121	+0.2348
X_8	Yield	+0.2415	-0.0270	-0.2500	-0.1644
X_9	Number of fruits	-0.1194	+0.1116	+0.2234	+0.0624
X_{10}	Weight of fruit	-0.1911	-0.1147	+0.0455	-0.0616
X_{11}	Length of fruit	+0.3837**	-0.2948*	-0.1036	-0.1385
X_{12}	Girth of fruit	+0.1166	+0.0727	+0.0979	-0.2442
X_{13}	Flesh thickness	-0.1804	+0.0097	+0.0673	+0.4297**
X_{14}	Number of seeds per fruit	+0.1656	-0.0111	+0.1386	-0.1818
X_{15}	100-seed weight	+0.2635	-0.2133	+0.6292**	-0.3245*
X_{16}	Total soluble solids	+0.1859	-0.2202	-0.0797	+0.1404
X_{17}	Vitamin C content	-0.0953	+0.0174	-0.2688	-0.0462
X_{18}	Protein content		+0.0174	-0.7168**	+0.0247
X_{19}	Phosphorus content			-0.0481	+0.1206
X_{20}	Potassium content				-0.0351
X_{21}	Iron content				x

* Significant at 5 per cent level
** Significant at 1 per cent level

favourable for the above traits. Environmental correlation was negative and significant between number of primary branches and yield per plant (r_e = -0.2868). Length of main vine showed highly significant, positive, environmental correlation with number of seeds per fruit and significant positive correlation with total soluble solids. Node at which the first female flower appeared was found to have highly significant and negative environmental association with yield per plant (r_e = -0.7569). Again, the environmental correlation between node at which the first female flower appeared and days for picking maturity was negative and significant. Node at which the first female flower appeared also had positive, significant environmental association with flesh thickness and protein content.

Highly significant, positive, environmental correlations were observed between days for opening of the first female flower and (i) flesh thickness (ii) vitamin C content. Between number of female flowers and (i) percentage of female flowers (ii) flesh thickness (iii) vitamin C content and (iv) protein content also, highly significant, positive, environmental correlations were obtained. Significant and negative environmental correlation was also observed between number of female flowers and 100-seed weight and between percentage of female flowers and days for picking maturity.

Days for picking maturity showed highly significant and negative environmental correlation with flesh thickness and significant negative correlation with 100-seed weight. Weight of fruit was found to exhibit highly significant, negative environmental correlation with vitamin C content. But length of fruit showed highly significant, positive, environmental correlations with flesh thickness, number of seeds per fruit, 100-seed weight and protein content, and significant negative correlation with total soluble solids. Girth of fruit in a similar way was found to have highly significant, positive, environmental correlations with flesh thickness, number of seeds per fruit and vitamin C content and negative correlation with 100-seed weight.

Flesh thickness and number of seeds per fruit showed highly significant and negative environmental correlations with total soluble solids, while the former also had highly significant, positive correlation with iron content. 100-seed weight was found to have highly significant positive correlation with potassium content and significant, positive and negative environmental correlations with total soluble solids and iron content, respectively. Finally, highly significant, negative, environmental correlation was observed between protein content and potassium content (r_e = -0.7468).

3. PATH COEFFICIENT ANALYSIS

The path coefficient analysis showing the direct and indirect effects of yield components, namely, number of primary branches per plant, length of main vine, number of female flowers per plant, number of fruits per plant, weight of fruit and length of fruit, was done based on the genotypic correlation coefficients of significance. The results are presented in Table 10 and Fig. 7, 8 and 9.

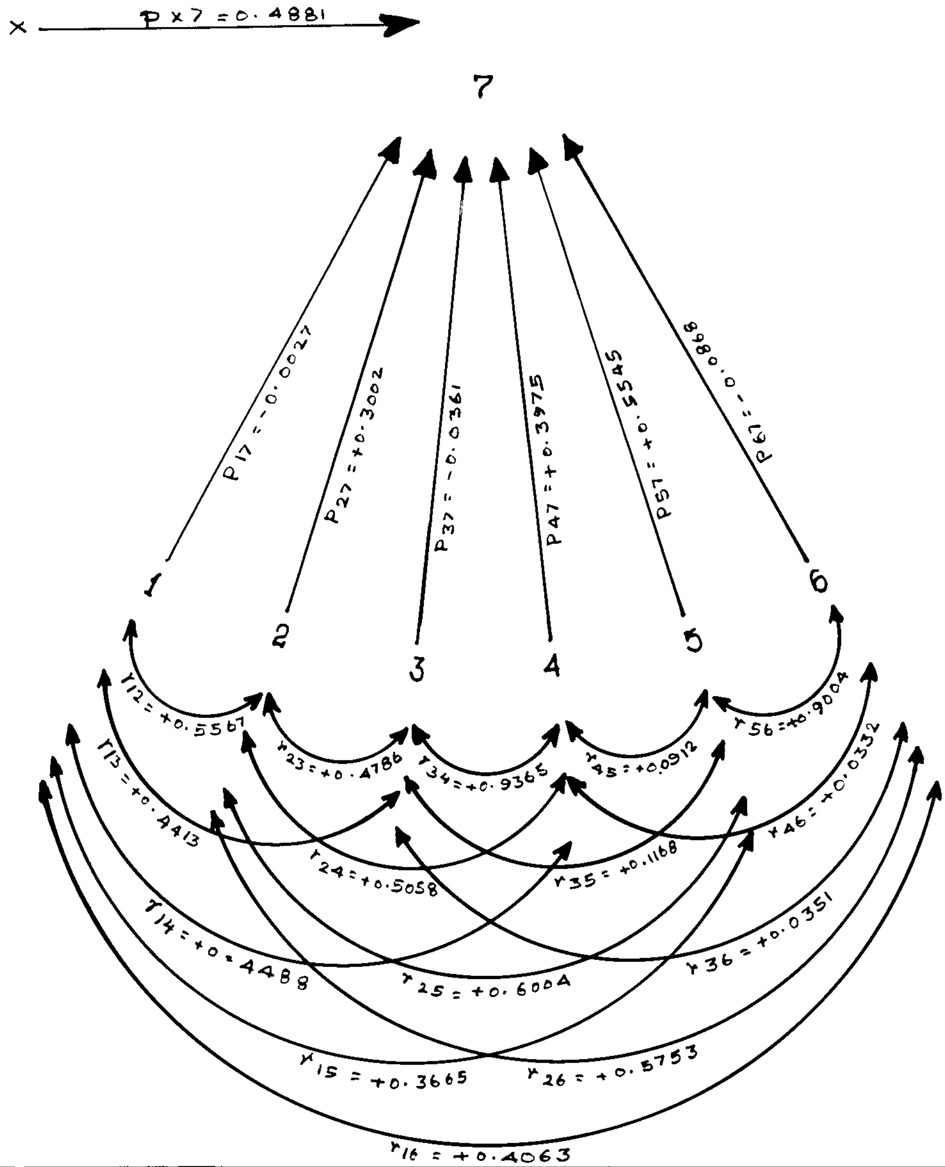
The path analysis revealed that weight of fruits exerted the maximum positive direct effect on fruit yield than any other components. Other characters which showed positive direct effects on

Table 10. Path coefficient analysis - Direct (underlined) and indirect effects of yield components on fruit yield

Character	Number of primary branches per plant	Length of main vine	Number of female flowers per plant	Number of fruits per plant	Weight of fruit	Length of fruit	Genotypic correlation with yield per plant
Number of primary branches per plant	-0.0027	+0.1971	-0.0159	+0.1783	+0.2032	-0.0352	+0.5248
Length of main vine	-0.0017	+0.3002	-0.0172	+0.2010	+0.3329	-0.0499	+0.7652
Number of female flowers per plant	-0.0011	+0.1436	-0.0361	+0.3722	+0.0647	-0.0030	+0.5403
Number of fruits per plant	-0.0012	+0.1518	-0.0338	+0.3975	+0.0505	-0.0028	+0.5620
Weight of fruit	-0.0009	+0.1802	-0.0042	+0.0362	+0.5545	-0.0781	+0.6877
Length of fruit	-0.0010	+0.1727	-0.0012	+0.0132	+0.4992	-0.0868	+0.5961

Residual effect = 0.4881

PATH DIAGRAM



→ PATH COEFFICIENTS

↔ CORRELATION "

1 - NUMBER OF PRIMARY BRANCHES

2 - LENGTH OF MAIN VINE

3 - NUMBER OF ♀ FLOWERS

4 - NUMBER OF FRUITS

5 - WEIGHT OF FRUIT

6 - LENGTH OF FRUIT

7 - YIELD PER PLANT

x - RESIDUAL FACTORS

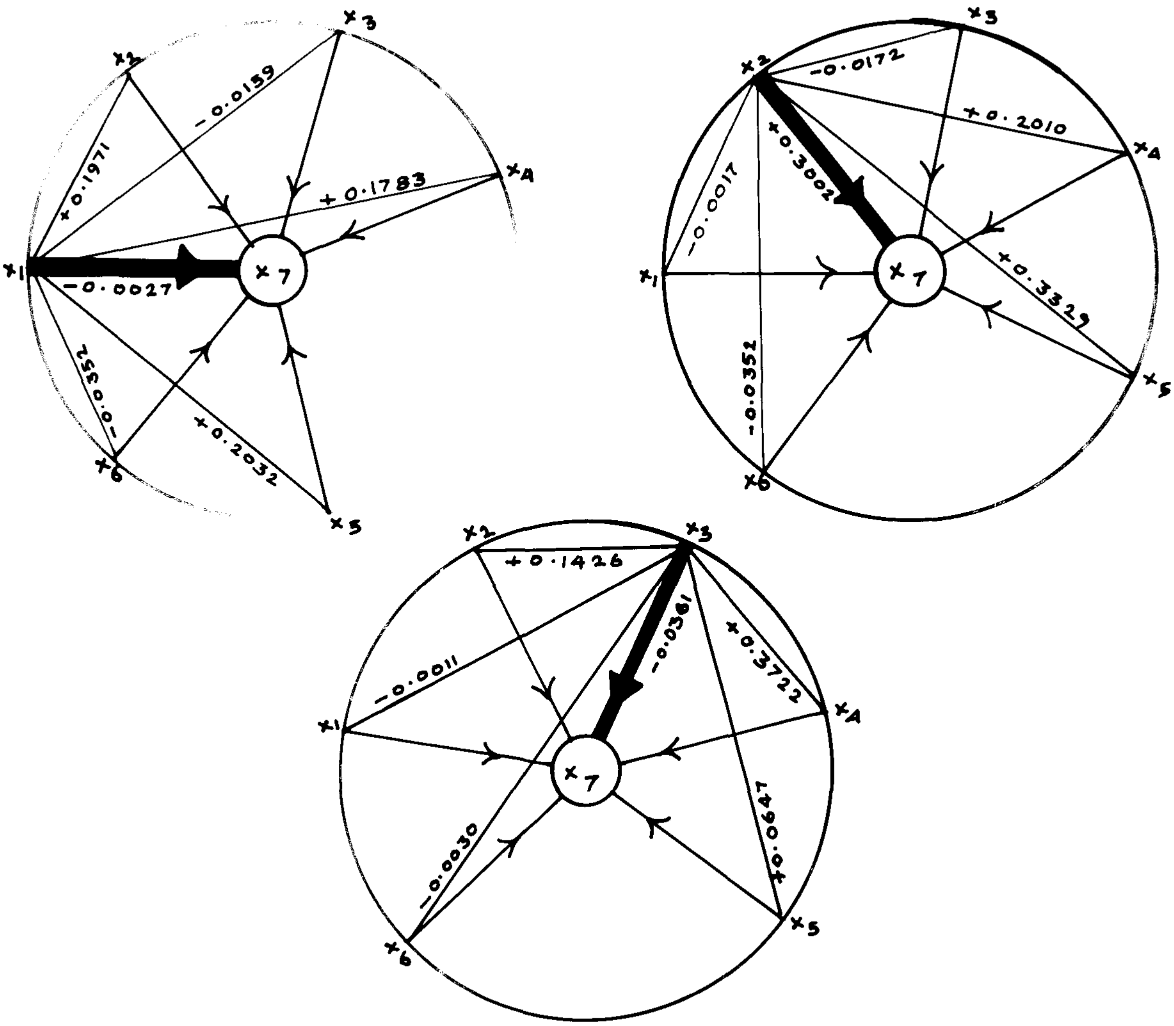
FIG: 7

yield were number of fruits per plant and length of main vine. The rest three characters showed negative direct effects.

The direct effect of number of primary branches on yield per plant was negative and very low (-0.0027). The high positive correlation coefficient, that existed between number of primary branches and yield (+0.5248) was well compensated by its positive indirect effects through weight of fruit (+0.2032), length of main vine (+0.1971) and number of fruits per plant (+0.1783). The indirect effects of number of primary branches through number of female flowers and length of fruit were negative and low.

Length of main vine showed a moderately high positive direct effect on fruit yield (+0.3002). The indirect effects of length of main vine through weight of fruit (+0.3329) and number of fruits (+0.2010) were high and positive, enabling the correlation coefficient positive and the highest (+0.7652) among the characters studied. Length of main vine also showed negative indirect effects on yield through number of primary branches, number of

DIRECT AND INDIRECT EFFECTS OF YIELD COMPONENTS



DIRECT EFFECTS

INDIRECT ..

X_1 - NUMBER OF PRIMARY BRANCHES

X_2 - LENGTH OF MAIN VINE

X_3 - NUMBER OF FEMALE FLOWERS

X_4 - NUMBER OF FRUITS

X_5 - WEIGHT OF FRUIT

X_6 - LENGTH OF FRUIT

X_7 - YIELD PER PLANT

FIG: 8

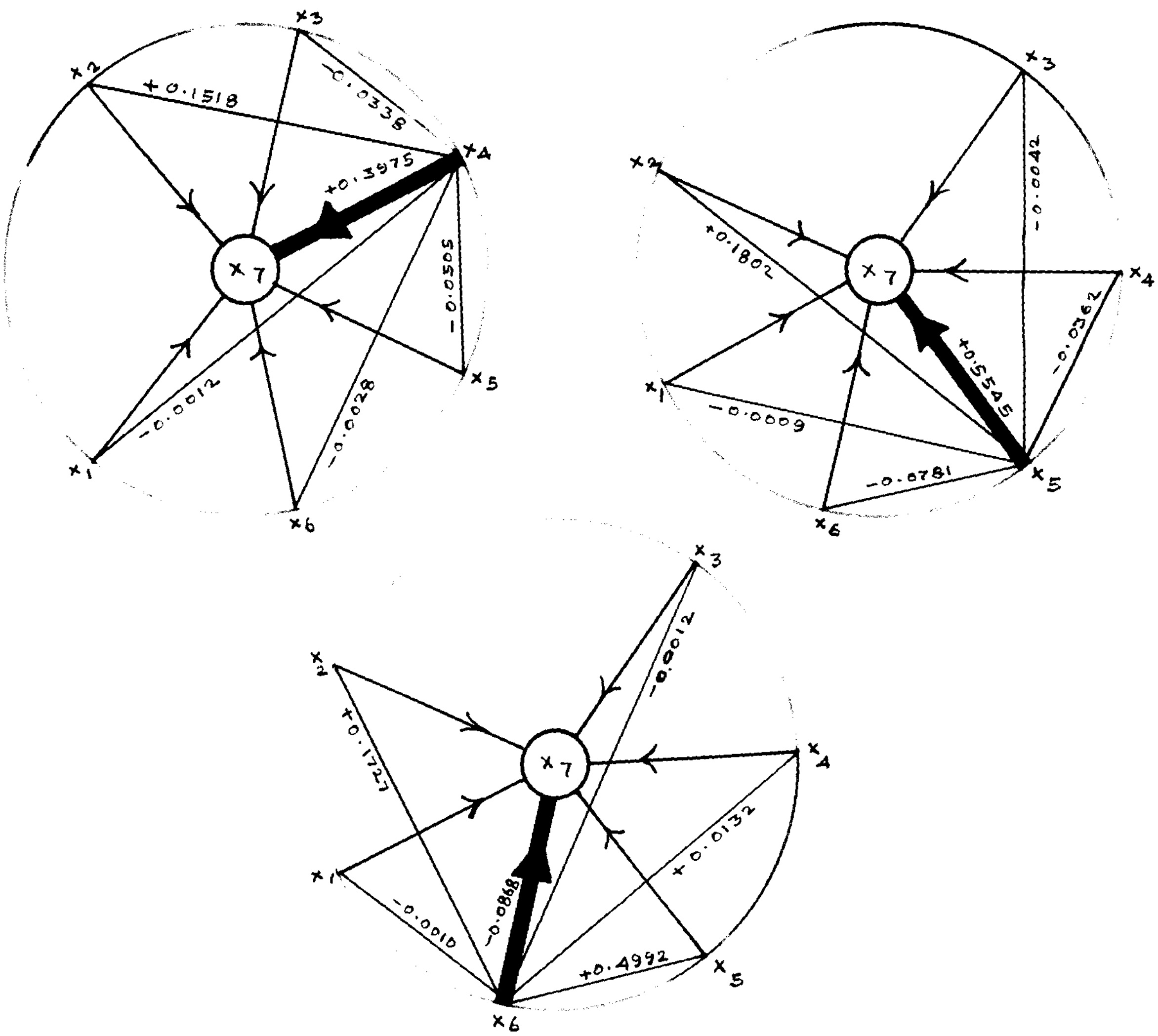
female flowers and length of fruit which were not perceptible.

The path analysis also showed that the direct effect of number of female flowers on fruit yield was negative and negligible (-0.0361). The highly significant, positive correlation (+0.5403) was shown to be solely due to its indirect effects through number of fruits per plant (+0.3722), length of main vine (+0.1436) and weight of fruit (+0.0647). However, the indirect effects of number of female flowers through number of primary branches and length of fruit were negative and of low magnitude.

Number of fruits per plant was confirmed to be an important contributor of yield because the direct effect on fruit yield was high and positive (+0.3975) among the characters studied, except in the case of weight of fruit. The indirect effect through length of main vine (+0.1518) was fairly promising. The indirect effects through other characters were negative and very low.

Weight of fruit showed the maximum direct effect

DIRECT AND INDIRECT EFFECTS OF YIELD COMPONENTS



DIRECT EFFECTS

INDIRECT "

x_1 - NUMBER OF PRIMARY BRANCHES

x_2 - LENGTH OF MAIN VINE

x_3 - NUMBER OF ♀ FLOWERS

x_4 - NUMBER OF FRUITS

x_5 - WEIGHT OF FRUIT

x_6 - LENGTH OF FRUIT

x_7 - YIELD PER PLANT

FIG: 9

on fruit yield (+0.5545) confirming that it is the most important contributing factor for yield in bitter gourd. The indirect effect through length of main vine (+0.1802) was positive and fairly high, but it was partly nullified by its indirect negative effects through other characters like length of fruit (-0.0781), number of female flowers (-0.0042) and number of primary branches (-0.0009).

Length of fruit had negative direct effect on fruit yield (-0.0868), the magnitude of the effect being very low. But the highly significant positive correlation (+0.5961) was well compensated by its appreciably high indirect positive effects through weight of fruit (+0.4992) and length of main vine (+0.1727). The indirect effect of length of fruit through number of fruits per plant was also positive and low (+0.0132). Other indirect effects of length of fruit through number of female flowers and number of primary branches were negative and very low.

The residual effect due to the unknown causal factors influencing the yield was 0.4381, thus indicating that the six characters studied in the path analysis contributed to about 51 per cent of the yield.

4. SELECTION INDEX

Multiple regression function was fitted to ascertain the extent of contribution of each factor in a group towards yield and also to predict the yield based on the phenotypic performance of three characters, namely, length of main vine, number of fruits per plant and weight of fruit, which had high positive direct effects. The following regression equation was thus obtained.

$$Y = -7.2168 + 0.8990X_2 + 0.0492^{**}X_9 + 0.0335^{**}X_{10}$$

$$(R^2 = 0.7469,\ R = 0.8667)$$

where Y = Expected yield

X_2 = Length of main vine

X_9 = Number of fruits per plant

X_{10} = Weight of fruit

** = Significant at 1 per cent level

R^2 = Coefficient of determination

R = Multiple regression coefficient

The coefficient of determination (R^2) was 0.7469 indicating that about 74 per cent of the fruit yield was determined by these three characters. The multiple regression coefficient (R) was 0.8667 which showed the closeness between predicted yield and actual yield.

The regression function was highly significant as revealed from the analysis of variance given in Table 11. The partial regression coefficients were tested for their significance. It was found that the partial regression coefficients for number of fruits per plant and weight of fruit were highly significant (t_9 = 2.885, t_{10} = 3.541). Although the partial regression coefficient for length of main vine was not significant, the estimated value (t_2 = 2.035) closely approached to the table value (2.08). Thus it was clear that length of main vine also had a profound influence on yield along with weight of fruit and number of fruits per plant and the lack of significance was due to chance alone.

Table 11. Analysis of variance - Regression function of three characters X_2, X_9 and X_{10}

Source of variation	d.f.	S.S.	M.S.	'F' value
Regression	3	70.97	23.66	21.14**
Error	21	23.50	1.12	
Total	24	94.47		

** Significant at 1 per cent level

DISCUSSION

DISCUSSION

The prime objective in plant breeding is to pick up desirable genotypes. But a genotype is not a separate identity by itself and is to be measured through a phenotype. As such a survey of observable variation in the available population becomes highly desirable.

Of the various estimates of quantitative variability, mean, range and the variation around the mean are the very basic ones. Success in genetic improvement of a crop would depend upon a wide genetic base and the large genetic variability resulting from it. In the present investigation, it may be seen that the range of variation for almost all characters is large, particularly in respect of phosphorus content, vitamin C content, potassium content, weight of fruit, number of female flowers per plant, number of fruits per plant, number of primary branches per plant, length of fruit, iron content and days for opening of the first female flower. The range of variation observed in yield per plant is also promising (Table 4). This shows that the available population has sufficient amount of variation for most of the characters studied for which selection can be practised. The investigations by Mehrotra and Dixit (1973) in brinjal, Kirti Singh *et al.* (1974) in bhindi, Thakur and Nandpuri (1974) in watermelon, Tikka *et al.* (1974) in cluster bean, Awasthi *et al.* (1976) in chilli, Parthasarathy *et al.* (1976) in tomato and Saini *et al.* (1976) in peas, have shown that a wide range of variation was present for most of the characters considered in those crops.

The observed variation alone is not sufficient for a breeder. A knowledge of the extent and nature of genetic variability is all the more important. So there is an imperative need of partitioning the overall variability into heritable (genetic) and non-heritable (non-genetic) components, because of the high influence of environment on the quantitative characters. Estimates of variance components obtained for the twenty-one characters in the present study have indicated that very high phenotypic and genotypic variances were present in phosphorus content, vitamin C content, potassium content, weight of fruit, number of female flowers and number of fruits per plant (Vide Table 5). In bhindi, Kirti Singh *et al.* (1974)

obtained high estimates of phenotypic and genotypic variance for the chemical constituents and other characters of fruit.

Variance estimates have also shown that variations observed in most of the characters are mainly due to genetic causes, because of the predominence of genotypic variance over the environmental variance. Similar observations were recorded by Rao et al. (1977) in bhindi and Arya and Saini (1977a) in chilli. Only in the case of number of seeds per fruit, the environmental variance was found to be more than the genotypic variance. This may be due to the influence of environmental factors affecting pollination, fertilization and development of seed. Tripathi and Lal (1975) obtained similar results in cluster bean. A good amount of variability observed in other characters like weight of fruit, 100-seed weight and iron content is also contributed by the environmental factors. Similar findings were also reported by Singh et al. (1964) in cluster bean and Rao et al. (1977) in bhindi.

The magnitude of variance, as such, does not reveal the relative amount of variability as ascertained through coefficients of variation. High genotypic coefficient of variation indicates that genotypic variability present in the crop for the character is high and enables us to compare with that present in other characters. The values estimated for the phenotypic and genotypic coefficients of variation (vide, Table 6 and Fig.2) have revealed that yield per plant, vitamin C content, number of fruits per plant, iron content, number of female flowers per plant and phosphorus content had high estimates (above 20 per cent). This suggests that there is a high degree of genetic variability in the crop for these characters as compared to others and therefore, these could be utilised in the crop improvement programmes. Several reports in vegetables are in support of this view. In bitter gourd, Srivastava and Srivastava (1976) obtained high values of genotypic coefficient of variation for number of fruits and yield per plant. Reports by Anand and Torrie (1963) in soybean, Kirti Singh *et al.* (1974) in bhindi, Pande *et al.* (1975) in french bean, Tripathi and Lal (1975) in cluster bean, Parthasarathy *et al.* (1976) in tomato, Mishra and Roy (1976) in brinjal, Arya and Saini (1977a) in chilli and Lakshmi and Goud (1977) in cowpea can also be cited in support of the above findings.

Characters having moderate estimates of genotypic coefficient of variation (10-20 per cent) were number of primary branches, length of main vine, node at which the first female flower appeared, days for picking maturity, weight of fruit, length of fruit, flesh thickness, total soluble solids, protein content and potassium content. Among the characters studied, number of seeds per fruit, 100-seed weight, girth of fruit, percentage of female flowers and days for opening of the first female flower have shown low values of genotypic coefficient of variation (below 10 per cent) and these traits therefore, offer little scope for selection.

However, with the help of genotypic coefficient of variation alone it is difficult to ascertain the amount of variation that is heritable (Gandhi et al. 1964). The heritable portion of the variation can be found out with the help of heritability estimates. 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. Results of the investigations now undertaken clearly indicate that all characters except number of seeds per fruit had high heritability. The characters like yield per plant, number of fruits per plant, vitamin C content and number of female flowers per plant which had given high genetic coefficient of variation, also had high heritability estimates. Heritability estimate was highest for number of fruits per plant (99.80 per cent) and yield per plant (99.74 per cent). Other characters like number of primary branches, length of main vine, node at which the first female flower appeared, days for opening of the first female flower, weight of fruit, length of fruit, flesh thickness, phosphorus content and potassium content also showed high values of heritability exceeding 90 per cent. Hence, these traits could be improved by selection, because of the fact that, high heritability indicates the effectiveness with which selection of genotypes can be based on phenotypic performance (Johnson et al., 1955 a). However, heritability value in itself provides no indication of the amount of genetic progress that would result from selecting the best individuals. Similar results have been reported by Nandpuri and Kumar (1973) in chilly, Srivastava and Sachan (1973) in brinjal, Srivastava and Srivastava (1976) in bitter gourd and Arya and Saini (1977a) in Capsicum.

Among the characters studied, number of seeds per fruit showed the lowest heritability estimate (43.37 per cent), thus limiting the scope of selection for this trait. In cluster bean, Tripathi and Lal (1975) observed the lowest estimate of heritability (48.91 per cent) for number of seeds per pod.

Heritability values give a useful indication of the relative scope of selection in the material in hand, but to arrive at more reliable conclusions, heritability and genetic advance should be jointly considered. Johnson et al. (1955a) in their studies with soybean have suggested that heritability estimates along with genetic gain (genetic advance in percentage of mean) is more useful than the heritability alone in predicting the resultant effect for selecting the best individuals. In the present study, the genetic advance was estimated as absolute for a character and also as the percentage of mean (genetic gain) for comparing different characters.

Expected genetic advance estimated in absolute values made the point clear that, by selecting 5 per cent superior plants from the available population, it would be possible to improve the yield by 4.08 kg per plant, number of branches by 9.22 per plant, length of main vine by 1.23 metres, node at which the first female flower appeared by 7.22, days for opening of the first female flower by 7.83, number of female flowers by 31.40 per plant, percentage of female flowers by 2.21, days for picking maturity by [illegible].38, number of fruits by 31.22 per plant, weight of fruit by 55.35 g, length of fruit by 9.67 cm, girth of fruit by 2.04 cm, flesh thickness by 1.51 mm, number of seeds per fruit by 2.30 and 100-seed weight by 1.21 g. Regarding chemical constituents of fruits, total soluble solids showed an improvement by 1.21, vitamin C content by 83.38 mg, protein content by 3.69 g, phosphorus content by 160.23 mg, potassium content by 74.44 mg and iron content by 6.27 mg per 100 g of fruit.

The genetic gain estimate was maximum for yield (81.93 per cent) which was followed by vitamin C content (70.72 per cent), number of fruits per plant (64.30 per cent) and number of female flowers per plant (53.50 per cent). Among the chemical constituents of fruit, iron content (51.81 per cent) and phosphorus content (40.81 per cent) showed high values of genetic gain. These characters were also observed to have high heritability in addition to high genetic gain values which may be attributed to the additive gene effects (Panse, 1957) and as such, these traits can be improved through straight selection. By selecting the 5 per cent superior plants from the available material, it is possible to improve the various characters to that percentages as indicated by the genetic gain estimates. Srivastava and Srivastava (1976) obtained similar results in bitter gourd. The reports by Nandpuri et al. (1971) in chilli, Singh et al. (1974) in brinjal, Singh et al. (1976) in muskmelon, Rao et al. (1977) in bhindi, Singh et al. (1977) in tomato and Thakur and Choudhury (1977) in ridge gourd can also be cited in support of these findings.

Number of branches per plant, node at which the first female flower appeared, weight of fruit, length of fruit and total soluble solids also had promising values of genetic gain (30 to 40 per cent) and therefore, selection can be effectively practised for these traits also. However, characters such as days for opening of the first female flower, percentage of female flowers, girth of fruit and 100-seed weight were found to have high heritability and low genetic gain which may be attributed to the action of non-additive genes which includes dominance and epistasis (Panse, 1957). Hence, selection has limited scope for improving these traits. Johnson et al. (1955 a), with reference to their work in soybean had pointed out that high heritability need not be accompanied by high genetic gain estimates. Number of seeds per fruit appeared nearly stable because of the lowest heritability and lowest genetic gain estimates and so there is little scope for selection (Narasimha Rao and Pardhasaradhi, 1968).

The comparison of available population for different economic characters has revealed that the type B.G. 23 was the highest yielder, followed by

B.G. 21, B.G. 15 and B.G. 10. For early flowering, types B.G. 18, B.G. 7 and B.G. 1 could be recommended whereas for early maturity of the fruits, types B.G. 11, B.G. 10, B.G. 23, B.G. 13 and B.G. 8 were found to be good. However the low yielding types like B.G. 13, B.G. 3, B.G. 24 and B.G. 2 were observed to contain higher quantities of total soluble solids in their fruits as compared to others. Similarly the types B.G. 3, B.G. 13, B.G. 4 and B.G. 19 had significantly higher vitamin C content. Superior types identified for iron content were B.G. 19, B.G. 10, B.G. 15 and B.G. 12, while the protein content in the fruits of B.G. 25, B.G. 7, B.G. 15 and B.G. 24 was significantly higher than all other types. For growers interested in seed production, the types B.G. 20, B.G. 6, B.G. 14, and B.G. 8 can be recommended, since they have more number of seeds per fruit combined with increased 100-seed weight.

Thus it is clear that different types carry superiority with regard to various characters. Hence there is possibility of combining yield and other qualities by effective hybridization of superior varieties. Again, the high variability observed in yield per plant offers scope of exploiting hybrid vigour by crossing the distantly related individuals for yield.

In any crop improvement programme, it becomes necessary to have simultaneous progress of more than one character, especially in the case of a complex character like yield which is influenced by many other traits. This is due to the physiological and linkage relationships of genes covering various characters. Hence, before commencing a selection programme for the improvement of yield, the association between yield and its attributes should be understood. The simple correlation study is inadequate to measure the association, as different genotypes are susceptible to environment to varying degrees. Robinson et al. (1951) had pointed out that the estimations of genotypic and phenotypic correlations are useful in crop improvement programmes. Another important factor in the selection programme is that the environmental correlations between the character pairs considered, should not be significant. Genotypic correlation coefficients provide a measure of the genotypic association between the characters and reveal the characters that may be useful under consideration. With this idea in mind, the phenotypic, genotypic and environmental correlation coefficients between yield and its components and the intercorrelations among the yield components were worked out.

Except in a few cases, the phenotypic and genotypic correlations for any pair of traits seemed to be of comparable magnitude in the present study. However, the genotypic correlation coefficients were slightly higher than phenotypic correlation coefficients. This means that there is a strong inherent relationship between the characters under study, but their expression is impeded by the influence of environmental factors. Srivastava and Srivastava (1976) obtained higher values of genotypic correlation coefficients than phenotypic correlation coefficients between different pairs of characters in bitter gourd.

Yield is the end product of interaction of many factors. The association analysis in the present study has revealed that yield was highly associated with length of main vine, weight of fruit, length of fruit, number of fruits per plant, number of female flowers per plant and number of primary branches per plant, in the order. The association of number of female flowers, number of fruits, weight of fruit and length of fruit towards yield was logical. But the contributions by length of main vine and number of branches need physiological explanation. Perhaps, these traits may be enhancing the number of leaves and as such, the photosynthetic efficiency. Increased photosynthetic efficiency will result in increased dry matter accumulation and finally the economical yield. In bitter gourd, Srivastava and Srivastava (1976) reported that number of fruits per plant, number of female flowers and number of branches per plant were highly associated with yield. Similar findings were also made by Kirti Singh *et al*. (1972) in chilli, Thamburaj (1973) in ridge gourd, Kumar *et al*. (1976) in cowpea and Nandpuri *et al*. (1976) in tomato.

100-seed weight and girth of fruit had significant genotypic correlations with yield per plant but their phenotypic correlations were not significant. This may perhaps be attributed to the modifying effect of the environmental factors in the expression of genetic components of these traits.

Environmental correlation between yield and number of primary branches was negative and significant. This shows that the environment favourable for the development of primary branches will be unfavourable for yield. The possible reason may be that the environmental factors such as soil fertility and other favourable soil conditions increasing the vegetative growth may be affecting the reproductive phase of the plant adversely to some extent. Singh and Mehndiratta (1969) obtained negative and significant environmental correlation between yield per plant and number of branches per plant in cowpea.

Negative and highly significant environmental correlation was observed between yield per plant and node at which the first female flower appeared, but their phenotypic and genotypic correlations were low. This means that the environmental factors favourable for yield per plant will be unfavourable for early flowering. Perhaps, this environmental interaction may be the reason for the lack of association between the characters at phenotypic and genotypic levels.

Association of yield and its components alone is not adequate in any selection programme. A knowledge of the inter-relationship among the yield components is also needed. Doku (1970) with reference to his work in cowpea, had suggested that intercorrelations among the yield components should be estimated because, in a breeding programme, rate of improvement of one component does not hinder the improvement in other components. The intercorrelations estimated for the yield components in the present study have indicated that the length of main vine, number of primary branches, number of female flowers and number of fruits were strongly and positively associated with each other. Positive and highly significant correlations were also observed between number of primary branches and length of fruit and also between length of fruit and weight of fruit. Length of main vine exhibited positive correlations with weight of fruit and length of fruit. This complex set of correlations between various yield components clearly indicates that the improvement in length of main vine will definitely improve the number of primary branches, number of female flowers and number of fruits per plant and at the same time maintain a reasonably high weight and length of fruits. Therefore simultaneous improvement of these traits is possible by single selection. These findings to a certain extent are in agreement with the results obtained by Srivastava and Srivastava (1976) in bitter gourd. However, the association of days to first female flower with the yield components was not evident in the present investigation. Similar results were also reported by Molokojedova (1962) in cucumber, Khurana and Sadhu (1972) in soybean, Kirti Singh et al. (1972) in chilli and Kirti Singh et al. (1974) in bhindi.

The positive correlation observed at phenotypic and genotypic levels between node at which the first female flower appeared and days for opening of the first female flower clearly revealed that an early flowering variety will produce the first female flower at a lower node than a late variety.

Weber and Moorthy (1952) in their work in soybean had established that the knowledge of correlations between morphological and chemical characters would be useful in visual selection for chemical characters. In the present study, it was observed that the correlation between number of female flowers and protein content was significant and positive, at phenotypic and genotypic levels. This association can be explained on the basis of the fact that the protein includes aminoacids, such as, tryptophan which is a precursor of indole-acetic acid, an auxin needed for flower production in plants (Tukey, 1954). Again, experiments have shown that it is possible to increase the production of female flowers by the external application of growth regulators in bitter gourd (Prasad and Tyagi, 1963; Ravindran, 1971).

Girth of the fruit was found to be negatively and genotypically correlated with total soluble solids, phosphorus content andiron content. This suggests that the improvement in girth of fruit is possible at the expense of these quality aspects of fruits. This is similar to the findings of Kirti Singh et al. (1974) in bhindi and Barooah and Mohan (1976) in tomato.

The association analysis among the biochemical traits has indicated that improvement of various quality factors is possible simultaneously. The results, therefore, revealed that breeding for the improvement of total soluble solids will definitely improve the vitamin C content, phosphorus content and potassium content in the fruits and yet maintain a reasonably high protein content.

Association of characters determined by correlation coefficients 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 developed by Wright (1921) and first used by Dewey and Lu (1959) in plants, furnishes a means of measuring the direct effect of each trait, as well as, the indirect effect through other components of yield. From the results of the path analysis given in Table 10 and Fig. 7, 8 and 9, it was obvious that, though the correlation between length of main vine and yield was maximum, it was the weight of fruit that exerted the maximum direct effect (0.5545) towards yield. Next to weight of fruit, number of fruits per plants (0.3975) and length of main vine (0.3002) had positive direct effect on yield. The indirect effects of all other characters through these traits were also positive and high. Hence it is very clear that these three characters, namely, weight of fruit, number of fruits per plant and length of main vine, are the important characters contributing to yield in bitter gourd.

Except in the case of number of fruits per plant, the results of the path analysis do not agree with the findings of Srivastava and Srivastava (1976) in bitter gourd. In their investigation, number of female flowers per plant had the maximum direct effect on yield followed by number of fruits per plant and number of branches per plant and the indirect effect of all other traits was mainly through these traits. However, in the present study, number of primary branches per plant, number of female flowers per plant and also length of fruit were found to have negative and negligible direct effects towards yield. The major reason for the contrasting results may be attributed to the diversity of environmental conditions and populations included in the studies. Korla and Rastogi (1977) in chilli and Rao et al. (1977) in bhindi found findings similar to those obtained in the present study.

Length of main vine showed high indirect positive effect on yield through number of fruits per plant (0.2010) and weight of fruit (0.3329) thus compensating the high genotypic correlation coefficient. This may be explained based on the peculiarity noticed in the growth of main vine. In bitter gourd, occasionally, it is noted that due to the abnormal thickening of growing tip, further extension of vine is hindered and as such, production of fruits and their development are affected which in turn will reduce the yield. This suggests that the indirect effect of length of main vine is quite possible. This abnormal thickening of growing tip is worth investigating, for finding out the physiological relationship between length of main vine and yield.

In spite of the negative and negligible direct effect in the case of number of primary branches towards yield (-0.0027), its indirect effects through weight of fruit (+0.2032), length of main vine (+0.1971) and number of fruits per plant (+0.1783) were positive and high which was responsible for the high correlation coefficient. Perhaps, the number of primary branches may be influencing these traits by the photosynthetic efficiency centered in the leaves developed from the branches. Similarly number of female flowers also had negative and low direct effect (-0.0361) and the high correlation coefficient was mainly due to the compensating indirect effects through number of fruits per plant (+0.3722) and length of main vine (+0.1436). The length of fruit was also found to have negative direct (-0.0868) and the correlation was made up by the indirect effects through weight of fruit (+0.4992) and length of main vine (+0.1727). Among the indirect effects, length of fruit was found to exhibit the highest indirect effect through weight of fruit on yield. This means that if length is increased, the yield is improved depending on weight of fruit.

On close examination of the values, it is quite clear that the indirect effects of all characters through number of primary branches, number of female flowers and length of fruit are negative and low. These effects though small, are really nullifying the total effect of each component on yield. Therefore, a compromise among the various characters should be made in the selection programme for realising maximum yield.

Nandpuri et al. (1976) reported that the number of fruits and plant height had high direct effects on yield in tomato. Singh and Mital (1976) observed negative direct effect for fruit length in tomato. Korla and Rastogi (1977) suggested that the number of fruits, weight of fruit and plant height had appreciably high direct effects towards yield in chilli. Rao et al. (1977) reported that the number of fruits seemed to be the important yield contributing factor for yield in bhindi, as it had the highest direct effect.

The residual effect calculated in the path analysis was 0.4881, indicating that about 51 per cent of the yield is contributed by the six characters considered for the path analysis. This moderate residual effect may be because of the environmental factors, sampling error and the characters which were not considered in the path coefficient analysis. Sengupta and Kataria (1971) obtained high residual effect (0.541) in their investigation on soybean and this was suggested to be due to sampling errors and other characters which were not considered.

Hence, within the scope of the path analysis carried out in the present study, it can be concluded that greater emphasis has to be laid for improving the weight of fruit, number of fruits per plant and length of main vine which exerted positive and high direct effects and through which number of primary branches per plant, number of female flowers per plant and length of fruit exhibited high indirect effects towards yield. A compromise between these two groups of characters is appreciable. In short, if a selection procedure is designed to increase the weight of fruit, number of fruits per plant and length of main vine and to reduce the number of primary branches per plant, number of female flowers per plant and length of fruit to an optimum level, simultaneously, the fruit yield could be considerably increased.

In order to select the high yielding individuals based on phenotypic performance there is a need to formulate a selection index. Such a selection index will help to ascertain the extent of contribution of each factor in a group and also to predict the yield possible by adopting the function. The characters such as length of main vine (X_2), number of fruits per plant (X_9) and weight of fruit (X_{10}) which were found to be the important contributors of yield (Y), were used for formulating the selection index by the multiple regression analysis. The function constructed is as follows:

$$Y = -7.2168 + 0.8990\ X_2 + 0.0492^{**}X_9 + 0.0335^{**}X_{10}$$

The function was found to be highly significant and therefore, much improvement could be expected by using this equation for straight selection programmes of yield. From the estimate of coefficient of determination (R^2), it was clear that bout 74 per cent of the variation in yield was determined by these three characters, phenotypically.

The partial regression coefficients were highly significant in the case of weight of fruit and number of fruits per plant, eventhough the former had a high 't' value. Length of main vine also had high partial regression coefficient, but it was not significant as revealed by the 't' value. This shows that length of main vine also contributes to yield along with weight of fruit and number of fruits per plant and the lack of significance may be because of the low variability in the available population. The multiple regression analysis by Kirti Singh *et al.* (1974) in bhindi and Nandpuri *et al.* (1976) in tomato also showed similar results.

On close observation of the path analysis and multiple regression analysis, it is evident that the results of both analyses are in conformity. In both cases, weight of fruit exerted the maximum influence towards yield, followed by number of fruits per plant and length of main vine. The multiple regression coefficient estimated was 0.8667 and this indicated the closeness between the predicted and actual yield.

In conclusion, selection index has indicated that about 73 per cent of fruit yield in bitter gourd can be predicted if the observed value for length of main vine is multiplied by 0.8990, number of fruits by 0.0492 and that of weight of fruit by 0.0335 and from their sum of products 7.2168 is subtracted.

SUMMARY

SUMMARY

Studies were undertaken with 25 diverse bitter gourd types in the Department of Horticulture (Olericulture), College of Horticulture, Kerala Agricultural University, Vellanikkara, Trichur, during 1977-78 (October-February). The objectives were, to determine the extent of variability by estimating the various genetic parameters, to compute the extent of association by finding out the correlation coefficients, to assess the direct and indirect effects of characters towards yield by analysing the path coefficients and also to formulate a reliable selection index for the crop by resorting to multiple regression analysis. The findings are summarised below:

1. The bitter gourd types showed highly significant difference for all the twenty one characters studied. A wide range of variation was also observed in most of the characters.

2. Estimates of phenotypic, genotypic and environmental variances have revealed that a large portion of the variation in all characters except number of seeds per fruit was due to genetic factors.

3. The phenotypic and genotypic coefficients of variation estimated for different characters have also confirmed that the major portion of the total variation in all

characters except number of seeds per fruit was due to genetic causes. Yield per plant had the highest estimates for phenotypic and genotypic coefficient of variation. Other characters such as vitamin C content, iron content and number of fruits per plant also had high phenotypic and genotypic coefficients of variation exceeding 30 per cent. Girth of fruit showed the lowest estimates for the phenotypic and genotypic coefficients of variation.

4. Heritability in the broad sense was found quite high for all characters except number of seeds per fruit. Number of fruits per plant had the highest heritability of 99.80 per cent, which was closely followed by yield per plant (99.74 per cent) and vitamin C content (99.65 per cent) and the lowest heritability was recorded in number of seeds per pod (43.37 per cent).

5. Genetic advance estimated in absolute values was found to be promising in number of female flowers (31.40), yield per plant (4.08 kg), number of fruits per plant (31.22), weight of fruit (55.35 g), length of fruit (9.67 cm), vitamin C content (83.38 mg), protein content (3.69 g), phosphorus oontent (160.23 mg), potassium content (74.44 mg) and iron content (6.27 mg).

6. Estimate of genetic gain was highest for yield per plant

(81.93 per cent), followed by vitamin C content (70.72 per cent), number of fruits per plant (64.30 per cent), number of female flowers per plant (53.50 per cent), and iron content (51.81 per cent). Genetic gain estimates have indicated that by selecting five per cent superior plants from the available population, yield can be improved upto 81.93 per cent over the mean and others by the percentages as indicated by the estimates.

7. Characters such as yield, vitamin C content, number of fruits, number of female flowers, iron content and phosphorus content which exhibited parallelism in the high estimates of heritability and genetic gain may be suggested to be due to the action of additive genes. Hence these characters can be improved straight away through selection. Days for the opening of the first female flower, percentage of female flowers, girth of fruit and 100-seed weight were found to carry high heritability and low genetic gain which may be attributed to the action of non-additive genes including dominance and epistasis. Hence straight selection has limited scope for improving these traits. Number of seeds per fruit, which was found to exhibit low

heritability and low genetic gain, may be nearly stable.

8. Comparison of different bitter gourd types for the various economic characters in the present study has revealed that the type B.G.23 is the highest yielder, followed by B.G.21, B.G.19 and B.G.10.

9. Correlation studies have shown that the phenotypic and genotypic correlations for any pair of traits seem to be of comparable magnitude. The genotypic correlation coefficients, however, were slightly higher than phenotypic correlations in many cases.

10. Yield per plant was highly associated with length of main vine, weight of fruit, length of fruit, number of fruits per plant, number of female flowers per plant and number of primary branches per plant, both at phenotypic and genotypic levels.

11. Intercorrelations worked out in the present study showed that the characters exhibiting significant association with yield per plant were also highly intercorrelated genotypically and phenotypically. Hence the number of primary branches, length of main vine, number of female flowers per plant, number of fruits per plant, weight of fruit and length of fruit can be simultaneously improved.

12. Association analysis between morphological and biochemical characters has shown that the phenotypic and genotypic correlations between number of female flowers and protein content were positive and significant.

13. The study of association among biochemical characters has indicated that the improvement of various quality factors such as total soluble solids, vitamin C content, phosphorus content and potassium content is possible simultaneously.

14. Environmental correlation coefficients estimated for different pairs of characters made the point clear that the environmental factors favourable for certain characters are also favourable for others because of the positive and significant values. Environmental correlations were negative and significant between yield and number of primary branches, and node at which the first female flower appeared. Hence, the environmental factors favourable for yield will be unfavourable for these characters.

15. Path coefficient analysis employed in the present investigations brought out that the weight of fruit, number of fruits per plant and length of main vine had high direct positive effects on yield, in the order.

Indirect effects among themselves were also positive. Number of primary branches per plant, number of female flowers per plant and length of fruit had negative direct effects and the highly positive correlation coefficients were compensated by their indirect effects through weight of fruit, number of fruits per plant and length of main vine.

16. The indirect effects of all characters through number of primary branches, number of female flowers and length of fruit were negative and thus they nullified the total effect of each component on yield.

17. Residual effect was 0.4981, indicating that about 51 per cent of variation in yield is contributed by the six characters considered in the path analysis, genotypically.

18. Multiple regression analysis resulted in fitting the following function.

$$Y = -7.2168 + 0.8990\ X_2 + 0.0492^{**}X_9 + 0.0335^{**}X_{10}$$

where Y = Expected yield.

X_2 = Length of main vine

X_9 = Number of fruits per plant

X_{10} = Weight of fruit

** = Significant at 1 per cent level

The function was highly significant and therefore, much improvement in yield can be expected by using this function. Estimate of coefficient of determination was 0.7469 and thus it was clear that about 74 per cent of the phenotypic variation in yield was determined by the characters included in the multiple regression analysis.

19. Partial regression coefficients tested for their significance have shown that weight of fruit followed by number of fruits per plant contributed to a greater extent than length of main vine.

20. The results of path analysis and multiple regression analysis are in conformity. In both cases weight of fruit exerted the maximum influence on yield followed by number of fruits per plant and length of main vine.

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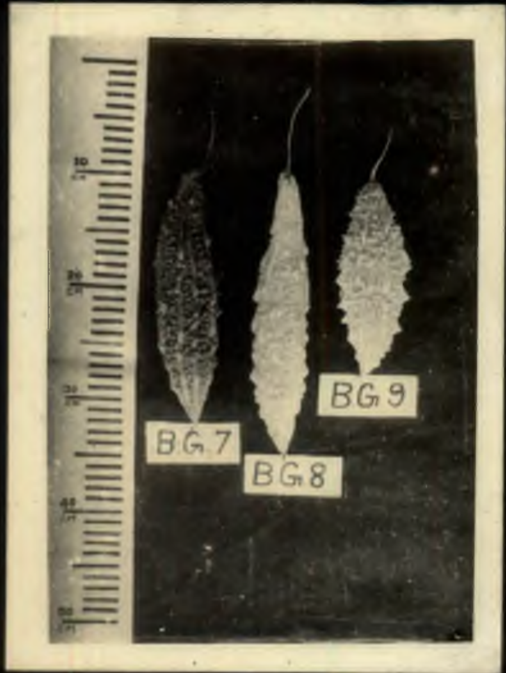
* Originals not seen

Appendix I. Meteorological data during the cropping period*
(Means of week)

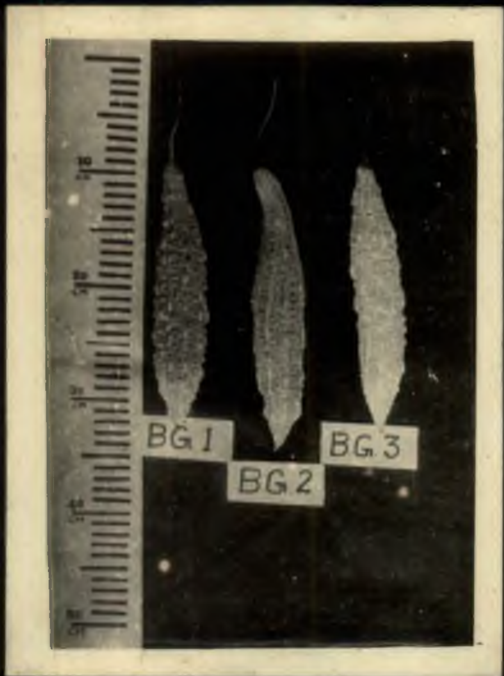
Weeks	Temperature in °C		Humidity in %		Rainfall in mm
	Maximum	Minimum	Morning	Evening	
22-10-77 - 28-'77	29.3	23.3	90	77	11.8
29-10-77 - 4-77	31.8	24.0	90	67	2.3
5-11-77 - 11-77	30.1	23.0	89	67	31.1
12-11-77 - 1r-77	30.1	23.8	90	78	13.0
19-11-77 - 2-77	29.9	21.9	92	80	16.2
26-11-77 - 2-77	30.5	23.6	86	69	0.2
3-12-77 - 2-77	30.9	22.2	79	56	-
10-12-77 - 12-77	30.0	22.2	69	49	-
17-12-77 12-77	30.5	23.0	70	51	-
24-12-77 12-77	31.2	20.3	80	48	-
1- 1-7 - 1-78	32.0	21.9	79	41	-
8- 1- - 1-78	31.4	20.9	80	48	-
15- 1 1- 1-78	31.4	19.1	76	41	-
22- 8- 1-78	32.6	21.9	77	41	-
29- 4- 2-78	33.3	21.5	78	45	-
5- 11- 2-78	34.1	22.4	83	45	-
12 18- 2-78	34.9	22.2	83	45	-
1 25- 2-78	34.4	22.2	87	52	-

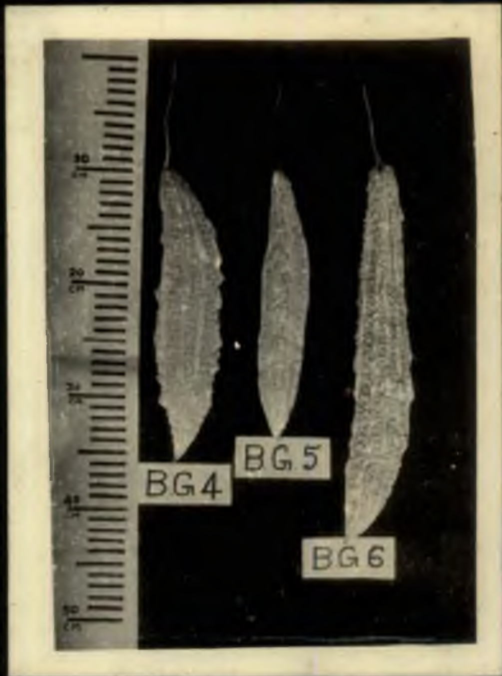
rce: Meteorological Observatory, District Agricultural Farm, Mannuthy

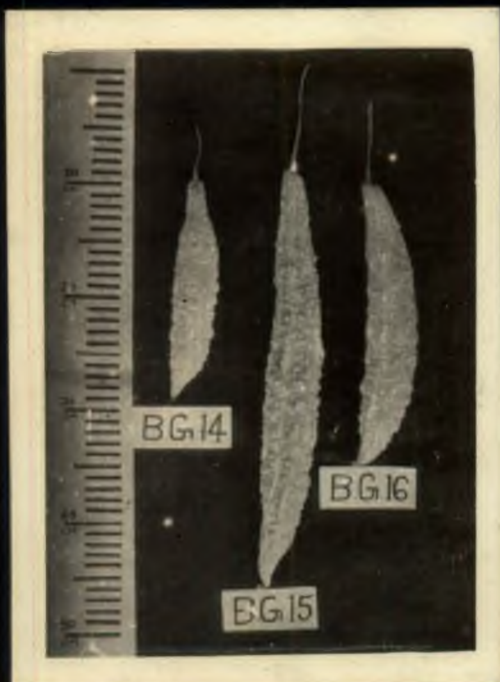
Plate I. A general view of the experimental field, showing the method of training


B.G.7
B.G.8
B.G.9


B.G.10
B.G.11
B.G.12
B.G.13


BG 1
BG 2
BG 3


BG 4
BG 5
BG 6


B.G.14
B.G.15
B.G.16


B.G.17
B.G.18
B.G.19


B.G.20
B.G.21
B.G.22


B.G.23
B.G.24
B.G.25

Plate III. Field performance of bitter gourd type B.G.3

Plate IV. Field performance of bitter gourd type B.G.4

GENETIC VARIABILITY, CORRELATION STUDIES AND PATH COEFFICIENT ANALYSIS IN BITTER GOURD

(Momordica charantia L.)

By

C. RAMACHANDRAN

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the

requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

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COLLEGE OF HORTICULTURE

VELLANIKKARA, TRICHUR

1978

ABSTRACT

Studies were undertaken with 25 diverse bitter gourd types in the Department of Horticulture (Olericulture), College of Horticulture, Kerala Agricultural University, Vellanikkara, Trichur, to estimate the genetic variability, correlation coefficients and path coefficients, and also to formulate a reliable selection index for the crop, during 1977-78.

The results have shown that the differences between types were highly significant for all the twenty one characters studied.

The estimates of variance components and coefficients of variation have indicated that the major portion of total variability in all characters, except number of seeds per fruit, was due to genetic causes. Heritability in the broad sense was found quite high for all characters except number of seeds per fruit. Expected genetic advance has shown that, by selecting five per cent superior plants from the available population, yield could be improved by 4.08 kg per plant.

Characters such as yield per plant, vitamin C content, number of fruits per plant, number of female flowers per plant, iron content and phosphorus content which exhibited parallelism in the high estimates of heritability and

genetic gain may be suggested to be due to the action of additive genes and can be straightly improved through selection. Type B.G.23 was found to be exceptionally high yielding.

Yield per plant was found to be highly correlated with length of main vine, weight of fruit, length of fruit, number of fruits per plant, number of female flowers per plant and number of primary branches per plant. The correlation coefficients among these yield components were also highly significant.

Path coefficient analysis has shown that the weight of fruit, number of fruits per plant and length of main vine had high direct positive effects on yield. Number of primary branches per plant, number of female flowers per plant and length of fruit exhibited low and negative direct effects on yield.

Multiple regression analysis resulted in fitting a function, indicating that, about 74 per cent of the fruit yield in bitter gourd could be predicted phenotypically, if the observed value for length of main vine is multiplied by 0.8990, number of fruits per plant by 0.0492 and weight of fruit by 0.0335 and from their sum of products 7.2168 is subtracted.