BIOMETRIC ANALYSIS OF YIELD AND OTHER ATTRIBUTES IN COLEUS (*Coleus parviflorus* Benth.)

By

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THESIS

submitted in partial fulfilment of the
requirement for the degree of

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1996

Dedicated to My
Beloved Parents

DECLARATION

I hereby declare that the thesis entitled '**Biometric Analysis of Yield and Other Attributes in Coleus (*Coleus parviflorus* Benth.)**' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other university or society.

Vellanikkara

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Certified that the thesis entitled '**Biometric Analysis of Yield and Other Attributes in Coleus (*Coleus parviflorus* Benth.)**' is a record of research work done independently by **Mr.K.M.Prakash**, 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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We, the undersigned members of the Advisory Committee of **Mr.K.M.Prakash**, a candidate for the degree of **Master of Science in Agriculture** with major in **Plant Breeding and Genetics**, agree that the thesis entitled '**Biometric Analysis of Yield and Other Attributes in Coleus (*Coleus parviflorus* Benth.)**' may be submitted by Mr.K.M.Prakash in partial fulfilment of the requirement, for the degree.

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PRAKASH, K.M.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Introduction

INTRODUCTION

Tuber crops are either the staple food or important subsidiary food for about one fifth of the people of the world. They have high potentiality for yielding large amount of food per unit area and are biologically efficient producers of calories. In India they are grown in over 1.3 million hectares and the production is about 16.4 million tonnes of tubers (Nayar and Nair, 1983). The tropical tuber crops including cassava and sweet potato account for about half of this area and production. Other tubers grown in India include the yams (*Dioscorea spp.*), aroids (Amorphophallus, Colocasia, Xanthosoma etc.), arrow root and coleus.

Among the minor tuber crops, coleus (*Coleus parviflorus* Benth.) [Syn. *Coleus tuberosus* or *Solenostemon rotundifolius* (Poir) J.K.Morton] which is popularly known as Chinese potato or poorman's potato is an important one grown extensively as a vegetable in South Indian States. The crop is being cultivated in Kerala in the uplands in the monsoon season and in rice fallows during summer, mainly in Thrissur, Palakkad, Malappuram, Wynadu and Thiruvananthapuram districts. Coleus is known as '*Koorka*'/'*Cheevakizhangu*'. locally and is grown in our homesteads and kitchen gardens as well.

The interspaces of coconut gardens are considered as potential areas for growing coleus in our state (Geetha, 1983). The varietal requirements of the crop in the uplands in the open condition seems to be different from that in the partially shaded coconut gardens.

The food value of coleus compares favourably with other tuber crops. Coleus tuber with its characteristic flavour has a special preference among consumers. Compared to other tubers it fetches a premium price in the market.

The yield of minor tuber crops in Kerala is low ranging from 20-80 q/ha mainly due to the lack of improved varieties (Hrishi and Nair, 1972). Research work on minor tuber crops in Kerala is meagre. In the case of coleus, only a few preliminary studies have been carried out. Geetha (1983) had investigated the nutritional requirements for economic production of coleus. But no systematic crop improvement works had been carried out to enhance the productivity of this crop. To start with, a critical analysis of variability in the crop and dependable tools for selection are envisaged in the present investigation. Studies on variability, correlation, association, regression, heritability, genetic advance, path analysis etc. will enable the breeder to formulate suitable breeding programmes and selection techniques to realize higher yield.

Selection is the basis of all crop improvement programmes, the success of which depends on the extent of genetic variability available in the base population. By selection we are identifying superior genotypes based on the observations of the phenotype. In selection for yield such attributes that show less variability due to environment need greater stress.

The variability can be partitioned into heritable and non-heritable components with the aid of genetic parameters such as genotypic coefficient of variation, heritability and genetic advance which serve as the basis for effective selection.

Relationship of plant characters determined by correlation coefficients have always been helpful in selecting desirable individuals/genotypes. Thus it is necessary to rely more on such morphological characters as indices of yield than the yield itself in the process of selection.

Yield being a complex character is dependent on a number of components and the association of yield with its component characters is of immense value in selecting superior genotypes with confidence. Therefore, it is necessary to know the direct and in direct effects of each of the component characters on yield especially when more number of variants are included. Path coefficient analysis developed by Wright (1921) provides the relative importance of each of the causal factors on effect and it involves effective partitioning of the correlation coefficients to direct and indirect effects.

Biometrical studies have proved themselves to be of immense worth to the plant breeders because they help in the clear understanding of absolute criteria on the basis of which inherently and economically superior and desirable genotypes could be isolated. With these views in mind, the present investigations were undertaken to fulfill the following objectives.

1. Assessment of genetic variability in coleus.
2. Assessment of interrelationship of characters and their relative effects on yield.
3. Identification of effective selection parameters for genetic improvement.
4. Identification of suitable genotypes of coleus for open and coconut based farming system in Kerala.

Review of Literature

REVIEW OF LITERATURE

The research works done on coleus are quite meagre.The little work done highlights the importance of further research on this crop for improving productivity and quality. Inspite of the vegetative propagation and lack of sexual reproduction, certain amount of variability has been reported in coleus. A review pertaining to the aspects of present study in coleus is undertaken. Similar works on related crops are also included. The important findings relevant to the present study are reviewed under the following heads.

1. Variability
2. Correlation
3. Heritability and genetic advance
4. Path coefficient analysis

2.1 Variability

A successful programme of breeding for high yield and other desirable characters require information on the nature and magnitude of variation in the available germplasm. Many workers have studied the extent of variability in tuber crops by working out genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV).

But the extent of genetic variability is more important than total variation since the greater the genetic diversity wider will be the scope for selection.

Kamalam *et al.* (1977) reported high variability and breeding potential together with scope for selecting early desirable genotypes in open pollinated seedling progenies of sweet potato for characters like vine length, stem thickness, petiole length, skin colour, flesh colour and weight of tubers.

In an investigation with 12 varieties of cassava to estimate genetic variability for seven quantitative characters, phenotypic coefficient of variation was higher than genotypic coefficients of variation for all characters. Phenotypic and genotypic coefficients of variation were high for number of nodes and tuber yield per plant (Biradar *et al.*, 1978).

Lakshmi and Amma (1980) reported that phenotypic coefficient of variation was higher than genotypic coefficient of variation for all characters in Asian greater yam. But genotypic correlations were higher than phenotypic correlations.

Variability within coleus was reported by Sreekumari and Abraham (1985). This variation in morphology especially three whorled phyllotaxy may be considered physiologically significant since they possess more biomass than ordinary plants.

In a study to estimate the variability among 10 varieties of cassava by Rai *et al.* (1986) characters like height of the plant, average weight of tubers, number of marketable tubers, girth of tubers, length of tubers and weight of tubers per plant showed higher phenotypic variance than genotypic variance. Height of the plant had maximum variation due to environment.

Analysis of hybrid progenies of sweet potato by Vimala *et al.* (1988) showed that yield variability was highly significant between family variances or means indicating superiority of some parental combinations.

Teratological variation in *Coleus parviflorus* was reported by Amalraj *et al.* (1989). Evaluation of forty collections at NBPGR, Vellanikkara showed that difoliately compound leaf, three whorled phyllotaxy, stem fasciation and octangular stem were observed on place of simple decussate leaves on quadrangular stem.

Venkatachalam *et al.* (1990) observed wide variation in tuber yield among accessions of coleus under Coimbatore conditions. However, no work was reported on the crop in the coconut based farming system.

Variability in the hybrid progenies of sweet potato was also reported by Pillai *et al.* (1990).

Goswami (1991) reported variation in growth attributes and quality parameters in some sweet potato genotypes at Assam.

Kamalam (1991) reported high variability for quantitative characters like vine length, vine thickness, number of branches, number of tubers and tuber yield in clonal population of sweet potato indicating scope for selection of desirable types.

Variability studies in cassava F_1 genotypes showed that genotypic coefficient of variation was high for all characters except stem diameter (Naskar *et al.*, 1991).

A field trial of sweet potato cultivars showed significant variation for characters like tuber length, tuber yield and weevil infestation (Sarkar *et al.*, 1992).

Evaluation of chemical composition and starch content of different cultivars of sweet potato showed significant difference in protein, starch, fibre and ascorbic acid contents (Batistuti *et al.*, 1992).

Genotypic coefficient of variation was significantly different for vine and root yield characters of two commercial Egyptian cultivars of sweet potato (Shalaby *et al.*, 1993).

In cassava the genotypic and phenotypic coefficient of variation for the different traits did not vary much revealing that they were not influenced much by environment and selection may be based on phenotypic values themselves (Suthanthirapandian *et al.*, 1994).

2.2 Correlation

Determination of correlation in sweet potato revealed that an increase in the length of vine causes significant increase in tuber yield. But leaf area had negative correlation with yield (Pushkaran *et al.*, 1976).

In a study to estimate correlation in sweet potato, Kamalam and Biradar (1977) found that number of tubers had positive significant correlation with yield. But length as well as weight of the vine showed significant negative correlations with yield.

In cassava harvest index, number of tubers per plant and mean tuber weight showed strong positive correlation with yield (Biradar *et al.*, 1978).

Lakshmi and Amma (1980) recorded positive significant correlation of number of shoots, number of branches and number of leaves with tuber yield in Asian greater yam.

Naskar *et al.* (1986) worked out correlation for seven characters in sweet potato and showed that number of branches, girth of tubers and length of tubers have high positive correlation with yield.

In a study to find the correlation of tuber yield with shoot characters in sweet potato, Ibrahim (1987) found no significant correlation.

Working out coefficient of correlation in Gram, Mallo and Sharma (1987) showed that the grain yield had significant positive association with number of pods per plant, number of primary branches and 100 seed weight.

In an experiment to determine the correlation and association between different characters and yield of taro, mean weight of cormel, number of cormels per plant and leaf area index were positively and significantly correlated with yield (Mohankumar *et al.*, 1990).

Correlation studies of kernel weight in groundnut with pod characters showed that seed weight was positively correlated with pod length, breadth, L/W ratio and pod weight (Manoharan *et al.*, 1990).

In a study to work out character association in groundnut pod yield was positively associated with pod number while plant height was negatively correlated with yield. But pod number and plant height were negatively correlated (Manoharan *et al.*, 1990).

In sunflower, Chidambaram and Sundaresan (1990) found out that plant height, head diameter and 100 seed weight had highly significant and positive correlation with seed yield. A significant and positive inter correlation was noticed between harvest index and oil content which indicated the importance of harvest index for improving oil content of sunflower.

Pathak and Dixit (1990) showed that seed yield per plant was significantly and positively correlated with stem girth, head weight, shelling percentage and 100 seed weight in sunflower.

Shanmughasundaram and Subrahmanian (1990) revealed a high positive and significant correlation of plant height, peduncle thickness, leaf number, grain number, grain weight and straw yield at genotypic and phenotypic level in sorghum.

Ganesamurthy and Dorairaj (1990) found out that in pegionpea seed yield showed positive and significant correlation with DMP, number of pods, number of clusters, number of branches, plant height, LAI, seeds per pod, days to flowering, pods per cluster, days to maturity, 100 seed weight, harvest index and pod length.

Correlation studies for 7 characters in cassava showed that tuber yield was positively and significantly correlated with all the characters except with petiole length (Naskar *et al.*, 1991).

Sreekumari and Abraham (1991) reported negative correlation between shading and tuber development in cassava and that it was less for shoot and leaf formation. There were significant differences of means for all characters for plant grown in shade and open. Girth of stem and tuber showed significant positive correlation with tuber yield under shade.

Gopalan and Balasubramanian (1993) noted positive and significant genotypic correlation between green fodder yield with plant height, number of leaves, leaf net length and stem girth in cowpea.

Nirmalakumari and Subramaniam (1993) reported that quantitative characters such as 50 percentage flowering, days from flowering to maturity, days to maturity, plant height, number of pods per plant, pod length, number of seeds per pod, harvest index, biological yield per plant and seed yield per plant were positively correlated with pod yield per plant in black gram.

Ranganayaki and Sreerangaswamy (1993) showed positive and significant association of seed yield with plant height, pods per plant, petiole length, leaf area, LAI, peduncle length and total DMP and negative significant association with seeds per pod in green gram.

A study of genotypic, phenotypic and environmental correlation in rainfed sweet potato revealed that marketable tuber yield was positively and significantly correlated with the number of tubers per plant but neck length was negatively correlated with yield (Nanda, 1994).

2.3 Heritability and genetic advance

Heritability specifies the proportion of total variability that is due to genetic causes or it is the ratio of genetic variance to the total variance (Allard, 1960). It indicates the effectiveness with which selection of genotypes can be based on phenotypic performance (Johnson *et al.*, 1962). The heritability estimates also provide a clear picture of the average effect of genes transmitted from parents to the offspring or the extent to which the variability of a quantitative character is transferable to the progeny. However, heritability estimates along with genetic gain were more useful and reliable than heritability estimate alone in predicting the selection response.

Reports on heritability and genetic advance are numerous for various quantitative characters in a number of cultivated plants especially in seed propagated crops, but its application in vegetatively propagated crops are quite meagre.

Investigations with 65 clones of sweet potato indicated that characters like weight of tubers per plant, number of leaves per vine and weight of foliage exhibited high heritability and low genetic advance. But girth of tubers and number of tuber per vine exhibited high heritability and high genetic advance (Thamburaj and Muthukrishnan, 1976).

High heritability estimates and genetic advance were reported for length of vine and number of tubers in sweet potato (Kamalam *et al.*, 1977).

In an investigation with 12 varieties of cassava heritability and genetic advance estimates were high for number of nodes and tuber yield per plant (Biradar *et al.*, 1978).

In dessert type banana Nayar *et al.* (1979) reported high heritability values for plant height, leaves per plant, hands and fingers per bunch, fruits per hand, fruit weight, pedicel length and roots per plant. Genetic advance was moderately high for plant height, weight of bunch, hands and fruits per bunch, weight of hands and fingers, fruit length, pedicel length and roots per plant.

Studies conducted by Mathew *et al.* (1979) in pineapple showed a higher value in heritability for sugar - acid ratio followed by non-reducing sugars. Heritability was minimum for leaf area. The number of leaves per plant, canning ratio and acidity values showed only very low heritability. Genetic advance was high for leaf area followed by number of leaves per plant and fruit weight.

In grapes the heritability and genetic advance for number of bunches per vines were also very high (Daulta *et al.*, 1980).

In peach, heritability estimates were high for ripe date, bloom date, amount of bloom and moderate for fruit firmness and acidity (Hensche *et al.*, 1982).

The genetic analysis of 23 groundnut genotypes showed a high heritability estimate combined with genetic advance for pod and kernel weight indicating that these characters are governed by additive genes (Manoharan *et al.*, 1990).

Naskar *et al.* (1991) reported high heritability estimates and genetic advance for plant height, stem diameter, number of tubers and tuber yield indicating their efficacy in selection by studying the performance of F_1 populations of cassava.

By genetic analysis of 12 characters in 25 accessions of taro, Pillai and Unnikrishnan (1991) reported high heritability and genetic advance estimates for characters like weight of cormels per plant and number of cormels per plant. These results show the scope of individual plant selection based on these characters for the genetic improvement of taro.

Evaluation of sweet potato lines for yield and its parameters at West Bengal revealed high heritability for vine length (Sen and Goswami, 1991).

Vimala and Lakshmi (1991) reported high heritability estimates for tuber length, tuber weight, number of branches, tuber girth and vine weight indicating additive genetic variance in sweet potato. Low heritability estimates were observed for vine length, vine girth, number of leaves per branch, petiole length and number of tubers.

In a study involving 76 genotypes of cassava Suthanthirapandian *et al.* (1994) reported that highest genetic advance was noticed in respect of number of leaves. Among economic characters highest genetic advance was noticed for tuber yield per plot followed by number of tubers, single tuber weight and tuber length. The highest heritability was for number of leaves.

In taro estimates of genotypic and phenotypic variance coupled with heritability estimate showed very high heritability for length and diameter of cormel. All the characters showed heritability exceeding 60 percentage. This indicates the scope for attaining high yielding clones from local population of taro (Apte *et al.*, 1994).

2.4 Path coefficient analysis

Path coefficient analysis suggested by Wright (1921) is a means of untangling direct and indirect contributions of various factors in building up a complex correlation. This method is based on the premise that the degree of influence of one variable upon other can be defined in quantitative terms. After the construction of causal diagram the value had to be assigned to each of the influencing path. The value assigned to these paths is termed as path coefficient. It is defined as the portion of standard deviation of a dependent variable if arising as a result of the variation in the independent variable. In order to have a coefficient indepdendent of physical units, path coefficients are expressed in terms of standard deviations of Y on X. Therefore, path coefficients may also be considered as standardized partial regression coefficients.

Dewey and Lu (1959) analysed the path between seed size, spikelets per spike, fertility, plant size and seed yield in wheat grass. They found that fertility had high positive direct effect towards seed yield followed by the plant size. The indirect effect of seed size, spikelets per spike and plant size through fertility were all negative.

Koeing and Walter (1960) studied the relationship between stalk diameter, leaf number, leaf area and grain yield of sorghum. They found high positive influence of these characters on grain yield.

Path analysis of fodder yield in barley was studied by Sharma *et al.* (1973). They included the morphological characters like plant height and tillers per plant along with grain yield and 1000 grain weight. The tiller per plant had a positive direct effect on fodder yield.

Solanki *et al.* (1973) analysed path coefficient with 49 genotypes of oats for fodder yield and its components. They obtained maximum direct inlfuence between green yield and height of the plant followed by leaf breadth.

Investigation with 65 clones of sweet potato by Thamburaj and Muthukrishnan (1976) indicated that the weight of foliage, girth of tuber and number of tubers per vine contributed maximum direct effect on tuber yield indicating the importance of these traits as selection indices for sweet potato. Characters like number of leaves, length of petiole and length of tuber had negative direct effect on tuber yield.

In a study to estimate path coefficients using six characters in ten varieties of sweet potato Kamalam *et al.* (1977) found out that number of tubers showed maximum positive direct as well as indirect effects on yield.

Path analysis in turmeric by Palhania *et al.* (1981) revealed that plant height had maximum direct contribution towards yield followed by number of secondary fingers and number of leaves.

Correlation and path coefficient analysis in sweet potato for 7 characters with 22 genotypes showed high positive correlation of characters like number of branches, girth of tuber and length of tubers with yield. Length of tuber showed maximum positive direct effect on yield (Naskar *et al.*, 1986).

Data from 25 hybrid lines and 3 local cultivars of sweet potato laid out at 3 sites in replicated trials were analysed to estimate the direct and indirect effects of shoot and root characters on tuber yield in sweet potato. The root characters viz., tuber girth, number of tubers and tuber length showed high path values than shoot characters, indicating that in a breeding programme for yield based on component character, shoot character, will be of little importance (Ibrahim, 1987).

Path analysis for pod yield in groundnut by Pushkaran and Nair (1988) revealed that fresh weight of pods had the highest positive direct effect on dry pod yield. Number of leaves, flowers and mature pods also had positive direct effects in that order. Number of mature pods exerted positive indirect effects through fresh weight of pods, number of basal primary branches, haulm yield and 100 pod weight. Length of shoot, number of basal primary branches, haulm yield and 100 pod weight had negative direct effect on pod yield.

Correlation and path analysis on yield components in taro by Mohankumar *et al.* (1990) revealed that mean weight of cormel, number of cormels per plant and LAI were positively and significantly correlated with yield. Maximum direct effect was observed for mean weight of cormels.

Path analysis of yield components in eight cassava accessions was undertaken and conclusion drawn. Single tuber weight contributed maximum direct effect to tuber yield. Single tuber weight, girth of the tuber and length of the tuber were found to be the three factors exerting considerable influence directly and indirectly upon tuber yield in cassava (Rekha *et al.*, 1991).

Material and Methods

MATERIALS AND METHODS

The investigations reported herein were carried out in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during July 1995 to June 1996.

3.1 Materials

The experimental material for the study consisted of 30 collections of coleus, 20 collections gathered from NBPGR, one collection from CTCRI and the rest from other localities of its cultivation. The list of collections with the salient details are presented in Table 1.

3.2 Methods

3.2.1 Experimental methods

3.2.1.1 Layout of experiment

Two experiments were laid out in randomised block design with three replications each having 30 collections of coleus, one in open upland condition and the other as an intercrop in coconut garden under uniform care and management following the package of practices recommendations (KAU, 1993). Each replication consisted of 30 subplots, one for each genotype consisting of two lines of 1.5 m each with 30 cm between plants within a line. The prevailing shade under the coconut garden was measured using a line quantum sensor.

For this, two sets of measurements were taken, one in open and the other in coconut garden and the percentage of light infiltration in the coconut garden worked out. The infiltration of sunlight in the coconut garden of about 20 years of age in the present trial was worked out to be 50 per cent.

The seed tubers collected from various sources such as NBPGR, CTCRI, parts of Thrissur and Wynadu were multiplied in a primary nursery and 45 day old 15 cm long top shoot bits were used for planting in the experimental field. The planting in the open field was done on 17-9-95 and that of intercrop on 19-9-95. In addition to the showers obtained during the season four irrigations were also given before the commencement of NE monsoon to ensure uniform establishment.

3.2.1.2 Characters studied

Random sampling technique was adopted to select sample plants for recording various morphological characters in both experiments. Five plants of every treatment were randomly selected from each replication leaving the border plants and were labelled. These marked plants were used for periodic observations and for collecting the data.

The following 15 characters were studied

1. Length of shoot
2. Number of branches/plant
3. Number of leaves/plant
4. Leaf area/plant
5. Days to flowering
6. Days to harvest
7. Tuber yield/plant

8. Number of tubers/plant
9. Haulms wieght/plant
10. Length of tuber
11. Girth of tuber
12. Tuber length/Tuber girth ratio
13. Individual tuber weight
14. Starch content of tuber
15. Protein content of tuber

In addition to the above metric characters observations on establishment, general vigour, flowering, incidence of pest and disease etc. were noted.

3.2.1.3 Procedure followed for collecting data

The biometric data were recorded as follows:

1. Length of shoot

The length of shoot was measured 60 days after planting as the height from the ground level to the tip of the top most leaf. The average of 5 plants were then computed and expressed in centimeters.

2. Number of branches per plant

The number of primary as well as secondary branches arising from main stem and primary branches respectively were counted for the marked plants of each treatment and the average worked out at 60 days after planting.

3. Number of leaves per plant

This was recorded by counting the total number of fully opened leaves on each of the marked plants at 60 days after planting and working out the average of 5 plants.

4. Leaf area per plant

Five fully opened leaves were selected at random from each of the sample plant for recording the length and width of leaf. The length was measured as the distance between base and tip of leaf blade. Width was recorded as the width at the centre of leaf blade. The average length and width of leaves were then computed and leaf area calculated as per the product method followed by Velayudhan *et al.* (1988).

5. Days to flowering

The number of days taken from planting till the appearance of first flower opened was recorded as days to flowering.

6. Days to harvest

Number of days taken from planting till the development of yellow colour of the plant due to the senecence was recorded as days to harvest. To ascertain the date of harvest tuber characteristics were also taken into consideration.

7. Number of tubers per plant

The average of tuber numbers obtained from 5 observational plants excluding aerial tubers was recorded as number of tubers per plant.

8. Tuber yield per plant

Fresh tuber weight of 5 randomly selected observational plants after removing under developed tubers and soil particles were recorded using a top weighing balance and the average expressed in grams.

9. Haulms weight per plant

It was calculated as the average fresh weight of 5 observational plants excluding tubers taken on a top weighing balance.

10. Length of tuber

It was measured as the average length of 25 tubers randomly selected from each treatment expressed in centimeters. The length was measured using a cord and meter scale.

11. Girth of tuber

It was recorded as the average girth of 25 tubers randomly selected from each treatment expressed in centimeters. The girth was measured using a cord and meter scale.

12. Individual tuber weight

It was recorded as the average of tuber weight of 5 observational plants in each treatment divided by thenumber of tubers expressed in grams.

13. Starch content of tubers

It was recorded by Acid Hydrolysis of starch to simple sugars like glucose which was then estimated by heating with anthrone in the presence of sulphuric acid.

14. Protein content of tubers

It was recorded by preparing protein suspension and mixing with sodium potassium tartarate. After adding the phenol reagent absorbency was noted at 750 nm. From a reference curve based on colour development protein content could be estimated.

3.2.2 Statistical analysis

Data on different characters studied in both experiments were subjected to separate statistical analysis. The analysis of variance technique for randomised block design was employed for the estimation of various genetic parameters. The extent of association among characters was measured by correlation coefficients. Path coefficient analysis was used for estimating the direct and indirect effects of various characters on yield.

The details of the statistical analysis followed in the present experiment are as follows:

3.2.2.1 Analysis of variance

The model used in the analysis of the design is

$$Yij = x + bi + tj + eij, \quad i = 1 \,\ldots\ldots\ldots 3$$

$$j = 1 \,\ldots\ldots\ldots 30$$

where

Yij = performance of j^{th} genotype in i^{th} block

x = general mean

bi = true effect of i^{th} block

tj = true effect of j^{th} genotype

eij = random error

3.2.2.2 Estimation of variability, heritability, expected genetic advance and genetic gain

3.2.2.2.1 Variability

Estimates of variance components were obtained by using the following formulae as suggested by Burton (1952). The formulae used in the estimation of variability at genotypic, phenotypic and environmental levels are given below:

a) Phenotypic variance (Vp) = (Vg) + (Ve)

where (Vg) = genotypic variance

(Ve) = environmental variance

b) Genotypic variance (Vg) = $\dfrac{MSv - MSe}{r}$

where MSv = Varietal mean square

MSe = environmental mean square

r = number of replications

c) Environmental variance (Ve)

d) Phenotypic coefficient of variation (Pcv) $= \dfrac{(Vp) \times 100}{x}$

where x = mean of the character under study

e) Genotypic coefficient of variation (Gcv) $= \dfrac{(Vg) \times 100}{x}$

d) Environmental coefficient of variation (Ecv) $= \dfrac{(Ve) \times 100}{x}$

3.2.2.2.2 Heritability

Heritability in the broad sense was estimated by using the formula suggested by Burton and Devame (1953)..ls1

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

3.2.2.2.3 Expected genetic advance

The expected genetic advance (GA) of the available germplasm was measured using the formula suggested by Lush (1949) and Johnson *et al.* (1955).

$$GA = \frac{(Vg) \times K}{(Vp)}$$

where K = Standardised selection differential

3.2.2.2.4 Expected genetic gain

The expected genetic advance expressed as percentage of mean is the expected genetic gain.

$$(GG) = \frac{GA \times 100}{x}$$

where (GG) = genetic gain

(GA) = expected genetic advance

(x) = mean of the character under study

3.2.2.2.5 Estimation of correlations

Phenotypic and genotypic covariances were worked out in the same way as variances were calculated. The different covariance estimates were calculated by the method suggested by Fisher (1954).

Phenotypic covariance between characters i and j

$$COV_{pij} = COV_{gij} + COV_{eij}$$

where

COV_{gij} = genotypic covariance between characters i and j

COV_{eij} = environmental covariance between characters i and j

$$COV_{gij} = \frac{MSP_{vij} - MSP_{eij}}{r}$$

where

MSP_{vij} = mean varietal sum of products of characters i and j

MSP_{eij} = mean error sum of products of characters i and j

r = number of replications

Phenotypic and genotypic correlation coefficients among the various characters were worked out in all possible combinations according to the formula suggested by Johnson *et al.* (1955).

Phenotypic correlation coefficient between characters i and j

$$r_{pij} = \frac{COV_{pij}}{V_{pi} \times V_{pj}}$$

where

V_{pi} = phenotypic variance of character i

V_{pj} = phenotypic variance of character j

Genotypic correlation coefficient between characters i and j

$$r_{gij} = \frac{COV_{gij}}{V_{gi} \times V_{gj}}$$

where

V_{gi} = genotypic variance of character i

V_{gj} = genotypic variance of character j

3.2.2.3 Path coefficient analysis

Path coefficients are standardised regression coefficients. In path coefficient analysis the correlation 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), Li (1955), Dewey and Lu (1959) for cause and effect systems were adopted for analysis. Eleven important component characters viz., shoot length, number of branches per plant, number of leaves per plant, leaf area per plant, days to flowering, days to harvest, number of tubers per plant, haulms weight per plant, tuber length, tuber girth and individual tuber weight were selected for path analysis to determine their direct and indirect effects on tuber yield.

Results and Discussion

RESULTS AND DISCUSSION

The data collected from the two experiments have been statistically analysed separately for open and shaded conditions. Hence the results are presented and discussed as two separate parts viz. Open condition and Shaded condition.

4.1 Open condition

4.1.1 Estimation of variability heritability and genetic advance

Observations on the behaviour of 30 coleus collections with reference to 15 characters viz. length of shoot at 60 days after planting (cm), number of branches per plant at 60 days after planting, number of leaves per plant at 60 days after planting, leaf area per plant at 60 days after planting (cm^2), days to flowering, days to harvest, tuber yield per plant (g), length of tuber (cm), girth of tuber (cm), length to girth ratio of tubers, individual tuber weight (g), starch content (%) and protein content (%) have been made from all the five observational plants in three replications in the open condition. The morphological description and variability observed on few qualitative characters during the different stages of growth are presented in Table 1. Certain extent of variability among the genotypes is evident from the Plates 1 to 7.

The mean value of all the 30 genotypes with respect to 15 economic characters are presented in Table 2. The general mean for each character along with F value, range, standard error and coefficient of variation are given in Table 3. The abstract of analysis of variance carried out for 15 characters is presented as Appendix-1. The genetic parameters like phenotypic and genotypic coefficients of

Plate 1. A general view of the experimental field in the open condition

Plate 2. Variability in the size and shape of leaves in the open condition

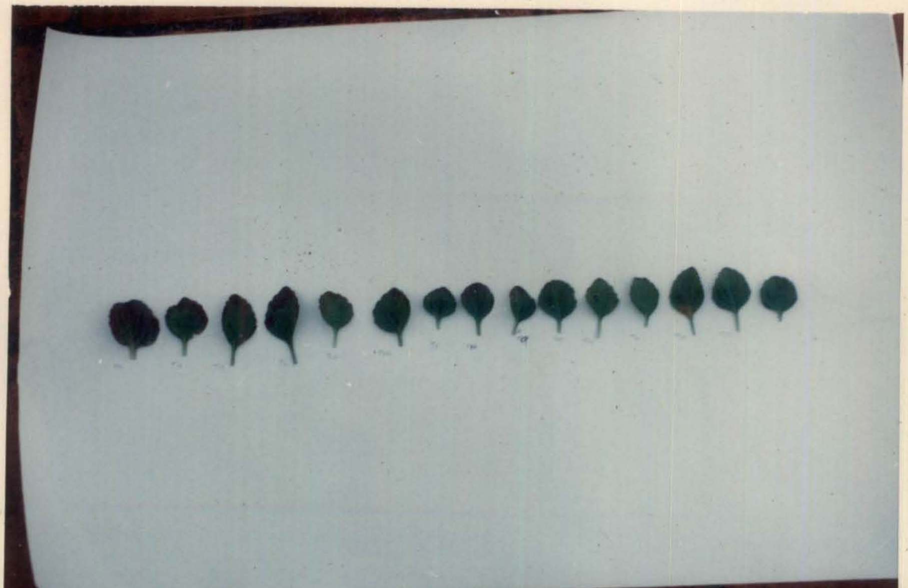


Table 1. Morphological description of 30 genotypes in the open condition)

Genotype	Branching habit	Plant type	General vigour	Leaf blade length	Leaf shape	Flowering nature	Inflorescence stalk length	Tuber flesh colour	Tuber shape	Easiness to peeling
	Characters									
1	2	3	4	5	6	7	8	9	10	11
T_1	Moderately branching	Bushy	Medium vigour	Low	Ovate	Low	Medium	Light yellow	Oblong	Good
T_2	Moderately branching	Semi erect	High vigour	Medium	Reniform	Medium	Long	Medium yellow	Oblong	Moderately
T_3	Moderately branching	Bushy	High vigour	Low	Ovate	High	Medium	White	Oval	Good
T_4	Low branching	Bushy	Low vigour	Low	Reniform	Low	Long	Light yellow	Oval	Good
T_5	Highly branching	Semi erect	Low vigour	Medium	Ovate	Medium	Short	Light yellow	Conical	Moderate
T_6	Highly branching	Semi erect	Medium vigour	Medium	Reniform	Medium	Long	Medium yellow	Spherical	Moderately
T_7	Low branching	Bushy	Low vigour	Low	Reniform	Medium	Short	Light yellow	Conical	Poor
T_8	Moderately branching	Semi rect	Low vigour	High	Reniform	Low	Medium	White	Spherical	Moderate
T_9	Low branching	Erect	Medium vigour	Low	Ovate	Medium	Short	Medium yellow	Irregular	Good
T_{10}	Moderately branching	Semi erect	Low vigour	Medium	Ovate	Low	Medium	Light yellow	Spherical	Good
T_{11}	Low branching	Semi erect	High vigour	Low	Ovate	Medium	Short	Meidum yellow	Spherical	Moderate
T_{12}	Highly branching	Semi erect	High vigour	Medium	Ovate	High	Long	Light yellow	Spherical	Poor
T_{13}	Highly branching	Erect	Medium vigour	Medium	Reniform	High	Medium	Light yellow	Spherical	Good
T_{14}	Low branching	Bushy	Medium vigour	Low	Ovate	Medium	Long	Medium yellow	Oval	Good

Contd.

Table 1. Continued

1	2	3	4	5	6	7	8	8	10	11
T_{15}	Moderately braching	Semi erect	Low vigour	High	Ovate	High	Long	Medium yellow	Irregular	Good
T_{16}	Highly branching	Semi erect	High vigour	High	Reniform	High	Long	Light yellow	Spherical	Good
T_{17}	Highly branching	Bushy	Medium vigour	High	Ovate	Low	Short	Light yellow	Conical	Moderate
T_{18}	Low branching	Bushy	Low vigour	Low	Ovate	Low	Medium	Medium yellow	Oblong	Moderate
T_{19}	Moderately branching	Semi erect	High vigour	High	Ovate	Medium	Medium	Light yellow	Spherical	Good
T_{20}	Highly branching	Bushy	Low vigour	Medium	Ovate	Low	Medium	White	Oblong	Good
T_{21}	Highly branching	Semi erect	Low vigour	Medium	Ovate	High	Medium	Medium yellow	Oval	Good
T_{22}	Highly branching	Erect	High vigour	High	Ovate	High	Short	Light yellow	Spherical	Good
T_{23}	Moderately branching	Erect	High vigour	High	Reniform	High	Short	Light yellow	Spherical	Good
T_{24}	Moderately branching	Erect	High vigour	Medium	Ovate	Low	Long	Light yellow	Spherical	Moderate
T_{25}	Moderately branching	Semi erect	Low vigour	Low	Ovate	High	Medium	Medium yellow	Irregular	Moderate
T_{26}	Moderately branching	Bushy	Low vigour	Low	Reniform	Long	Short	Light yellow	Spherical	Poor
T_{27}	Highly branching	Erect	Low vigour	High	Ovate	Medium	Long	Light yellow	Conical	Good
T_{28}	Highly branching	Erect	High vigour	High	Ovate	High	Long	Light yellow	Irregular	Good
T_{29}	Low branching	Bushy	Low vigour	Low	Ovate	High	Long	Light yellow	Spherical	Good
T_{30}	Low branching	Erect	Medium vigour	Medium		High	Meidum	Light yellow	Oval	Good

variation, heritability and genetic advance expressed as percentage of mean are presented in Table 4.

Shoot length

The mean values of shoot length in respect of 30 genotypes are presented in Table 2.

The result presented in the above table reveals that shoot length ranged from 27 cm to 51 cm among the 30 genotypes with a general mean of 36.64 cm. The maximum shoot length was for the genotype T_{23} and minimum for T_4. From the analysis of variance vide Appendix-1 it is clear that the differences among the genotypes for this character were highly significant.

The statistical parameters, such as mean, range, standard error and coefficient of variation vide Table 3 indicates the inherent differences among 30 genotypes for this character. The coefficient of variation (10.93) suggests a low extent of total variability for this character. The genetic parameters, viz. genotypic and phenotypic coefficient of variation, heritability in the broad sense and genetic gain are presented in Table 4. The genotypic coefficient of variation (13.92) is less than the phenotypic coefficient of variation (17.70) indicating that variations in genotypes do not contribute markedly to the total variability for the above character.

With the help of GCV alone it is not possible to estimate the amount of heritable variation and the effectiveness of selection for any character. Burton (1957) suggested that genotypic coefficient of variation along with heritability would provide a better picture of the amount of advance expected by phenotypic selection. The heritability is moderately high (61.9) for the above character showing that it is less influenced by environment (Fig.1). The values of heretability are expressed as percentage hereafter.

But heritability in conjuction with genetic advance is more effective and reliable in predicting the resultant effect of selection than heritability alone. But here the low genetic gain (22.57) shows that the high heritability is attributed to the presence of non-additive gene effects which include dominance and epistasis and genotype x environment interaction as well. But Kamalam *et al.* (1977) had reported high heritability and genetic advance for shoot length in sweet potato. A similar result was obtained by Singh and Mishra (1975) in sweet potato.

Tuber yield per plant

The mean value of tuber yield per plant in respect of 30 genotypes are presented in Table 2.

The results in the above table shows that maximum yield was 139.33 g (T_{19}) and minimum 53.31 g (T_4) with a general mean yield of 89.72 g (Table 3). Vide Appendix-1 shows that there was no significant differences among the 30 genotypes for tuber yield. This is in conformity with the results of Vimala (1994). However, the coefficient of variation of 34.62 vide Table 3 is moderate for this character. But the low GCV (14.63) compared to high PCV (37.58) along with the low heritability (15.2) and low genetic gain (11.73) shows that much of this variability exhibited is not due to genotypic differences but due to environmental influence on this character. Hence selection is not effective to improve this character.

Number of branches per plant

The results presented in Table 2 and 3 show that there is significant difference among the 30 genotypes for this character. The mean value for this character ranged from 10 to 28 with a general mean of 17.75. The low coefficient of variation (17.8) and standard error (1.824) vide Table 3 indicates that though there is significant difference among 30 genotypes the standard deviation of means is less. Since the PCV (24.29) is larger than GCV (16.51) the greater part of total variability observed is not due to genetic difference among the genotypes. The high heritability (46.2) and low genetic gain (23.15) suggest that the character may be controlled by nonadditive gene effects (Panse and Sukhatme, 1957). But Vimala and Lakshmi (1991) have reported high heritability and high genetic advance for this character in sweet potato. The result shows, that there is no scope for selection for improving this character.

Number of leaves per plant

The mean value of 30 genotypes are presented in Table 2.

A perusal of the data indicates that there is significant difference among various genotypes for this character (Appendix-1). The number of leaves per plant ranged from 203 to 621 with a general mean of 351.77. The coefficient of variation (28.45) vide Table 3 brings out the total extent of variability among genotypes. The GCV (22.58) and PCV (36.32) are moderate which indicates the share of genotypic difference to the total variation. Heritability (38.6) is moderate and the genetic gain in low (28.9). This shows that there is no scope for moderate improvement of this character by selection. Similar results were obtained by Vimala and Lakshmi (1991) in sweet potato and by Thamburaj and Muthukrishnan (1976) in cassava.

Leaf area per plant

The mean value of this character is presented in Table 2.

A perusal of the table shows that the character had a range from 1091 cm^2 to 6618 cm^2 with a general mean of 3371 cm^2. From Table 3 it is clear that there is significant difference among the genotypes for this character. The high coefficient of variation (40.24) indicates the large amount of variability exhibited by the 30 genotypes for this character. The slightly higher PCV (50.23) compared to GCV (30.1) indicates the role of environment than genotypic differences for the observed variability. However, moderately high heritability (35.7) and genetic gain (36.92) exhibited by this character vide Table 4. Suggests that there is scope for moderate improvement of this character via selection. But environmental effect can't be ignored for getting a better expression of this character.

Days to flowering

The mean value of 30 genotypes of coleus presented in Table 2. Suggests that the range for this character is 43 days to 62 days with a general mean of 55 days. The extent of total variability for this character is low as is evident from the low coefficient of variation (3.32) vide Table 4. The GCV (7.8) and PCV (8.53) are almost equal signifying the greater role of genotypic difference for total variability. The high heritability value (84.9) also confirms this fact. This points to the fact that the character can be improved by adopting phenotypic selection of the desired type. But since the genetic gain is low (14.9) selection doesn't offer much scope for improvement over the mean (Table 4).

Table 2. Mean values of the 15 characters for 30 genotypes in the open condition

Sl.No.	Shoot length	Tuber yield/ plant	No. of branches/ plant	No. of leaves/ plant	Leaf area/ plant	Days to flowering	Days to harvest	No. of tuber/ plant	Haulms wt./ plant	Tuberlength	Tuber girth	Individual tuber wt.	Starch content	Protein content	Tuber length/ Tuber girth
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T_1	33.07	85.17	18.00	202.88	1947.84	55.33	123.67	11.32	78.67	4.50	6.97	10.74	33.88	8.52	0.663
T_2	36.80	80.86	17.00	465.15	3476.38	54.67	124.67	13.60	80.42	4.33	6.39	9.84	33.61	8.45	0.680
T_3	28.97	107.30	16.07	227.00	1091.31	54.00	122.33	14.38	109.17	4.97	7.21	7.58	33.83	7.87	0.687
T_4	27.53	53.31	11.87	244.13	1799.61	55.53	122.67	9.51	64.20	3.96	6.95	6.62	34.15	7.57	0.567
T_5	36.63	81.91	19.07	370.41	3891.63	61.67	126.33	8.64	103.67	4.34	7.68	10.20	34.15	8.20	0.573
T_6	36.85	82.67	19.47	326.97	3027.36	55.00	124.33	12.07	79.67	4.41	7.55	9.32	33.86	8.36	0.597
T_7	30.47	71.55	15.47	296.54	2463.34	43.67	120.67	10.33	91.63	4.21	7.08	12.15	35.38	8.43	0.593
T_8	35.95	79.00	18.19	370.90	4423.69	53.67	121.67	8.33	132.01	4.21	6.69	8.13	33.15	8.07	0.627
T_9	40.17	81.11	14.90	316.40	2431.24	54.00	121.00	12.86	82.37	4.18	6.96	8.29	34.08	8.14	0.600
T_{10}	37.63	68.00	16.84	346.06	3168.19	62.00	126.00	5.35	79.00	4.59	7.00	12.13	33.04	8.32	0.653
T_{11}	34.17	64.00	15.88	286.43	2380.71	57.00	122.67	14.40	69.27	4.05	5.88	4.76	33.53	7.96	0.697
T_{12}	36.20	88.50	28.38	621.04	3811.35	55.33	122.67	15.73	77.00	4.34	6.23	6.00	33.06	7.36	0.697
T_{13}	42.88	108.00	29.51	384.50	3786.86	57.33	123.33	11.62	119.08	4.64	7.30	9.00	32.44	7.85	0.653
T_{14}	30.73	115.55	13.85	333.67	1893.87	55.00	123.67	12.58	113.62	4.41	8.06	19.94	32.86	7.53	0.553
T_{15}	36.00	70.78	17.48	294.30	4494.21	57.00	124.00	8.71	133.78	4.16	7.46	22.64	34.01	8.10	0.560

Contd.

Table 2. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T_{16}	36.73	90.44	20.93	324.10	4440.77	55.67	123.00	13.72	101.17	4.63	7.26	17.85	33.42	7.99	0.623
T_{17}	33.88	111.55	23.03	502.47	4168.39	46.33	122.00	11.20	139.82	4.82	7.93	9.88	33.94	8.32	0.567
T_{18}	32.87	64.22	15.73	238.07	1739.17	58.67	127.00	9.38	68.00	3.97	6.76	7.25	33.82	8.31	0.600
T_{19}	35.24	139.33	17.80	310.67	4270.25	60.00	126.00	17.07	120.67	4.27	8.10	8.72	32.64	8.08	0.530
T_{20}	31.88	64.55	20.27	339.03	3505.60	56.33	125.00	9.49	72.55	4.15	6.98	6.62	31.18	8.42	0.593
T_{21}	34.67	89.33	21.77	426.47	3548.67	60.00	127.00	9.40	70.48	3.81	7.19	10.58	32.66	7.92	0.537
T_{22}	51.55	75.00	19.27	347.87	5426.00	55.00	124.33	15.70	102.01	3.86	6.14	4.55	34.81	7.84	0.647
T_{23}	51.70	87.00	16.93	419.33	4804.00	61.00	127.33	13.87	249.20	4.27	7.49	6.25	32.97	7.39	0.613
T_{24}	40.47	134.57	16.03	402.50	3833.00	52.00	122.33	13.64	181.77	4.82	7.98	10.30	32.16	8.53	0.607
T_{25}	35.55	86.10	16.43	368.40	1938.33	54.00	123.33	9.00	96.53	4.79	8.05	9.13	32.92	8.08	0.603
T_{26}	33.00	73.78	16.33	281.13	1901.33	52.00	125.00	7.09	105.67	4.23	7.11	11.35	33.76	7.79	0.653
T_{27}	42.46	106.00	20.30	340.33	4440.67	43.33	121.00	9.62	140.00	4.84	8.38	10.76	31.78	8.35	0.580
T_{28}	42.68	131.78	20.00	380.27	6617.67	57.00	122.33	18.84	152.67	4.63	7.01	9.16	33.90	7.76	0.660
T_{29}	32.92	82.87	10.00	206.17	1891.33	55.67	121.00	9.33	103.12	4.50	7.82	9.23	32.28	8.40	0.577
T_{30}	39.71	115.78	14.83	579.83	3529.33	54.67	121.33	12.49	134.22	4.62	8.47	13.09	32.82	8.18	0.547
General mean	36.64	89.72	17.75	351.77	3371.40	55.10	123.69	11.64	108.40	4.39	7.26	10.09	33.33	8.07	0.611
CD	6.55	50.77	5.16	163.6	2220.00	2.99	1.60	6.13	59.85	0.95	1.52	4.97	10.29	0.27	0.179

Days to harvest

The result presented in Table 2 shows that the general mean for this character among 30 genotypes was 123 days. There is significant differences among the genotypes for this character (Table 3). The duration ranged from 120 (T_7) to 127 (T_{23}) days. Identification of short duration variety is of special importance. So far no short duration varieties are discovered. Actually there is not much variability among the varieties as is evident from the low coefficient of variation (0.84) vide Table 3. The high heritability (77.3) and almost same GCV (1.55) and PCV (1.76) shows that the exhibited variability is purely due to genotypic differences and that there is scope for phenotypic selection for this character from the types. However, the improvement over the mean will be less as is shown by low genetic gain (2.64) vide Table 4 and Fig.1.

Number of tubers per plant

The general mean value of this character was 11.64 ranging from 5.4 to 19 vide Table 2 and 3. From Appendix-1 it is clear that there is significant difference among the genotypes for this character. The coefficient of variation (32.23) suggests that there is considerable total variation among the population for this character. The low GCV (18.90) compared to PCV (37.36) shows that the contribution of genotypic difference to total variability is less than that due to environment. The heritability (25.6) and genetic gain (19.67) are low confirming that there is no scope for selection of superior phenotype for improving this character. But Naskar *et al*. (1991) reported high heritability and genetic advance for number of tubers in cassava.

Table 3. Mean, range, F values and standard error of mean and coefficient of variation for the characters in the open condition

Sl.No.	Characters	F value	Mean	Range		Standard eror	Coefficient of variation
				From	To		
1	Shoot length	5.87**	36.64	27.00	51.00	2.311	10.93
2	Tuber yield per palnt	1.54	89.72	53.00	139.00	17.932	34.62
3	Number of branches per plant	3.58**	17.75	10.00	28.00	1.824	17.81
4	Number of leaves per plant	2.89**	351.77	203.00	621.00	57.789	28.45
5	Leaf area per plant	2.66**	3371.00	1091.00	6618.00	784.070	40.28
6	Days to flowering	17.81**	55.00	43.00	62.00	57.789	3.32
7	Days to harvest	11.26**	123.69	120.00	127.00	0.564	0.84
8	Number of tubers per plant	2.03**	11.64	65.40	19.00	2.165	32.23
9	Haulms weight per plant	3.45**	108.38	64.00	249.00	21.142	33.79
10	Tuber length	0.85	4.39	3.80	5.00	0.335	13.25
11	Tuber girth	1.49	7.26	5.90	8.50	0.536	12.81
12	Tuber length/ Tuber girth	1.45	0.61	0.53	0.70	0.045	18.28
13	Individual tuber weight	1.32	10.08	4.60	22.00	3.515	60.37
14	Starch content of tuber	6.01**	33.34	31.00	35.00	0.363	1.89
15	Protein content of tubers	11.46**	8.07	7.40	8.50	0.097	2.09

** Significant at 1 per cent level

Haulms weight per plant

From Table 2 and 3 it is clear that the mean value for this character is ranging from 64 g to 249 g with the overall means of 108.38 g and coefficient of variation of 33.79. The high GCV shows that the genotypic differences exert considerable variability among the genotypes. The relatively high heritability (45) shows that most of the observed variability is heritable. The high heritability with high genetic gain (42.18) shows that this character is mainly controlled by additive gene effects and hence selection among types can improve the mean performance. The environment has very negligible control of this character.

Tuber length

The mean value in respect of 30 genotypes for this character is presented in Table 2. A perusal of the table shows that the general mean for the character is 4.39 cm. From Table 3 it is clear that tuber length varies from 3.80 cm to 5.00 cm among the genotypes and that there is no significant difference among the 30 genotypes for this character. Out of total variability present for this character, contribution of genotypic differences is too low. PCV is 13.27 and GCV is 0.72 showing the high contribution of environment to the total variability. The low heritability (0.3) also confirms the above fact and practically only a little genetic gain would be possible (Table 4) for this character by practising selection. However, Vimala and Lakshmi (1991) had reported high heritability estimates for tuber length in sweet potato.

Tuber girth

Table 2 and 3 indicates that there was no significant differences among genotypes for this character. The over all mean tuber girth was 7.26 cm with range from 5.90 cm to 8.50 cm with a coefficient of variation of 12.81 (Table 3). The greater PCV (13.82) compared to GCV (5.20) vide Table 4 suggests that environment has played a greater role in total variation. The very low heritability (14.2) as well as genetic gain (3.99) suggests that there is no scope for straight selection to improve this character. This is in agreement with the report of low heritability of tuber girth in sweet potato by Thamburaj and Muthukrishnan (1976). But this is in contrast to the report of Vimala and Laskhmi (1991) of high heritability for tuber girth in sweet potato.

Tuber length to tuber girth ratio

There was no significant difference among 30 genotypes for this ratio. The mean value for various genotypes ranged from 0.53 to 0.70 with a general mean of 0.61 and coefficient of variation was 18.28 (Table 3).

Individual tuber weight

The mean value of this character ranged from 4.6 g to 22 g with a general mean of 10.08 g. The coefficient of variation was 60.37 (Table 3) showing that there was large extent of total variability for this character. The higher PCV (63.53) compared to a low GCV (19.79) indicates the higher role of environmental difference contributing to the total variability among genotypes rather than the genotypic difference among them. The low heritability (9.7) and poor genetic gain

Table 4. Genotypic coefficient of variation, Phenotypic coefficient of variation, heritability, genetic advance and genetic gain for 14 selected characters in the open condition

Sl. No.	Characters	Coefficient of variation		Heritability	Genetic advance	Genetic gain
		Genotypic	Phenotypic			
1	Shoot length	13.92	17.70	0.619	8.27	22.57
2	Tuber yield/plant	14.53	37.58	0.152	10.53	11.73
3	No. of branches/plant	16.51	24.29	0.462	4.11	23.15
4	No. of leaves/plant	22.58	36.32	0.386	101.67	28.90
5	Leaf area/plant	30.01	50.23	0.357	1245.01	36.92
6	Days to flowering	7.86	8.53	0.849	8.21	14.90
7	Days to harvest	1.55	1.76	0.773	3.27	2.64
8	No. of tubers/plant	18.90	37.36	0.256	2.29	19.67
9	Haulms weight/plant	30.55	45.55	0.450	45.73	42.18
10	Tuber length	0.72	13.27	0.300	1.20	27.90
11	Tuber girth	5.20	13.82	0.142	0.29	3.99
12	Individual tuber weight	19.79	63.53	0.097	1.28	12.69
13	Starch content	2.44	3.09	0.625	1.32	3.96
14	Protein content	3.91	4.43	0.777	0.52	7.06

x_1 Shoot length

x_2 Tuber yield per plant

x_3 Number of branches per plant

x_4 Number of leaves per plant

x_5 Leaf area per plant

x_6 Days to flowering

x_7 Days to harvest

x_8 Number of tubers per plant

x_9 Haulms weight per plant

x_{10} Tuber length

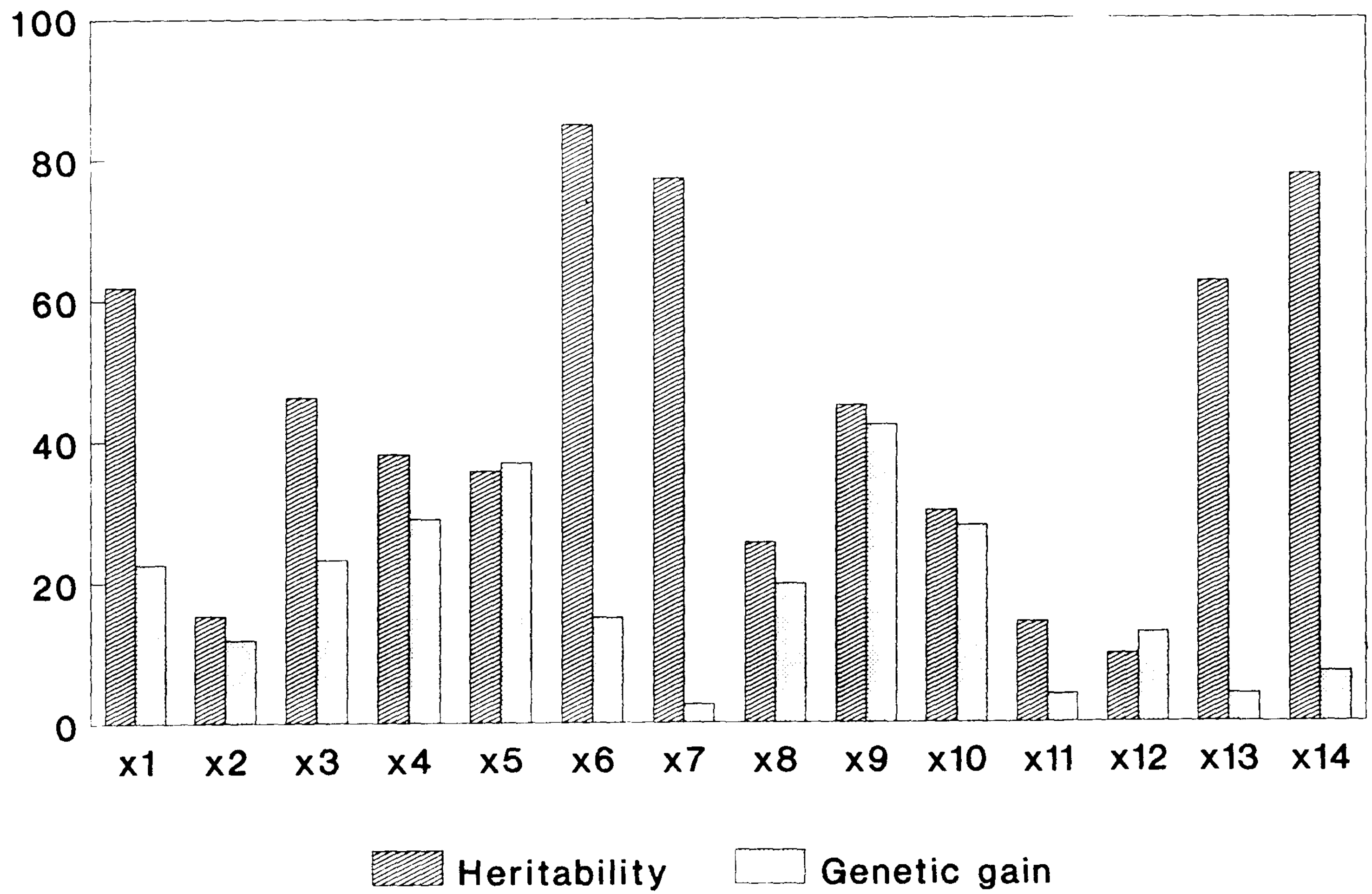
x_{11} Tuber girth

x_{12} Individual tuber weight

x_{13} Starch content of tubers

x_{14} Protein content of tubers

Fig.1. Heritability and expected genetic gain in the open condition



(12.69) suggests that this character can't be improved by selection because much of the variability is due to environmental factors.

Starch content of tubers

The result from Table 2 shows that starch content of tubers ranged from 31 to 35 per cent with a general mean of 33.34 per cent. From Table 3 it is clear that there is significant difference among treatments for this character. The low coefficient of variation (1.89) shows that the inherent variability for this character among genotypes is too low. The low GCV (2.44) and PCV (3.09) and moderately high heritability (62.5) shows that this character is under non-additive gene action which include dominance, epistasis and interaction with environment as well. So, selection has limited scope for the improvement of this character (Fig. 1).

Protein content of tubers

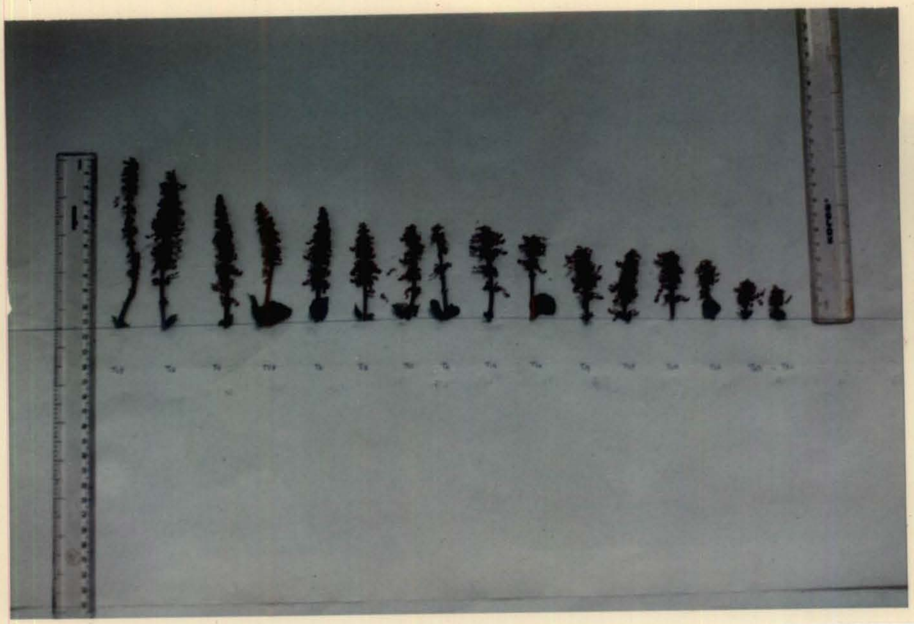
Table 2 shows that in general the protein content of tubers ranged from 7.4 per cent to 8.5 per cent with a general mean of 8.07 per centage. From Table 3 vide Annexure-I it is evident that the 30 genotypes differed significantly for the character. The very high heritability (77.7) and low GCV (3.91) compared to PCV (4.43) suggests that the role of genotypic difference to the total variability is limited but the variation is heritable. Here it is clear that the character is under non-additive gene action as the genetic gain is low (7.06) and hence selection has no scope for improving the character.

4.1.2 Correlation between yield and other components

The genotypic and phenotypic correlation coefficients were estimated

Plate 3. Variation in the nature of flowering in the open condition

Plate 4. Variability in inflorescence characteristics in the open condition



based on genotypic, phenotypic and environmental variance for the selected characters. The correlation between yield and selected component characters and inter correlation among yield components at genotypic and phenotypic level are furnished in Table 5 and 6 respectively.

Generally the phenotypic and genotypic correlation coefficients followed the same trend of association. The genotypic correlation coefficients were slightly higher than the phenotypic correlation coefficients for most of the characters. The greater phenotypic correlation points to the fact that the correlated response is more due to environment than genotype and that these character can't be selected for yield improvement. Hereafter the word correlation will denote genotypic correlation.

Strong positive correlation was shown by characters like number of leaves per plant (0.508), haulms weight per plant (0.716), number of tubers per plant (0.620), leaf area per plant (0.542), shoot length (0.418), tuber length (0.325), tuber girth (0.823) and starch content (0.730) with tuber yield per plant. But strong negative correlation was shown by tuber yield and days to harvest (-0.363). Tuber yield was also negatively correlated with days to flowering (-0.173) and protein content (-0.093). Naskar *et al.* (1986) has also reported high positive correlation of length and girth of tubers with tuber yield. Lakshmi and Amma (1980) have also reported high positive correlation of number of leaves per plant with tuber yield in Asian greater yam. But Kamalam and Biradar 91979) have reported positive significant correlation of number of tubers with yield but significant negative correlation for length of vine. Positive correlation of tuber yield was obtained with individual tuber weight (0.055) and number of branches per plant (0.162) as well.

Table 5 shows that most of the positive correlations were significant at 1 per cent level except for number of tubers which was significant at 5 per cent level.

From Table 6 it is clear that the character days to flowering was negatively correlated with all the characters except shoot length and number of tubers per plant. The positive correlation between shoot length and days to flowering (0.157) is logical as the vegetative growth before flowering adds to the shoot length. The negative correlation of shoot length with other characters may be due to some physiological reasons which hinter the development of tubers due to utilization of stored photosynthates for vegetative growth. Shoot length is positively correlated with number of tubers (0.471) and tuber length (0.464) but has negative correlation with other characters like tuber girth (-0.549), starch content (-0.078), protein content (-0.213) and individual tuber weight (-0.416). The positive association of shoot length with tuber length and number indicates that the increase in shoot length helps to accumulate more starch by way of increased photosynthesis and helps in increasing the tuber number and its growth.

Number of tubers per plant had maximum significant negative correlation with tuber length (-0.916) followed by individual tuber weight (-0.652) and tuber girth (-0.549). But as the number of tubers increases since biomass is increasing there is a positive correlation with starch content. The negative correlation btween tuber number and size had been reported in few tuber crops by many workers.

Girth of tuber showed maximum positive correlation with individual tuber weight (1.00) followed by starch content (0.756) and protein content (0.383). Maximum negative correlation was on length of tuber (-1.00).

Table 5. Phenotypic, genotypic and environmental correlation coefficients between tuber yield and other characters in the open condition

Sl. No.	Characters	Phenotypic correlation	Genotypic correlation	Environmental correlation
1	Shoot length	0.134	0.418	0.010
2	Number of branches per plant	0.162	0.179	0.170
3	Number of leaves per plant	0.256**	0.508**	0.184
4	Leaf area per plant	0.252**	0.542**	0.171
5	Days to flowering	-0.098	-0.173	-0.101
6	Days to harvest	-0.151	-0.363**	-0.062
7	Number of tubers per plant	0.620**	0.396*	0.683**
8	Haulms weight per plant	0.461**	0.716**	0.402**
9	Tuber length	0.399**	0.325**	0.441**
10	Tuber girth	0.497**	0.823**	0.441**
11	Individual tuber weight	0.183	0.055	0.202
12	Starch content	0.098	0.730**	0.225*
13	Protein content	-0.093	-0.033	-0.240*

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

Plate 5. Variation in general features of individual plants at harvest in the open condition

Plate 6. A view of the variation in tuber shape in the open condition

Protein content and yield was negatively correlated (-0.033). This may probably due to the fact that conversion of low energy starch to protein reduces the quantity of starch during assimilation of photosynthates. High genotypic correlation indicates the inherent association of the character with the other.

In the present study starch content of tubers and shoot length showed strong positive correlation with the tuber yield coupled with high heritability estimates (Table 4 and 5). The environmental correlation coefficient for haulms weight is significant showing the greater influence of environment for its greater correlation with yield. Thus for identification of high yielding genotypes more emphasis has to be laid on these two characters viz. starch content of tubers and shoot length. However, individual tuber weight had strong positive correlation (1.00) with girth as well as length of tuber suggesting that improvement in individual tuber weight may be brought about by the selection for any of these two characters.

4.1.3 Path analysis

The association analysis based on correlation coefficients of components with yield will not provide a true picture of the relative merits or demerits of each of the components to final yield, since an individual component may either have a direct influence in the improvement of yield or indirect role through other components in the improvement of yield or both. Path coefficient analysis developed by Wright (1921) and applied for the first time in plants by Dewey and Lu (1959) furnished a means of the direct and indirect effects of individual components to final yield.

Results of path coefficient analysis in the present study vide Fig.2 have revealed that number of tubers per plant has maximum direct effect (0.5932) towards tuber yield per plant followed by tuber girth (0.3047) and individual tuber weight (0.2300).

But the indirect effect of the trait with maximum direct effect viz. number of tubers vide Fig.2 is negative with individual tuber weight (-0.001) and is also negative with shoot length (-0.0272), number of leaves per plant (-0.0150) and leaf area (-0.0035) but positive with all other traits. This is the reason for the moderately high genotypic correlation of this character with yield (0.396).

Tuber girth has on the other hand a greater genotypic correlation (0.823) with tuber yield and has very little negative indirect effect with shoot length (-0.0041), number of branches per plant (-0.250) and number of leaves per plant (-0.0050) which are otherwise positively correlated with yield. However, tuber girth has positive indirect effects with all other characters (Table 7).

Individual tuber weight has got 3rd maximum direct effect on yield and is positive (0.2300). But its negative indirect effects with leaf area (-0.0015), days to flowering (-0.0038) and days to harvest (-0.0005) are negligible. It has got positive indirect effect with all other characters. The remaining tuber character viz. tuber length has moderately high genotypic correlation with yield and has positive direct effect. The moderately high genotypic correlation may be due to its positive indirect effect through leaf area (0.0014), days to harvest (0.0073), number of tubers per plant (0.0965), haulms weight per plant (0.0430), tuber girth (0.1028) and individual tuber weight (0.0005).

Table 6. Genotypic and phenotypic correlation coefficients among eight selected characters in open condition

Characters	Days to flowering	Shoot length	No. of tubers/ plant	Tuber girth	Starch content	Protein content	Tuber length	Individual tuber weight
Tuber yield per plant	-0.173 (-0.098)	0.418** (0.134)	0.396** (0.620)	0.823** (0.497)	0.730** (0.098)	-0.033 (-0.094)	0.325** (0.399)	0.055** (0.183)
Days to flowering		0.157 (0.126	0.094 (0.016)	-0.346** (-0.155)	-0.183 (-0.053)	-0.308** (-0.254)	-1.000 (-0.186)	-0.062 (-0.098)
Shoot length			0.471** (0.273)	-0.037 (-0.013)	-0.078 (-0.059)	-0.213** (-0.142)	0.464** (0.007)	-0.416** (-0.097)
Number of tubers per plant				-0.549** (-0.001)	0.181 (0.036)	-0.453** (-0.251)	-0.916** (0.160)	-0.652** (-0.113)
Girth of tuber					0.756** (-0.194)	0.383** (0.139)	-1.000** (-0.303)	1.000** (0.201)
Starch content						-0.095 (-0.065)	-1.000** (-0.091)	0.096 (-0.013)
Protein content							1.000** (0.111)	0.194 (0.043)
Tuber length								1.000** (0.024)

Figures in brackets indicate phenotypic correlation coefficients
** Significant at 1 per cent level
* Significant at 5 per cent level

Considering the genotypic correlation, direct and indirect effects, tuber girth, number of tubers, individual tuber weight and tuber length are the important traits contributing to tuber yield in coleus (Fig. 2).

The results of the present study also have indicated that the direct effect on tuber yield of the traits viz., shoot length (-0.0993), number of leaves per plant (-0.0654), leaf area per plant (-0.0135), days to harvest (-0.0406) are negative though these traits have exhibited moderate to high significant genotypic correlation coefficients with tuber yield. Thus for exampl, leaf area per plant has been observed to have positive indirect effect on tuber yield through number of branches per plant (0.0616), days to flowering (0.0014), number of tubers per plant (0.1530), haulms weight per plant (0.0641), tuber length (0.1288) and individual tuber weight (0.0256). Similar explanation holds good for characters like shoot length, number of leaves per plant and days to harvest also.

Hence from the results of path coefficient analysis carried out in the present study it can be concluded that greater emphasis has to be laid for improving girth of tubers, number of tubers per plant, individual tuber weight and tuber length which have exerted positive and high direct effect and through which other components have also exerted maximum indirect effects towards tuber yield.

Thus analysis of variance for 15 characters in the open condition indicated highly significant differences in respect of 10 characters. This indicated the inherent differences among the 30 genotypes under study. The highest coefficient of variation was for individual tuber weight (60.37) followed by leaf area per plant (40.28) and tuber yield per plant (34.62). The lowest coefficient of variation was for

Table 7 Direct and indirect effects of eleven selected component characters on tuber yield under open condition

Characters	rg	Shoot length	No. of branches/ plant	No. of leaves/ plant	Leaf area/ plant	Days to flowering	Days to harvest	No. of tubers/ plant	Haulm wt./ plant	Length of tuber	Girth of tuber	Individual tuber wt.
Shoot length	0.418	-.0993	.0213	-.0142	-.0053	.0051	-.0046	.1627	.0796	.0028	.0126	-.0217
Number of branches per plant	0.179	-.0141	+.1500	-.0281	-.0055	-.0012	-.0042	.1286	-.0084	.0051	-.0508	.0138
Number of leaves per plant	0.508	-.0216	.0645	-.0654	-.0063	-.0021	0005	.1363	.0577	.0133	.0233	.0147
Leaf area per plant	0.542	-.0392	.0616	-.0306	-.0135	.0014	-.0044	.1530	.0641	.0128	-.0053	.0256
Days to flowering	-0.173	-.0133	-.0048	.0036	-.0005	.0380	.0250	.0132	-.0116	-.0211	.0311	-.0230
Days to harvest	-0.363	.0114	.0157	.0009	.0015	.0234	-.0406	-.0714	-.0125	-.0212	-.0251	.0027
Number of tubers per plant	0.396	-.0272	.0325	-.0150	-.0035	.0008	.0049	.5932	.0501	.0193	.0139	-.0001
Haulms weight per plant	0.716	-.0451	-.0072	-.0215	-.0049	-.0025	.0029	.1694	.1753	.0291	.1309	.0451
Tuber length	0.325	-.0023	.0065	-.0073	.0014	-.0067	.0073	.0965	.0430	.1187	.1028	.0005
Tuber girth	0.823	-.0041	-.0250	-.0050	.0002	-.0039	.0033	.0270	.0753	.0401	.3047	.0283
Individual tuber weight	0.055	.0094	.0090	.0042	-.0015	-.0038	-.0005	.0003	.0344	.0002	.0375	.2300

rg = genotypic correlation coefficient between tuber yield and its components
Figures underlined represents direct effects
Residual effect = 0.2728

x_1 Shoot length

x_2 Number of branches per plant

x_3 Number of leaves per plant

x_4 Leaf area per plant

x_5 Days to flowering

x_6 Days to harvest

x_7 Number of tubers per plant

x_8 Haulms weight per plant

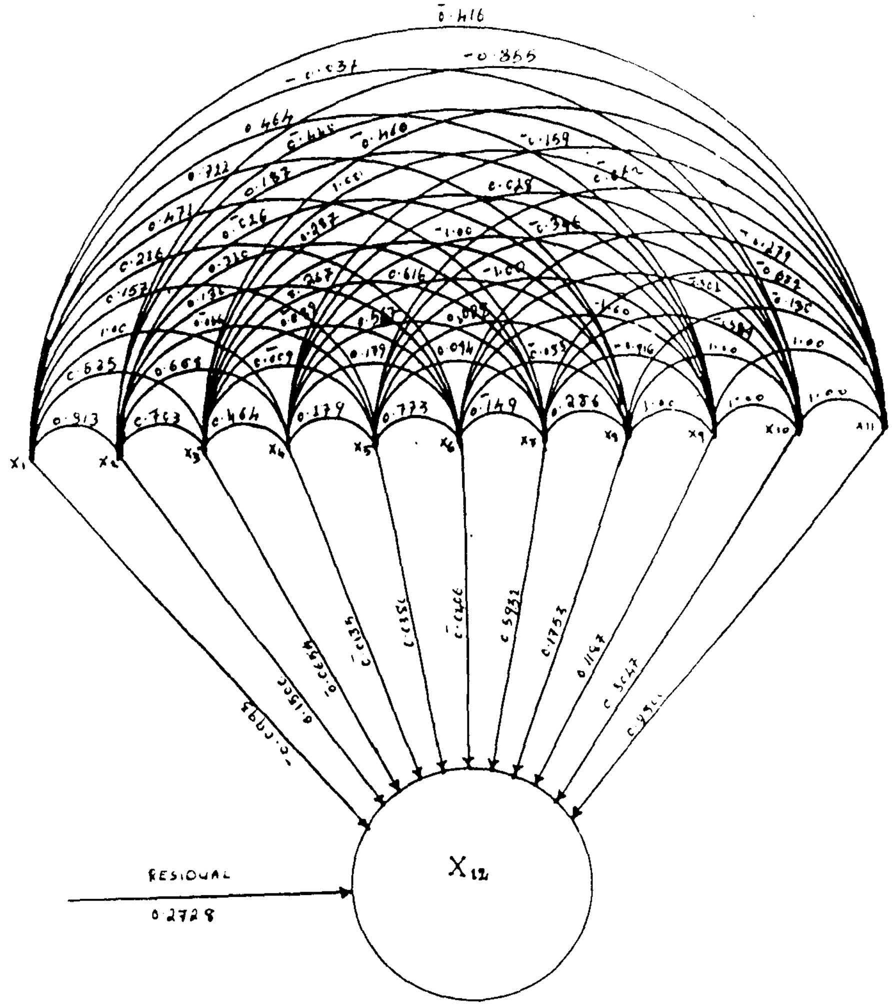
x_9 Tuber length

x_{10} Tuber girth

x_{11} Individual tuber weight

x_{12} Tuber yield per plant

Fig.2. Path diagram showing the direct and indirect effects of independent variables on tuber yield per plant in the open condition



⟶ Path coefficients ◡ Genotypic correlations days to harvest (0.84) followed by starch content of tubers. In general the phenotypic coefficients of variation (PCV) were higher than the respective genotypic coefficients of variation (GV). The highest GCV was for haulms weight per plant (30.55) followed by leaf area per plant (30.01). The lowest GCV was observed for tuber length (0.72) followed by days to harvest (1.55). The high GCV indicated the greater share of genotypic difference for the observed variability of these characters. The heritability values were more than 50 per cent in respect of 5 out of 15 characters. These were, therefore less influenced by the environment. Highest heritability was for days to flowering (84.9) followed by protein content (77.3), lowest heritability was for individual tuber length (0.3) followed by individual tuber weight (9.7). The high heritability shows high heritable variation and low heritability indicates low heritable variation of these characters. But the improvement over mean by selection would be less for economically useful tuber characters like protein content and starch content as is evident from their low genetic gain (7.06 and 3.96 respectively). The correlation studies revealed that for identification of high yielding genotypes emphasis has to be given for shoot and tuber characters. Improvement in individualtuber weight may be brought about by selection for either length or girth of tuber. From path analysis it can be concluded that greater emphasis has to be laid for tuber characteristics like tuber girth, number of tubers per plant, individual tuber weight and tuber length which have exerted positive and high direct effect and through which other components have also exerted maximum indirect effect toward, tuber yield.

The residual effect calculated in the path coefficient analysis is only 0.2728. This indicates that more than 70 per cent of yield in coleus is contributed by the eleven component traits considered for path analysis in open condition. This comparatively low value of residual effect obtained in the present study adequately supports the correct choice of yield components in coleus for path coefficient analysis.

4.2 Shaded condition

4.2.1 Estimation of variability, heritability and genetic advance

Observations on the behaviour of 30 coleus collections with reference to 15 characters viz. length of shoot at 60 days after palnting (cm), number of branches per plant at 60 days after planting, number of leaves per plant at 60 days after planting, leaf area per plant at 60 days after planting (cm^2), days to flowering, days to harvest, tuber yield per plant (g), length of tuber (cm), girth of tuber (cm), length to girth ratio of tubers, individual tuber weight (g), starch content (%) and protein content (%) have been made from all the 5 observational plants in three replications in the shaded condition.

The mean value of all the 30 genotypes with respect to 15 economic characters are presented in Table 8. The general mean, standard error, F value, range and coefficient of variation for each character is presented in Table 9. The abstract of analysis of variance carried out for 15 characters is presented as Appendix-2. The genetic parameters like phenotypic and genotypic coefficients of variation, heritability and genetic advance expressed as percentage of means are presented Table 10. The heritability values are expressed as percentage hereafter.

Shoot length

The mean values of shoot length in respect of 30 genotypes are presented in Table 8.

Plate 7. A general view of the experimental field in the shaded condition

Table 8. Mean values of the 15 characters for 30 genotypes in the shaded condition

Sl.No	Shoot length	Tuber yield plant	No of branches plant	No of leaves plant	Leaf area plant	Days to flowering	Days to harvest	No of tubers plant	Haulms wt / plant	Tuber length	Tuber girth	Individual tuber wt	Starch content	Protein content	Tuber length tuber girth
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T_1	18.61	33.87	4.81	42.20	308.07	61.00	125.00	11.79	70.30	3.66	4.33	7.10	32.81	6.25	0.843
T_2	25.52	66.92	6.68	49.27	778.77	60.00	124.00	9.52	79.66	4.15	4.71	7.00	32.06	6.37	0.877
T_3	30.47	22.07	10.50	39.33	655.28	60.67	127.33	4.10	160.99	2.27	2.60	5.40	33.09	6.40	0.870
T_4	19.43	90.81	4.86	39.60	288.11	60.00	124.33	11.55	71.82	3.13	4.43	7.86	31.84	7.34	0.707
T_5	24.90	62.48	7.61	41.97	408.07	62.33	125.33	9.41	81.18	4.16	4.64	6.60	33.69	6.99	0.897
T_6	21.35	77.18	5.39	38.02	112.85	63.67	126.00	10.34	78.15	4.11	4.83	7.44	33.60	7.44	0.847
T_7	25.33	54.59	6.61	43.58	656.80	68.00	124.67	8.48	80.70	4.21	5.07	6.41	33.54	6.84	0.830
T_8	19.20	88.39	5.03	34.61	255.28	65.33	124.33	12.27	70.96	3.73	4.41	7.19	34.15	7.67	0.843
T_9	25.90	55.89	7.57	38.85	361.07	59.33	124.00	8.66	81.66	4.10	4.37	5.75	32.38	6.75	0.933
T_{10}	24.28	56.99	7.06	37.08	548.77	62.33	124.67	9.26	80.85	4.10	4.47	6.10	32.53	7.60	0.920
T_{11}	18.73	90.44	4.99	32.48	255.90	69.00	126.33	11.16	70.21	3.70	4.47	8.09	32.11	7.89	0.823
T_{12}	21.38	79.93	5.91	86.20	492.41	64.67	131.33	10.79	77.66	1.82	4.44	7.42	32.51	8.07	0.860
T_{13}	25.63	57.85	6.90	61.20	265.00	62.67	123.67	8.67	81.78	2.83	3.25	6.64	31.12	7.50	0.870
T_{14}	21.97	79.56	5.72	27.35	90.11	63.67	126.67	10.31	77.79	4.05	4.56	7.69	31.50	7.64	0.877
T_{15}	26.03	50.76	7.49	43.75	387.03	62.67	124.00	8.13	80.21	4.08	5.01	6.15	30.97	7.59	0.0837

Contd

Table 8. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T_{16}	36.60	24.68	7.89	118.11	1511.93	65.00	123.33	4.67	129.08	2.69	2.34	5.19	32.31	7.81	1.153
T_{17}	21.03	81.72	5.71	45.44	448.28	69.00	125.00	10.22	77.55	3.82	4.40	7.98	33.00	7.45	0.870
T_{18}	21.87	87.67	5.72	54.03	548.60	72.00	128.00	9.74	79.16	3.71	4.62	8.98	31.91	8.04	1.277
T_{19}	33.31	26.82	9.97	99.96	1353.27	74.33	125.67	4.40	157.54	2.80	2.20	5.85	32.71	8.29	1.277
T_{20}	25.07	40.81	7.34	67.32	927.81	71.67	126.00	7.70	80.90	2.81	3.24	5.21	33.14	7.66	0.870
T_{21}	26.07	43.48	7.84	49.80	366.62	68.67	126.67	7.90	80.60	3.18	3.42	5.46	33.13	8.37	0.930
T_{22}	29.89	21.95	10.35	33.27	403.96	66.33	126.00	3.70	163.14	2.33	3.02	5.84	32.93	7.92	0.883
T_{23}	34.30	19.12	10.65	65.93	1021.23	62.33	130.67	4.14	167.81	2.18	2.59	4.59	31.08	7.68	0.847
T_{24}	30.97	19.91	9.93	56.61	709.22	59.33	132.33	4.45	156.19	2.25	2.40	4.48	31.84	7.49	0.937
T_{25}	26.70	37.20	8.03	29.14	475.39	72.33	124.33	9.65	83.29	2.68	3.27	3.79	32.98	7.27	0.817
T_{26}	32.79	23.65	9.67	77.13	1016.82	59.67	124.67	4.48	146.36	2.22	2.18	5.21	32.57	7.04	0.817
T_{27}	26.20	40.64	6.73	66.52	567.78	59.00	128.67	9.53	82.87	2.81	2.35	4.21	32.74	8.03	1.200
T_{28}	31.40	25.25	9.92	110.60	1675.27	65.00	130.00	3.65	148.51	2.06	2.30	5.55	34.14	8.32	0.893
T_{29}	25.80	36.73	7.53	58.98	503.91	69.00	131.33	10.29	81.73	2.47	3.45	3.54	32.53	8.02	0.717
T_{30}	34.67	19.92	10.77	106.41	1466.96	74.00	128.67	3.85	165.28	2.20	2.25	5.15	32.29	7.77	0.975
General mean	26.18	52.24	7.51	56.48	638.68	65.10	126.43	8.09	101.47	3.20	3.65	6.12	32.57	7.52	0.90
CD	2.41	5.98	1.76	4.46	10.76	3.07	3.41	0.53	3.12	0.11	0.25	1.05	0.99	0.30	0.07

The result presented in the above table clearly shows that shoot length ranged from 16.61 cm to 36.60 cm with a general mean of 26.18 cm. From Appendix-2 it s clear that the genotypes differed significantly for this character. The maximum was for T_{16} and minimum for T_1.

The statistical parameters viz., means, range, standard error and coefficient of variation vide Table 9 indicates the inherent differences among genotypes for this characters. The low coefficient of variation (5.64) point out that the total variability for this character is limited.

The genetic parameters like GCV (19.13) and PCV (19.95) with high heritability (92) and moderate genetic gain (37.81) for this character vide Table 10 and Fig.3. Suggests that phenotypic selection for this character is effective and that there is scope for improvement of this character over the mean. A similar case of high heritability, genetic advance and high GCV was reported for vine length in sweet potato by Kamalam *et al.* (1977). A similar result was obtained by Singh and Mishra (1971) in sweet potato.

Tuber yield per plant

The mean value of tuber yield per plant in respect of 30 genotypes are presented in Table 8.

The result in the above table shows that maximum yield was 90.81 g (T_4) and the minimum was 19.12 g (T_{23}) with a general mean of 52.24 g. From Appendix-2 it is clear that there is significant difference among the genotypes for the complex character. The total variability among genotypes is but low as is evident from low coefficient of variation (7.01). The high GCV and PCV shows that much of the total variability is due to the genotypic differences. The very high value of heritability (97.9) also confirms the heritable nature of variation. Since the genetic gain is also very high, this economically important character can be improved by following phenotypic selection. A similar report of high heritability and genetic advance estimates was made by Biradar *et al.* (1978) in cassava. Kamalam *et al.* (1977) also reported high heritability and genetic advance for tuber yield per plant in cassava.

Number of branches per plant

The result presented in Table 8 shows that this character had mean va lues ranging from 4 to 10 with an overall mean of 7.5. From Appendix-2 it is clear that there is significant difference among treatments for this character. The genetic parameters such as GCV (24.16), PCV (28.12) and heritability (73.8) shows that the variation is mainly contributed by genotypic differences and that there is a good extent of heritable fraction. The genetic gain (42.74) being moderate confirms the above fact. Hence there is scope for improvement of this character by selection among the different genotypes.

Number of leaves per plant

The data presented in Table 9 suggests that this character has a wider range extending from 27.35 to 118.10 with a general mean of 56.50. A perusal of Appendix-2 shows that there is significant difference among the genotypes for this character. The genetic parameter viz. GCV (44.62) and PCV (44.89) indicates the greater role of genotypic difference in the total variability. The very high heritability

(98.8) also confirms the above fact. But Thamburaj and Muthukrishnan (1976) has reported high heritability and low genetic gain for number of leaves in sweet potato. Low heritability of number of leaves was also reported by Vimala and Lakshmi (1991) in sweet potato. But Suthanthirapandian (1994) has reported highest genetic advance for number of leaves in cassava. But the high genetic gain (91.4) along with high heritability vide Table 10 and Fig.3. suggests that phenotypic selection can be resorted to improve the character.

Leaf area per plant

The mean value of this character is presented in Table 9. A perusal of Table 9 shows that there is significant difference among the 30 genotypes for the character. The character had values ranging from 90.11 cm^2 to 167.5 cm^2 with a general mean of 638.70 cm^2. The high GCV (62.31) and very high heritability (95.9) shows that this character is little influenced by environment and hence simple phenotypic selection will be effective for its improvement. So the extent of genetic gain is less showing that much improvement over the present mean value is not possible by selection. But it is clear that the character is under non-additive gene action. But Mathew *et al.* (1979) reported a low heritability of leaf area in pineapple.

Days to flowering

The mean value of this character is presented in Table 8. A close observation of the result reveals that there is a wide range in the days to flowering from 59 days to 74 days with a general mean of 65 days. The GCV (7) and PCV (7.57) are almost same showing that genotypic differences for this character was reflected in the total variability. High heritability (85.5) and low genetic gain suggests that this character is under non-additive gene action viz. dominance and epistasis. Hence selection has but little scope for its improvement.

Days to harvest

Table 8 shows the mean values of 30 genotypes for this character. From Table 9 it is clear that there is significant difference among genotypes for this character. The general mean for the duration of the 30 genotypes was 126 days with means ranging from 123 days to 132 days. Identification of short duration varieties is of special importance as in coleus short duration varieties are not reported so far. The low GCV (1.85) compared to PCV (2.52) suggests that the genotypic differences among the collections has less contribution to total variability. Also the heritability is only moderate (54.1) showing that this character is controlled by environment and hence the genetic gain is less (13.33) meaning that there is no scope for selection.

Number of tubers per plant

The result presented in Table 8 and 9 shows that the number of tubers per plant ranged from 3 to 12 with a mean of 8. The genetic parameters such as GCV (34.9) and PCV (35.12) suggests that the character is not much affected by environment. The very high heritability (98.7) and genetic gain (71.35) vide Table 10 and Fig.3 suggests that the character is under additive gene action and that selection is effective for improvement of this economic character from among this genotypes. Naskar *et al.* (1991) and Suthanthirapandian *et al.* (1994) also reported a high heritability of number of tubers in cassava. The high heritability for this character can be of much practical importance in making selection.

Haulms weight per plant

From Table 8 and 9 it is clear that there is wide range of means for this character for the 30 genotypes ranging from 70 g to 168 g with a general mean of 101.47 g. The genetic parameters GCV (35.82) and PCV (35.87) are equal showing that the character is controlled by genotype than environment. The high heritability (99.7) and genetic gain suggests that there is scope for selection to improve this character.

Tuber length

The mean value in respect of 30 genotypes for this character is presented in Table 8. A perusal of the table shows that mean tuber length ranged from 2 cm to 4 cm with the overall mean of 3.21 cm. The genetic parameters such as GCV (23.85) and PCV (23.95) along with high heritability (99.2) and genetic gain (48.9) offers moderate scope for improvement by selection for this character. However, Suthanthirapandian (1994) reported high genetic advance for tuber length in cassava.

Tuber girth

From Table 8 and 9 it is clear that there is significant difference among genotypes for this character. The mean values for this character ranged from 2.18 cm to 5.07 cm with an overall mean of 3.65 cm. The genetic parameters viz. GCV (27.76) and PCV (28.06) together with the high heritability (97.8) and genetic gain (56.71) vide Fig.3 offers better scope for improvement of this character by selection. A similar case of high heritability and genetic gain of tuber girth is also reported by Vimala and Lakshmi (1991) in sweet potato.

Individual tuber weight

The Table 8 and 9 vide Appendix-2 shows that there is significant difference among the 30 genotypes for this character. The wide range of mean values from 3.5 g to 9 g indicates the scope for selection from this existing variability. Genetic parameters such as heritability (80.5) vide Fig.3 and genetic gain (39.47) shows that this character is under additive gene action. Such high heritability of single tuber weight was earlier reported by Suthanthirapandian (1994) in cassava.

Tuber length to tuber girth ratio

Singnificant differences was noticed for this character among the 30 genotypes. The mean values ranged from 0.71 cm to 1.28 cm with a general mean of 0.90 cm. Since the ratio primarily depends on the two basic characters viz. tuber length and girth seperate mentioning of the ratio is not relevant, all the genetic parameters were high for this character indicating its improvement through selection.

Starch content of tubers

The result from Table 8 shows that starch content of tubers ranged from 30.97 to 34.15 percent with a general mean of 32.57 per cent. The coefficient of variation vide Table 9 is also less, signifying the limited total variability shown for this character. The low genetic parameters such as GCV (2.3) and PCV (2.97) shows that environment didn't play a major role in the expression of this character. Also the above average heritability (60.1) with low genetic gain (3.68) suggests that this character is controlled by non-additive gene action which include dominance and epistasis.

x_1 Shoot length

x_2 Tuber yield per plant

x_3 Number of branches per plant

x_4 Number of leaves per plant

x_5 Leaf area per plant

x_6 Days to flowering

x_7 Days to harvest

x_8 Number of tubers per plant

x_9 Haulms weight per plant

x_{10} Tuber length

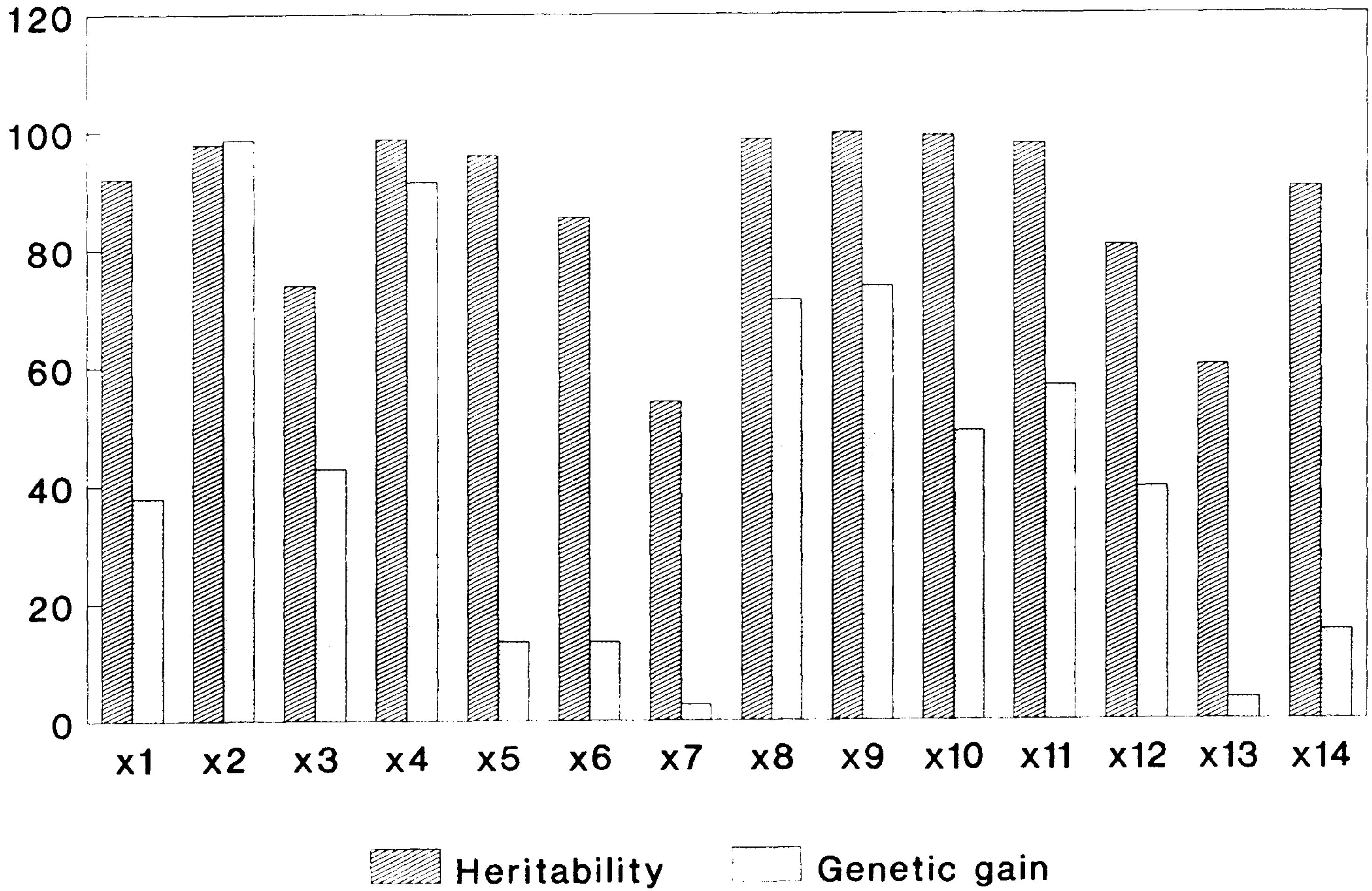
x_{11} Tuber girth

x_{12} Individual tuber weight

x_{13} Starch content of tubers

x_{14} Protein content of tubers

Fig.3. Heritability and expected genetic gain in the shaded condition



Protein content of tubers

Table 8 shows that the protein content of tubers ranged from 6.25 to 8.37 per cent with a general mean of 7.52 per cent. The low coefficient of variation vide Table 9 indicates the low extent of total variability seen for this character. The genotypic and phenotypic coefficient of variation 7.46 and 7.84 respectively vide Table 10 and Fig.3 for this character also shows that it was not influenced much by environment and selection may be based on phenotypic values themselves. The high heritability (90.4) but low genetic gain (15) suggests non-additive gene action for this character. Hence selection is not effective for improvement of this character.

4.2.2 Correlation between yield and other components

The genotypic correlation coefficients of 13 selected component characters with yield of tubers estimated based on genotypic, phenotypic and environmental variances for these characters are presented in Table 11. The inter correlation among eight selected component characters both at genotypic and phenotypic level are furnished in Table 12.

Generally the genotypic and phenotypic correlation followed the same trend of association. The genotypic correlation coefficients were slightly higher than the phenotypic correlation coefficients for most of the characters except for starch content. The greater phenotypic correlation compared to the genotypic correlation observed on certain characters points to the greater role of environment in the correlated response of these characters. The higher genotypic correlation between the characters indicate inherent association between various characters.

Table 9. Mean, range, F value, standard error of mean and coefficient of variation for the different characters in the shaded condition

Sl.No.	Character	F value	Mean	Range		Standard error	Coefficient of variation
				From	To		
1	Shoot length	35.54**	26.18	16.61	36.60	0.852	5.64
2	Tuber yield per plant	144.19**	52.24	19.12	90.81	2.114	7.01
3	Number of branches per plant	9.46**	7.50	4.81	10.77	0.623	14.38
4	Number of leaves per plant	236.49**	56.50	27.35	118.10	1.577	4.84
5	Leaf area per plant	11906.25**	638.70	90.11	16.75	1.029	1.03
6	Days to flowering	18.62**	65.10	59.00	74.33	1.085	2.89
7	Days to harvest	4.53**	126.43	123.30	132.30	1.206	1.71
8	Number of tubers per plant	230.22**	8.10	3.65	12.27	0.186	3.99
9	Haulums weight per plant	1083.70**	101.47	70.21	167.80	1.105	1.89
10	Tuber length	147.42**	3.21	2.06	4.21	0.039	2.14
11	Tuber girth	137.10**	3.65	2.18	5.07	0.086	4.12
12	Tuber length/ Tuber girth	23.94**	0.90	0.71	1.28	0.123	4.85
13	Individual tuber weight	13.38**	6.13	3.54	8.98	0.372	10.53
14	Starch content of tubers	5.51**	32.57	30.97	34.15	0.353	1.88
15	Protein content of tubers	29.09**	7.52	6.25	8.37	0.105	2.44

** Significant at 1 per cent level

Here after the word correlation will denote genotypic correlation.

Tuber yield per plant was significantly and positively correlated with number of tubers per plant (0.896), tuber length (0.787), tuber girth (0.844) and individual tuber weight (0.873) vide Table 11. Thamburaj and Muthukrishnan (1970) obtained high degree of positive correlation between number of tubers, girth of tubers, length of tuber, number of leaves and number of branches with tuber yield in sweet potato. But in the present study the association of number of leaves (-0.510) and number of branches (-0.994) were significantly negative with tuber yield.

Strong negative correlation was shown by other characters viz. shoot length (-0.945), leaf area per plant (-0.680), days to harvest (-0.337) and haulms weight per plant (-0.820) with tuber yield. Maximum negative correlation of tuber yield was shown by number of branches per palnt (-0.994). Kamalam *et al.* (1977) also has reported a significant negative correlation of shoot characters such as shoot length and number of branches per plant with tuber yield in sweet potato. Pushkaran *et al.* (1976) have also reported significant negative correlation of leaf area with tuber yield in sweet potato. But Mohankumar *et al.* (1990) reported a significant positive correlation of leaf area with corm yield in taro. The significant negative correlation of number of branches with tuber yield may be due to the fact that increase in the number of branches makes use of the stored carbohydrate causing its reduction in yield.

From Table 12 it is clear that days to flowering is positively correlated with starch content (0.230) and protein content (0.514). This is true from the fact that tuber formation in coleus is followed by flowering and hence a reduction of

Table 10. Genotypic coefficient of variation, Phenotypic coefficient of variation, heritability, genetic advance and genetic gain for 14 selected characters in shaded condition

Sl. No.	Character	Coefficient of variation		Heritability	Genetic advance	Genetic gain
		Genotypic	Phenotypic			
1	Shoot length	19.13	19.95	0.920	9.90	37.81
2	Tuber yield/plant	48.41	48.92	0.979	51.57	98.71
3	No. of branches/plant	24.16	28.12	0.738	3.21	42.74
4	No. leaves/plant	44.62	44.89	0.988	51.62	91.40
5	Leaf area/plant	62.31	64.93	0.959	25.31	13.37
6	Days to flowering	7.00	7.57	0.855	8.68	13.33
7	Days to harvest	1.85	2.52	0.541	3.43	2.70
8	No. of tubers/plant	34.90	35.12	0.987	5.78	71.35
9	Haulms weight/plant	35.82	35.87	0.997	74.77	73.68
10	Tuber length	23.85	23.95	0.992	1.57	48.90
11	Tuber girth	27.76	28.06	0.978	2.07	56.71
12	Individual tuber weight	21.39	23.84	0.805	2.42	39.47
13	Starch content	2.30	2.97	0.601	1.20	3.68
14	Protein content	7.46	7.84	0.904	1.10	15.00

Table 11. Phenotypic, genotypic and environmental correlation coefficients between tuber yield and other characters in the shaded condition

Sl. No.	Characters	Phenotypic correlation	Genotypic correlation	Environmental correlation
1	Shoot length	-0.899**	-0.945**	-0.047
2	Number of branches per plant	-0.838**	-0.994**	0.096
3	Number of leaves per plant	-0.501**	-0.510**	0.007
4	Leaf area per plant	-0.673**	-0.680**	-0.137
5	Days to flowering	-0.048	-0.076	0.389**
6	Days to harvest	-0.255*	-0.337**	-0.107
7	Number of tubers per plant	0.883**	0.896**	0.100
8	Haulms weight for palnt	-0.810**	-0.820**	0.074
9	Tuber length	0.778**	0.787**	0.213*
10	Tuber girth	0.827**	0.844**	0.036
11	Individual tuber weight	0.815**	0.873**	0.630
12	Starch content of tuber	-0.010	0.008	-0.181
13	Protein content of tuber	-0.156	-0.159	-0.143

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

Table 12. Genotypic and phenotypic correlation coefficients among eight selected characters in shaded condition

Characters	Days to flowering	Shoot length	No. of tubers/ plant	Tuber girth	Starch content	Protein content	Tuber length	Individual tuber weight
Tuber yield per plant	-0.076 (-0.048)	-0.945** (-0.899)	0.896** (0.883)	0.844** (0.827)	0.008 (-0.010)	-0.159 (-0.156)	0.787** (0.778)	0.873** (0.815)
Days to flowering		0.073 (0.059)	-0.064 (-0.062)	-0.093 (-0.087)	0.230** (0.150)	0.514** (0.451)	-0.124 (-0.109)	-0.017 (0.036)
Shoot length			-0.945** (-0.902)	-0.826** (-0.788)	-0.122 (-0.088)	0.159 (0.157)	-0.720** (-0.690)	-0.717** (-0.620)
Number of tubers per plant				0.789** (0.774)	0.051 (0.041)	-0.162 (-0.156)	0.727** (-0.721)	0.558** (0.491)
Tuber girth					-0.001 (-0.011)	-0.308** (-0.297)	0.930** (0.914)	0.728** (0.652)
Starch content						0.012 (-0.030)	0.042 (0.030)	-0.050 (-0.043)
Protein content							-0.294** (-0.277)	-0.106 (-0.098)
Tuber length								0.695** (0.627)

Figures in brackets indicate phenotypic correlation coefficients
** Significant at 1 per cent level
* Significant at 5 per cent level

accumulated photosynthates occurs after flowering or there is an increase in starch and protein content as the days to flowering is prolonged. The negative correlation with tuber length and tuber girth shows that if tubers are not formed earlier their enlargement in the late stages may be adversely affected by a late flowering of the crop. Correlation between tuber length and girth (-0.930) suggests that improvement of one character is at the expense of the other as has been reported in other tuber crops by many workers. Tuber length had positive significant association with individual tuber weight (0.695). Starch content had a slight positive correlation (0.008) with yield while protein content of tubers had a negative correlation (-0.159) with yield of tubers per plant.

In the present study number of tubers per plant with genotypic correlation 0.896 and tuber girth with genotypic correlation 0.844 had highly significant positive correlation with yield as well as high heritability and genetic gain (Tables 10 and 11). The environmental correlation coefficient for individual tuber weight was high (0.630) showing the greater influence of environment for its greater correlation with yield. Thus for identification of high yielding genotypes emphasis has to be done on these two characters viz. number of tubers per plant and tuber girth.

4.2.3 Path analysis

The results of path analysis (Fig. 4 and Table 13) showed that number of tubers contributed maximum direct positive effect (0.6255) to tuber yield followed by individual tuber weight (0.4575) and haulms weight per plant (0.1502). The high direct influence of number of tubers was intensified further by the positive indirect effects through individual tuber weight, girth of tubers, length of tuber, number of branches per plant and shoot length though it was reduced to some extent with the

Table 13. Direct and indirect effects of eleven selected component characters on tuber yield under shaded condition

Characters	rg	Shoot length	No.of branches/ plant	No.of leaves/ plant	Leaf area/ plant	Days to flowering	Days to harvest	No.of tubers/ plant	Haulm wt./ plant	Length of tuber	Girth of tuber	Individual tuber wt.
Shoot length	0.945	*-.0773*	-.0702	+.0191	.0130	.0010	-.0003	-.5588	.1234	-.0070	-.0434	-.2818
Number branches per plant	0.994	0.627	*-.0864*	.0127	.0009	.0021	-.0002	.5259	.1199	-.0067	-.0372	-.2610
Number of leaves per plant	-0.510	-.0495	.0367	*.0299*	.0152	-.0038	-.0007	-.3586	.0784	-.0054	-.0364	.1375
Leafe area per plant	0.680	-.0586	-.0489	.0264	*.0172*	-.0051	-.0006	.4615	.1029	-.0065	-.0406	.1738
Days to flowering	-0.076	.0031	.0073	.0045	.0035	*-.0252*	-.0011	.0177	.0005	-.0013	-.0044	.0821
Days to harvest	-0.337	-.0063	-.0054	.0056	.0025	-.0071	*-.0040*	-.0718	.0366	-.0038	-.0154	-.0236
Number of tubers per plant	0.896	.0690	.0727	-.0171	-.0127	-.0007	.0005	*.6255*	-.1400	.0075	.0436	.2353
Haulm weight per plant	-0.820	-.0635	-.0690	.0156	.0118	-.0001	-.0010	-.5833	*.1502*	-.0082	-.0451	-.2011
Tuber length	0.787	.0507	.0539	-.0151	-.0104	.0030	.0014	.4367	-.1143	*.0107*	.0523	.2609
Tuber girth	0.844	.0586	.0562	-.0190	-.0122	.0019	.0011	.4760	-.1182	.0098	*.0572*	.2808
Individual tuber weight	0.873	.0473	.0493	-.0090	-.0065	-.0045	.0002	.3217	-.0660	.0061	.0351	*.4575*

rg genotypic correlation coefficient between tuber yield and its components
Figures underlined represents direct effect
Residual effect 0.0205

x_1 Shoot length

x_2 Number of branches per plant

x_3 Number of leaves per plant

x_4 Leaf area per plant

x_5 Days to flowering

x_6 Days to harvest

x_7 Number of tubers per plant

x_8 Haulms weight per plant

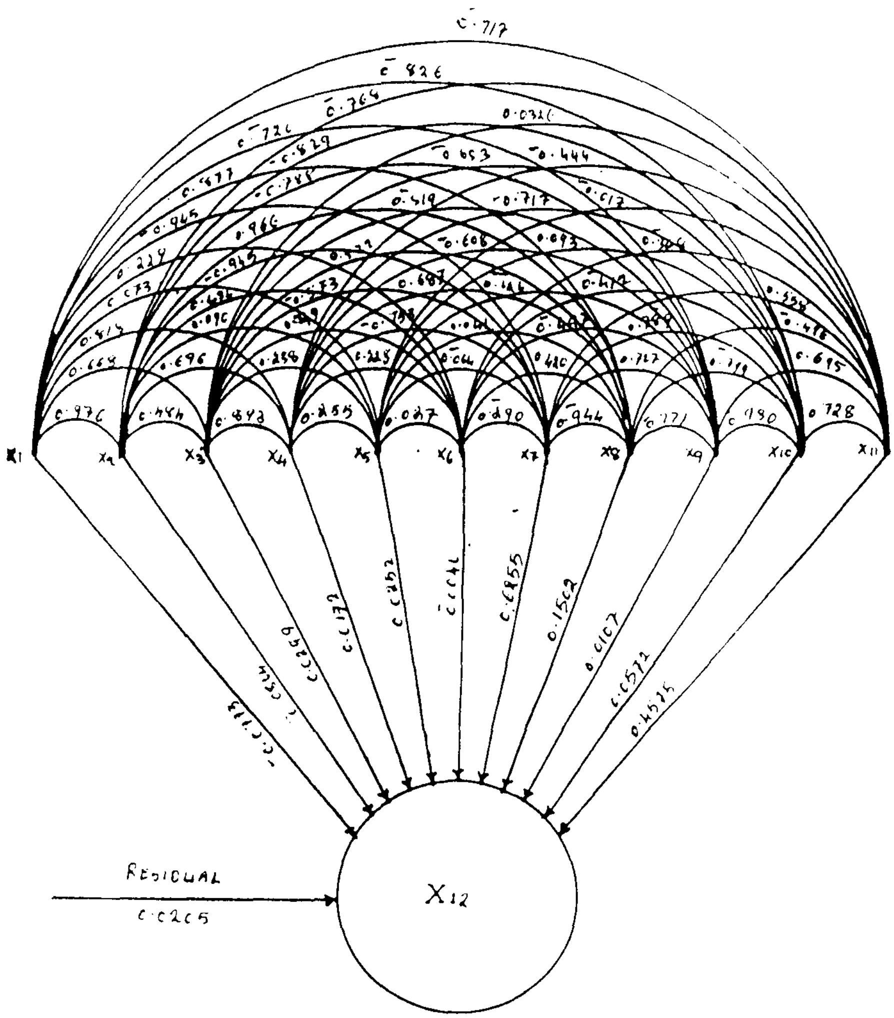
x_9 Tuber length

x_{10} Tuber girth

x_{11} Individual tuber weight

x_{12} Tuber yield per plant

Fig.4. Path diagram showing the direct and indirect effects of independent variables on tuber yield per plant in the shaded condition



⟶ Path coefficients ‿ Genotypic correlations negative effects through number and area of leaves per plant, days to flowering and haulms weight per plant (Table 13). The positive direct association of leaf area per plant, number of leaves per plant and haulms weight per plant was insignificant when compared to the high negative correlation of these characters with yield of tubers due to the high negative indirect effects via number of tubers and individual tuber weight.

Among the shoot characters maximum negative direct effect on tuber yield was shown by number of branches followed by shoot length. The strong negative correlation of these characters with tuber yield is due to their significant negative indirect influence on individual tuber weight (Table 13). In the case of haulms weight the direct effect was positive whereas its association with tuber yield was significantly negative both at genotypic and phenotypic levels. It seemed that the positive effect had been masked by the negative indirect influences through individual tuber weight, girth of tuber, length of tuber, number of tubers, days to harvest, days to flowering, number of branches per plant and shoot length.Among the shoot characters which showed significant genotypic and phenotypic correlations with yield (Table 12), shoot length, number of branches per plant, days to flowering and days to harvest showed negative direct effects. All tuber characters which showed significant positive correlation at genotypic and phenotypic level also had direct positive effect on tuber yield.

Since number of tubers per plant showed the maximum direct effect and the highest positive correlation with yield (Fig. 4 and Table 2), it can be indicated that this character should be a criterion for selection of a high yielding plant type in coleus in the shaded condition. Individual tuber weight also had a direct association with tuber yield and its magnitude was mainly increased by the indirect effect through number of tubers. All the shoot characters showed negative correlation with yield and none of them showed significant direct effect while all the root characters showed positive significant correlation and direct effect. From this it is clear that inclusion of shoot characters did not bring any improvement to the predictability of yield in the crop. In a breeding programme for yield based on component characters shoot characters will be of little importance.

In a similar study with sweet potato Ibrahim (1987) has also reported that the root characters viz. tuber girth, number of tubers and tuber length showed high path values than shoot characters.

The residual effect calculated in the path coefficient analysis is only 0.0205. This indicates that 98 per cent of yield in coleus under shaded condition is contributed by eleven component traits considered for path analysis. The comparatively low value of residual effect obtained in the present study adequately supports the correct choice of yield components in coleus for path coefficient analysis.

The path coefficient analysis thus projects the number of tubers, individual tuber weight and tuber girth as the three factors exerting the greatest influence directly and indirectly upon tuber yield in shade grown coleus.

Thus analysis of variance for 15 characters in the shaded condition has indicated highly significant differences in respect of all the characters. This indicated the inherent differences among the 30 genotypes under study. The highest coefficient of variation was for tuber yield per plant (14.38) followed by individual tuber weight and the lowest for leaf area per plant (1.03) followed by days to harvest (1.71). In general the phenotypic coefficient of variations (PCV) were higher than the respective genotypic coefficients of variation (GCV). The highest GCV was for leaf area per plant (62.31) followed by tuber yield per palnt (48.41). The lowest GCV was observed for days to harvest (1.85) followed by starch content (2.30). The high GCV indicated the greater share of genotypic differences to the total variability observed for these characters. The heritability was more than 70 per cent for all the 12 characters showing that they were less influenced by environment. The highest heritability was for haulms weight per plant (99.7) followed by number of leaves per plant (98.8). Lowest heritability was observed for days to harvest (54.1) followed by starch conent (60.01). But genetic gain by selection was maximum for tuber yield per plant (98.71) followed by number of leaves per plant (91.40). Moderately high genetic gain of tuber characters shows the scope for improvement of the same by selection. The correlation studies revealed that for identification of high yielding genotypes emphasis has to be given for characters like number of tubers per plant and tuber girth which have high positive correlation with yield at genotypic level (0.896 and 0.844 respectively). The path coefficient analysis projects characters like number of tubers, individual tuber weight and girth of tuber as the three major components exerting direct and indirect effects on tuber yield under shaded condition.

In general the 30 collections of coleus showed some amount of difference in certain qualitative traits like tuber shape, shape and size of leaf, length of inforescence stalk, extent of flowering etc. (Plates 1 to 7). The crop stand was better in open than under shaded condition.

x_1 Shoot length

x_2 Tuber yield per plant

x_3 Number of branches per plant

x_4 Number of leaves per plant

x_5 Leaf area per plant

x_6 Days to flowering

x_7 Days to harvest

x_8 Number of tubers per plant

x_9 Haulms weight per plant

x_{10} Tuber length

x_{11} Tuber girth

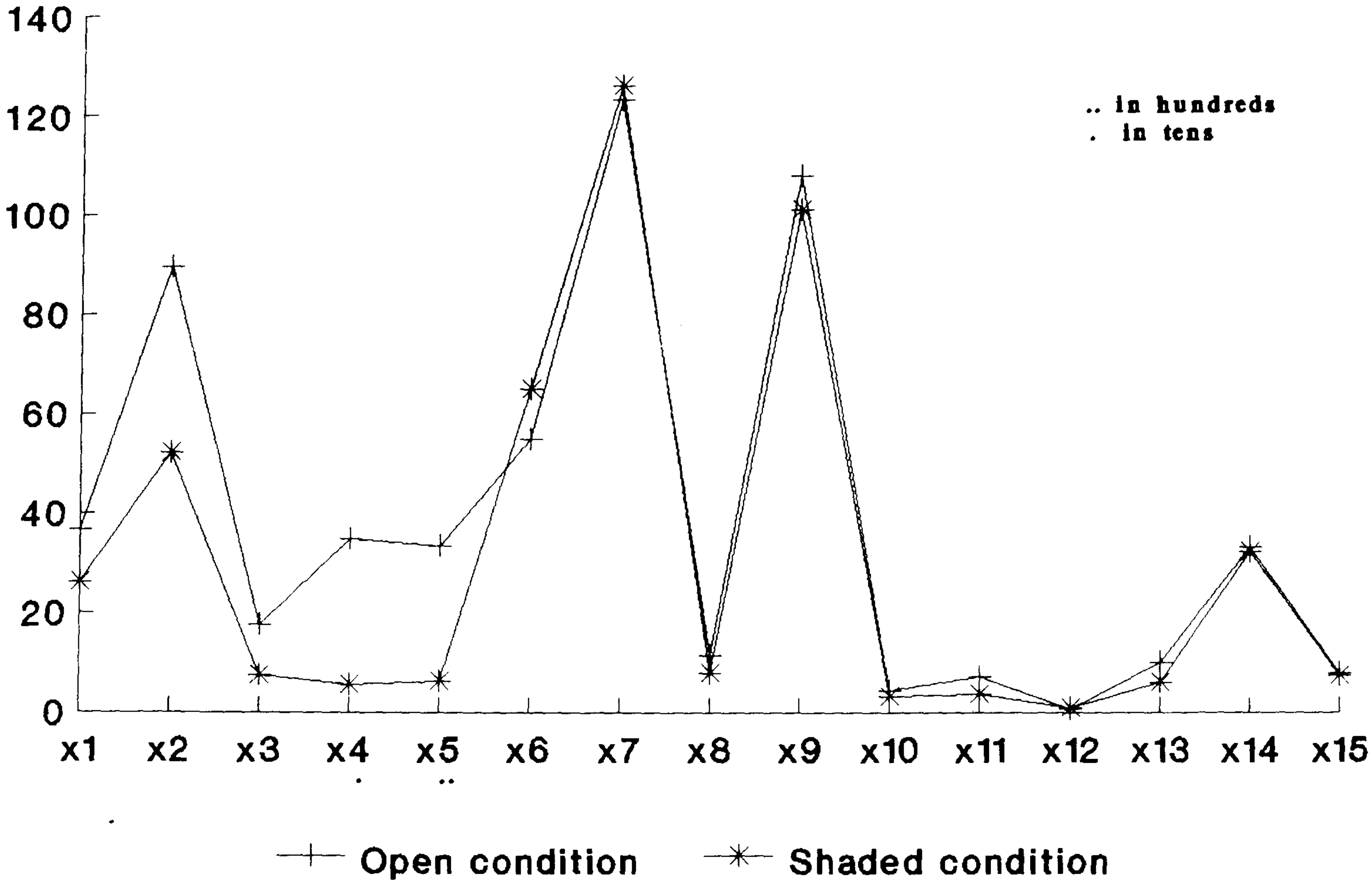
x_{12} Tuber length/Tuber girth

x_{13} Individual tuber weight

x_{14} Starch content of tubers

x_{15} Protein content of tubers

Fig.5. Mean values of the characters in open vs. shaded conditions



The 30 genotypes of coleus showed significant difference of mean values for most of the characters studied under both conditions. The mean values were significantly higher in open condition for all characters except days to flowering and days to harvest (Fig.5). The genetic parameters such as genotypic and phenotypic coefficients of variation and genotypic and phenotypic correlations followed the same trend of association in both situations. However heritability values varied significantly in both situations. High heritability and genetic gain suggests that economic characters like protein content and days to harvest in open condition and tuber yield and other tuber characteristics viz., length, number and girth of tubers in the shaded condition can be improved by selection. From path analysis it was clear that number of tubers per plant has maximum direct effect on tuber yield in both situations. All other tuber characters also had direct positive effect on tuber yield under both situations.

Summary

SUMMARY

Biometric analysis of yield and other attributes in coleus (*Coleus parviflorus* Benth.) was undertaken in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during the period 1995-1996. Thirty collections of coleus with certain extent of morphological variation were raised in a randomised block design with three replications in open as well as shaded conditions. Observations on fifteen economic characters were recorded from all the observational plants in three replications in both situations. The data were subjected to suitable statistical analyses for estimating the variability available in the material, for working out the heritable portion of the variability and for finding out the degree of association of different components of yield with yield directly or indirectly.

Part I. Open condition

The important findings are summarised below:

1. The 30 genotypes of coleus showed significant difference for all the shoot characteristics and some tuber characteristics viz. number of tubers/plant, starch content and protein content. Other tuber characters like tuber yield per plant tuber length tuber girth and tuber length to girth ratio didn't show significant differences among genotypes.

2. Estimates of phenotypic and genotypic coefficients of variation have shown that phenotypic coefficients of variation were higher than genotypic coefficients of variation for all the characters.

3. Heritability estimates in the broad sense was high for characters like protein content, days to harvest and days to flowering and moderate for shoot length, number of branches per plant, haulms weight per plant and starch content. Very low heritability was observed for characters like tuber length, tuber girth, number of tubers per plant and individual tuber weight.

4. Genetic gain was moderately high for shoot characters like leaf area per plant and haulms weight per plant and moderately low for tuber characters like tuber yield per plant and number of tubers per plant.

5. Highest heritability was for days to flowering (84.9) followed by protein content (77.3) and lowest for tuber length (0.3).

6. The low genetic gain of economically useful characters such as protein and starch content of tubers suggest that selection can bring less improvement over the mean value.

7. Positive significant correlation was shown by shoot characters like shoot length, number of leaves per plant, haulms weight per palnt, leaf area per plant and tuber characteristics like tuber girth, tuber length and starch content and tuber number with tuber yield. But negative significant correlations was observed for days to harvest, negative but non significant correlations were observed for characters viz. protein content and days to flowering with tuber yield.

8. The results of path analysis have revealed that number of tubers per plant had maximum direct effect on tuber yield. Also all the tuber characters like number of tubers, length and girth of tuber and individual tuber weight had positive direct effect to tuber yield per plant. Shoot characters except haulms weight had direct negative effect on tuber yield. The negative correlation of shoot characters with tuber yield indicates their negative indirect effect on tuber yield through other characters.

9. The residual effect of 0.2708 suggests that more than 70 per cent of the variation of yield were contributed by the eleven component characters considered for path coefficient analysis.

Part II. Shaded condition

The important findings are summarised below:

1. The 30 genotypes of coleus showed significant difference for all the shoot and tuber characteristics.

2. Estimates of phenotypic and genotypic coefficients of variation have shown that phenotypic coefficients of variation were higher than genotypic coefficients of variation for all the characters.

3. Heritability estimates in the broad sense was high (above 70%) for all characters except days to harvest (54%) and starch content (60%).

4. Genetic gain was maximum for tuber yield per plant (98.71) and minimum for days to harvest (2.70).

5. Medium heritability (60.10) was shown by starch content while low heritability (54.10) was shown by days to harvest.

6. High heritability and high genetic gain of characters like tuber yield per plant, number of leaves per plant, number of tubers per plant and haulms weight per plant suggest that they are under additive gene action which can be improved by selection.

7. Positive significant correlations were shown by all the tuber characteristics except protein content (-0.159). While significant negative correlations were shown by all the shoot characters with tuber yield per plant.

8. The results of path analysis have revealed that number of tubers per plant had maximum direct effect on tuber yield per palnt. The tuber characters like number of tubers per plants, tuber girth, tuber length and individual tuber weight had positive direct effect on tuber yield. But all shoot characters except number of leaves per plant and leaf area had negative direct effects on tuber yield.

9. The residual effect of 0.0205 suggests that 98 per cent of the variation in yield were contributed by the eleven component characters considered for path coefficient analysis.

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Appendices

APPENDIX-1

ABSTRACT OF ANOVA IN THE OPEN CONDITION

Source	df	Mean squares							
		Shoot length	Tuber yield per plant (g)	Number of branches per plant	Number of leaves per plant	Leaf area per plant (cm^2)	Days to flowering	Days to harvest	Individual tuber weight
Treatment	29	94.124**	1481.762	35.765**	28937.658**	4914756.958**	59.562**	10.734**	49.034
Replication	2	26.238	17435.211	42.034	32750.672	36640.635	6.011	0.344	284.652
Error	58	16.038	964.772	9.990	10018.753	1844313.244	3.344	0.954	37.079

Source	df	Number of tubers/plant	Haulms weight (g)	Tuber length (cm)	Tuber girth (cm)	Tuber length/ Tuber girth	Starch content (%)	Protein content (%)
Treatment	29	28.602**	4628.981**	0.287	1.291	0.007	2.381**	0.326**
Replication	2	94.745	27566.981	0.280	11.184	0.051	1.652	0.150
Error	58	14.082	1341.045	0.338	0.864	0.012	0.396	0.028

** Significant at 1 per cent level

APPENDIX-2

ABSTRACT OF ANOVA IN THE SHADED CONDITION

Source	df	Mean squares							
		Shoot length	Tuber yield per plant (g)	Number of branches per plant	Number of leaves per plant	Leaf area per plant (cm²)	Days to flowering	Days to harvest	Individual tuber weight
Treatment	29	77.462**	1932.691**	11.030**	1913.198**	515886.609**	65.865**	19.751**	5.569**
Replication	2	101.378	1609.843	28.373	375.140	3540.591	258.421	98.250	12.409
Error	58	2.179	13.403	1.165	7.459	43.329	3.537	4.359	0.416

Source	df	Number of tubers/ plant	Haulms weight (g)	Tuber length (cm)	Tuber girth (cm)	Tuber length/ Tuber girth	Starch content (%)	Protein content (%)
Treatment	29	24.054**	3966.381**	1.763**	3.109**	0.046**	2.061**	0.976**
Replication	2	13.075	313.151	0.070	0.001	0.006	1.086	0.014
Error	58	0.104	3.660	0.005	0.023	0.002	0.374	0.034

** Significant at 1 per cent level

BIOMETRIC ANALYSIS OF YIELD AND OTHER ATTRIBUTES IN COLEUS (*Coleus parviflorus* Benth)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Studies were undertaken with thirty genotypes of coleus in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during 1995-96 to estimate the extent of genetic variability, association among the selected characters and its partition into direct and indirect effects through path coefficient analysis under open as well as shaded conditions.

The results have shown that the differences between the types were highly significant for most of the characters in the open condition and for all the characters in shaded condition.

Low heritability and low genetic advance were shown for most of the economically important tuber characters in the open while the heritability and genetic advance were much greater in the shaded for the economically important characters. Expected genetic advance has shown that by selecting five per cent superior plants from available population, tuber yield could be increased by 52 g per plant in the shaded condition.

Correlation studies have indicated that shoot characters like shoot length, number of leaves per plant and leaf area per plant and tuber characteristics like number of tubers per plant, tuber girth and tuber length are highly correlated with yield under open condition. However under shaded condition all the shoot characters are negatively correlated and all the tuber characters like number, length, girth and individual weight are to be given emphasis for identifying a high yielding genotype because of their high positive genotypic correlation with tuber yield.

Path analysis projects that greater emphasis has to be laid for improving girth of tuber, number of tubers per plant individual tuber weight and tuber length in the open condition in selection while number of tubers, individual tuber weight and tuber girth should be given emphasis when selection is done for tuber yield in shade grown coleus.