STABILITY ANALYSIS OF SELECTED MUTANTS OF COLEUS (*Solenostemon rotundifolius* [Poir.] J.K. Morton)

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Stability analysis of selected mutants of *Coleus* (*Solenostemon rotundifolius* [Poir.] J.K. Morton)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellanikkara
16-5-2003

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CERTIFICATE

Certified that the thesis entitled **"Stability analysis of selected mutants of *Coleus* (*Solenostemon rotundifolius* [Poir.] J.K. Morton)"** is a record of research work done independently by Mr. Shinoj under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

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Introduction

1. INTRODUCTION

Improvement of crop plants for yield and quality is the major and the most important aim of plant breeding. By various methods of plant breeding the breeders already have developed high yielding cultivars, which will give superior performance over the existing local cultivars. However, some of the varieties so developed may not perform better due to the interaction of genotypes with different environments. Though the newly developed cultivar is highly suited for the environment in which it is developed, it may not be performing well in another environment. This effect is generally called as the genotype x environment interaction. Comstock and Moll (1963) stated that larger the interaction, lesser would be the chances of progress under selection, in breeding programme.

One of the major success of biometrical techniques during the last few years has been in the investigations, elucidation and understanding of the genotype x environment interactions (Breese, 1972). Genotype x environment interaction implies the joint regulation of the phenotype by the genotype and the environment. Plant breeders are aware of the difficulties in crop improvement that arise from the influence of non-genetic factors in the performance of crops. Complications arising from differential response of genotypes to environments have also been considered in detail by many workers including Allard and Bradshaw (1964), Breese (1969) and Hill (1975).

Plants can make a physiological adjustment, which permits them to cope with the fluctuations in their immediate environments. It is collectively known as adaptations, which will give them stability in their performance over the environments.

Various models for the analysis of stability of genotypes over different environments have been formulated. By these models, the study of genotype x environment interaction is possible and general adaptation among different genotypes over various environments can be studied.

The plant breeders can develop cultivars specifically adapted to different environments or adapted to a broad spectrum of environments. A high level of genotype x environment interaction is favoured in breeding for specific environments. But this leaves the possibility of changing environments in the same location over seasons or years. So, the more effective alternative is to select cultivars on the basis of stability.

The performance of any genotype mostly depends on environmental interactions. Estimation of phenotypic stability which involves regression analysis has proved to be a valuable technique for assessing the response of various genotypes under differing environmental conditions and evaluation of genotype x environment interaction will give an idea of buffering capacity of the gene under study. The low magnitude of genotype x environment interaction indicates consistent performance of a population over varied environments.

Finley and Wilkinson (1963) made the first systematic approach to the analysis of phenotypic stability of cultivars or genotypes. Here two parameters namely, mean value over the locations and regression coefficients are used to asses stability. In 1966 Eberhart and Russel made further improvements in stability analysis by partitioning the genotype x environment interaction of each genotype into to parts, slope of regression line and deviation from the regression line. This model measures three parameters of stability, viz., mean values over environments, regression coefficients and deviation from the regression line and thus provide reliable information about stability.

Coleus (*Solenostemon rotundifolius* (Poir) J.K. Morton) is popularly known as 'Chinese potato' or 'Poor man's potato'. It is an environmentally friendly crop, which requires only small amount of fertilizers and is extensively cultivated in the homesteads of Kerala. Though this is considered as a minor tuber crop, the nutritive status of the crop compares favourably with many of the major tuber crops. *Coleus* tubers contains 20.1 to 30.0 per cent dry matter, 14.7 to 20.20.8 per cent starch, 0.04 to 0.31 per cent protein and 0.57 to 0.96 per cent sugar (Sreekumari and Abraham, 1985). The aromatic vegetable-cum-tuber possess an elite flavour and taste, which gives it a good consumer preference. It also possesses medicinal properties. The major uses are in heart diseases, abdominal colic, respiratory disorders, insomnia and convulsions. They are also used in the treatment of dysentery and certain eye disorders (Ammon and Muller, 1985).

The plant is a bushy annual herb belonging to the family Lamiaceae. The plants produce small dark brown aromatic tubers in cluster in the base of the stem. The crop prefers a hot humid climate for growth. Low night temperature is essential for proper tuberisation. The normal season is confined to the months of July to November.

The yield of minor tuber crops in Kerala is relatively low, ranging from 20 – 80 quintals per hectare. This is attributed to the poor yielding ability of the existing varieties (Hrishi and Nair, 1972). In the case of *Coleus*, per hectare yield is very low, which is one of the constraints in the cultivation of this crop.

In the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara, eleven mutants have been developed. The present study envisages to asses the yield stability of these mutants in the central zone of Kerala, where *Coleus* is being cultivated.

The main objectives of the present study are as follows

- Yield stability over various locations
- Response of genotypes in different environments
- Identification of best genotypes for the central zone of Kerala.

Review of literature

2. REVIEW OF LITERATURE

The genotype x environment interaction has been widely observed to play an important role in the expression of phenotypes. The interdependence of inherent endowment and environment influence had long been recognized in crop plants. In simple words, genotype x environment interaction can be considered as the variation that arises from the lack of correspondence between the genetic and non-genetic factors on the development of an individual. Therefore, for the improvement of yield and other characters in crop plants realization about the importance of such interactions is a must and the breeding programmes are selected accordingly.

A review of the works that had been done so far in various crops by geneticists and biometricians reflects the considerable importance that has now been attached to it in plant breeding programmes. It also gives an insight into the probable mechanisms by which the plant species combat the fluctuations in the environment.

2.1. ENVIRONMENT

When genotype x environment interaction is considered it will only be appropriate to have a clear understanding about the environment and its kinds. Environment is constituted by physical, chemical and biological factors and it influences, the biological organisms.

Comstock and Moll (1963) have classified the environments into two types.

2.1.1. Micro Environment

Micro-environment is the environment of a single organism as opposed to that of another, growing at the same time and in almost the same space. It includes variables having small unrecognized individual effects like physical and chemical attributes of soil, climatic variables like temperature and humidity, distribution and quality of solar radiation, insects pests and diseases to which the plants are exposed.

2.1.2. Macro Environment

Macro environment is composed of variables with large individual effects like locations, season or years, fertilizer levels, planting dates etc.

Allard and Bradshaw (1964) gave another classification of the environment.

2.1.3. Predictable Environment.

It includes the permanent features of the environment such as climate, soil type and day length. It also includes the controllable variables like, the level of fertilizer application, sowing dates, sowing density and methods of harvesting.

2.1.4. Durable Environment

It comprises the weather fluctuations such as difference between seasons in the amount and distribution of rainfall and the prevailing temperatures.

A low level of genotype x environment interaction will be desirable for the unpredictable environment so as to ensure maximum uniformity in performance. However, a high level of interaction is preferred in predictable environment to produce maximum increase in performance.

2.2. GENOTYPE X ENVIRONMENT INTERACTION

Genotype x environment interaction had long been known to occur in crop plants. Perhaps one of the earliest workers to recognize the importance of environment in determining the phenotypic expression was Johannsen. He stated that genes alone were not responsible for the personal endowments of an individual; the environment also had a part to play in determining the life situation (Johannsen, 1909). His pioneering work paved the way to a greater understanding of those processes by which the genotype and environment jointly regulate the development of particular individual; which was to have repercussions far beyond the confines of plant breeding.

Keeble and Pellow (1910) found 'Well-known seasonal fluctuations' affected height in peas, Akerman(1922) reported genetic difference affecting the chlorophyll of oat which was undeletable when the plant were grown in subdued light, but revealed it self by the bleaching and death of one genetic class when they were grown in direct sun light.

Hayes (1922) observed a very low correlation between the protein content of self-fertilized normal varieties of maize and the percentage of protein of their progeny grown in the following years; and he attributed it to the fluctuations in the environment. Similar parent off spring correlations were also obtained by Immer and Ausemus (1931), and O'Kelley and Hull (1932,1933).

The early reports on the environmental effects mentioned above can be regarded as mere casual observations, since no effort had been done to asses the interactions quantitatively. In later years, works had been done to measure the interaction effects and work out the stabilities parameter in various crops.

Though genotype x environment interaction have received considerable attention in recent years, in many important crops very little works of this nature had been done. A crop wise picture of some of the important research work in this line is presented below.

2.2.1. Potato

Nandekar *et al.*,(1993) evaluated seven varieties of potato for stability parameters with respect to tuber yield. Significant genotype x environment interaction was observed for tuber yield.

Haynes *et al*, (1995) reported significant clone x year interaction in the experiment 'genotype x environment interactions for specific gravity in diploid potatoes'. Haynes *et al*, (1997) in another study regarding the genotype x environment interaction for resistance to common scab in tetraploid potato observed significant genotype x environment interaction for the traits.

Eleven promising potato clones possessing late blight tolerance were evaluated for tuber yield, variability and adaptation across 10 environments in Kenya by Lungaho *et al*,(1998) and combined analysis of variance for tuber yield showed significant effects of genotypes, environments and genotype environment interaction.

Silva Pereira *et al*,(1998) estimated genotype x environment interaction produced using the additive main effects and multiplicative interaction (AMMI) model and the analysis of linear regression to compare the yield stability of potato, and suggested the AMMI analysis for the purpose.

Rajkumar and Kang (2001) in his stability analysis for tuber yield per plot analysed forty five genotypes and reported significant genotype x environment interaction.

2.2.2. Sweet Potato

According to Li (1975) in sweet potato additive component of genetic variance was relatively more important than none-additive for total root weight, average weight per root and number of roots. For total weight of leaves and stem, the main components of genetic variance were non-additive type. Similar results were obtained by Jones (1986).

Genetic Variability was studied in forty one varieties of sweet potato by Singh and Mishra (1975) for six character viz, length of vine per plant, number of branches per plant, number of leaves per plant, total leaf area per plant, number of tubers per plant and yield of tubers per plant. A wide range of genetic variability was observed in the quantitative characters. Differences among the varieties were highly significant, phenotypic, genotypic and environmental variances were of higher nature for all the characters studied except for number of branches per plant. Total leaf area gave the highest genotypic coefficient of variation, followed by length of vine, number of leaves and yield of tubers.

Investigations carried out by Thamburaj and Muthukrishnan (1976) indicated that in general, genotypic coefficient of variation was lower than phenotypic coefficient of variation indicating larger measure of environmental influence. The weight of tuber per plant, number of leaves per vine and the weight of foliage exhibited a high degree of both phenotypic and genotypic coefficients of variation while girth of stem had the least coefficient of variation.

In a study conducted with ten varieties of sweet potato, genotypic coefficient of variation was found to be lower than phenotypic coefficient of variation for all the characters studies indicating significant genotype x environment interaction (Kamalam *et al.*, 1977).

Kamalam *et al,(1978)* evaluated eight sweet potato cultivars for stability performance of yield at nine locations of Kerala to find out a suitable cultivar. The mean differences between the cultivars were highly significant, but none of the cultivars was ideally stable.

Maluf *et al.(*1983) observed high heritability values in sweet potato for number of tubers and vine length.

When eleven characters were evaluated in 15 cultivars of sweet potato, weight of dry matter, length of main stem, stem/tuber weight, internodes length and yield showed high heritability values, tuber weight and number of tubers had high genotypic coefficient of variation and genetic advance followed by yield per plant, length of main stem and number of branches (Lin, 1983).

Variability in the hybrid progeny of sweet potato was noted by Pillai *et al* (1990).

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

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

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

Evaluation of chemical composition and starch content for different cultivars of sweet potato showed significant difference in protein, starch, fiber and ascorbic acid content (Batistute *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).

Phemba *et al.*, (1998) evaluated eight sweet potato genotypes of diverse origin for their performance and stability in seven representative environments and combined analysis of variance showed significant differences between genotypes and environments, and significant genotype x environment interaction effects.

2.2.3. Cassava

In asexually reproducing plants like Cassava, any combination of genetic factors that yields a superior genotype can be used through clonal propagation. In such circumstances, all genetic variability can be used and heritability estimates have meaning (Hanson, 1963).

Biradar *et al.* (1978) conducted detailed investigation with 12 varieties of cassava to estimate genetic variability for seven quantitative characters. In general, phenotypic coefficient or variation was higher than the genotypic coefficients of variation for all the characters studied. Phenotypic and genotypic coefficient of variation, heritability and genetic advance estimates were high for number of nodes and tuber yield per plant, indicating considerable scope for the improvement of economic traits like tuber yield.

Kawano *et al.* (1978) *has* reported that there was enormous genetic variation for the harvest index in seedling populations of cassava and by virtue of its high heritability could be effectively used as an indicator for seedling selection.

In cassava heritability of harvest index was much higher than that of root yield and total plant weight under both very high yielding and low yielding environments. This indicated that harvest index was a highly stable character over a wide range of environments while yield and total plant weight were not that much stable (Anon, 1979)

Six diverse cassava populations were grown during 1979-80 and 1980-81 at IITA and were investigated to estimate genetic parameters for twenty-two traits of cassava. The data on analysis revealed that considerable variation exists both within and between populations for most of the characters. The coefficient of variation for phenotype and genotype were largest for root yield, quite large for the roots per plant and root size, moderate for harvest index and total number of branches and low for stem girth, canopy width and plan height at harvest (Mahungu *et al.*, 1983)

In a study to estimate the variability among ten varieties of cassava by Rai *et al.* (1986), characters like height of plant, average weight of tuber, number of tubers, girth of the 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.

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

In cassava Suthanthirapandian *et al.* (1994) reported that 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 can be based on phenotypic value itself.

2.2.4. Coleus

Coleus, which is classified under a minor tuber crop, has not yet gained enough importance because of the western based research. The researchers are now slowly recognizing the importance of this crop due its medicinal importance. Characterising the minor tuber crop with greater clarity contributes to food security in periods of nutritional stress and they merit more public sector attention than they have received (Blench, 1997). As of now no organised research has done in *Solenostemon rotundifolius*, which is classified under minor tuber crop.

This belongs to the genus *coleus* and to the family Lamiaceae. The generic name is derived from the Greek word *Koleos* meaning sheath.

Variability within coleus was reported by Sreekumari and Abraham (1985).Teratological variations in *Coleus perviflorus* was reported by Amalraj *et al.* (1989).

Vimala (1994) reported that there was no significant difference in yield between the different accessions of *Coleus* maintained in the germplasm at CTCRI, Trivandrum. But one accession CP-58 gave a comparatively higher yield and was released as 'Sreedhara'.

Prakash (1996) reported that tuber characters like tuber yield per plant, tuber length, tuber girth and tuber length to girth ratio did not show any significant difference among genotypes of *Coleus*.

2.3. STABILITY IN CROP PLANTS

Plants are equipped in a variety of ways to cope up with their environments. This is made possible by the general and specific adaptations developed in species or population during the course of evolution (Wallace and Srb, 1963). Considerable interest exists in the mechanism by which an individual stabilize its behaviour in the face of varying environmental influences (Bradshaw, 1965).

Mather (1943), proposed that an adapted genotype or population is one which survives the selection pressure by exhibiting a better performance than that of the standard.

Wild populations of plants display a series of comprehension between special and general adaptations, depending upon the prevailing ecological circumstances and post-evolutionary history (Mather, 1943)

Lerner (1954) termed 'Genetic homeostasis' for the mechanism by which genotypes are flexible and can adjust their genotypic and phenotypic states in response to the different environmental conditions.

Grafius (1956), working on oats, explained the phenomenon of component compensation as a mechanism in parting homeostasis for the complex characters like yield. Similar biological explanations were reported by Bains and Gupta (1972) in Wheat and Peter and Rai (1976) in tomato.

Adams and Shank (1959) reported that the coefficients of variability in different environments were larger for the inbreds than hybrids.

Jain and Allard (1960) found that the maintenance of genetic variability in self-pollinated crops depended not only on the low incidence of natural crossing among the genetically diverse lines but also on the substantial heterozygote advantage.

Allard (1961), working on lima beans, reported that advanced generation hybrid population were highly buffered. Similar results were obtained by Finlay (1963) in barley.

Simmonds (1962) reviewed the evidences that mixed population in self-pollinated crops were more stable in yield than their components.

Griffing and Langridge (1963) reported that the heterozygotes in self-pollinated crops did not differ in the heterotic response under favourable environments; but under unfavourable environments, the hybrids had a greater advantage over the homozygotes. Allard and Workman (1963) obtained similar results working on lima beans.

Allard and Bradshaw (1964) suggested two ways by which a variety can achieve stability and termed them individual buffering and population buffering.

Rao *et al.* (1969) disproved the belief that hybrids were meant for better farming conditions, in their studies on the stability of hybrids and varieties of sorghum under stress and non-stress conditions.

Heterozygosity was found to play a significant part in determining response to different environments in both diploids and tetraploid potatoes (Sekhon and Rowe, 1969).

Reich and Atkins (1970) reported that two-component hybrid blends of sorghum were the most stable in a trial that involved parental lines, hybrids and two-component blends of parental lines besides hybrid blends.

Jowett (1972) found the hybrids in sorghum to be more stable than parents and obtain evidences which suggests that three-way crosses might be more stable than single cross hybrids. However, Majisu and Doggert (1972) obtained no convincing evidence of stability differences between varieties and hybrids as broad genotype grouping.

Studies had also been carried out to relate stability directly to the metabolic and other functions occurring at cellular level.

Das and Jain (1972) reported significant correlation in stability of yield with chiasma frequency and mitotic index in Wheat, there by indicating the possibility of ascertaining stability by cytological parameters.

Tai and Young (1972) working with potato defined the general adaptatability as having average genotypic stability and above average mean performance.

Tara Mohan and Jain (1975) working on Wheat, found that a stable variety was equipped with the ability to maintain a relative constancy in the amount of DNA and relative plasticity in the synthesis of RNA.

Kamalam *et al.*(1978) working with sweet potato reported that major componenet for difference in stability is due to the linear regression and not due to deviations from the linear function.

Mahajan and Khehra (1992) in maize reported that inbred line in hybrid combination performed well than the hybrids and also deviations from the regression appeared to be a more important parameter than regression for measuring stability.

Tomar and Singh (1992)in a study for the phenotypic stability of hybrids reported that, though in general, the genotypes with relatively high performance possesed low stability, a hybrid , RG-10 x G-27 was highly stable with the highest mean value.

Balakrishnan *et al.*(1993)working with garlic emphasizes the need for attempting non-linear methods for studying the stability of garlic varieties.

Haynes *et al.*(1995) in his work in diploid potatoes for specific gravity reported that there was no correlation between average specific gravity and the stability indicating that selection for high specific gravity should not result in clones that are less stable for specific gravity.

Dumoulin *et al.*(1996) reported that in pea the environmental effects were important since all components including all interaction terms between year , location and sowing date were significant.

Haynes *et al.*(1997) in his experiments in potato reported that most scab resistant genotypes were most unstable, whereas, the most susceptible genotypes were the most stable.

Ahuja *et al.*(1998)while working in cotton observed that, in general morphotypes stable for yield were unstable for percent bollworm damage.

Srivastava and Kamalesh Ram (1998) working with sesame reported that yield stability analysis and estimation of drought susceptibility index indicate that the genotypes which have poor yield potential under non-stress condition are more resistant to moisture stress. However, the wide range of yield stability index suggests that breeding objective should be to combine the high yield potentiality of genotypes with stability.

Hegde *et al.* (2000) in niger reported that, the stability parameters appeared to be governed by different genes or genes in combination. However linear components was larger in magnitude than the non-linear.

Solanki *et al.*(2000) in his study 'stability analysis for seed yield in finger millet' showed that both linear and non-linear components of genotype x environment interaction were significant in the yield stability of garlic.

2.4. HERITABILITY AND GENETIC ADVANCE

Heritability indicates the effectiveness with which the selection of genotypes can be based on phenotypic performance (Johnson *et al.*, 1955). It specifies the proportion of total variability that is due to genetic causes or it is the ratio of the genetic variance to the total variance (Allard, 1960). The heritability estimates also provides a clear picture of the average effect of the genes transmitted from parents to the offspring or the extent to which the heritability of the quantitative character is transferable to the progeny. However heritability estimates along with genetic gain were more useful 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 15 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 tubers 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). Kawano *et al.* (1978) had reported that there was enormous genetic variation for harvest index in seedling populations of cassava and by virtue of its high heritability could be effectively used as an indicator for seedling selection. In cassava, heritability of harvest index was much higher than that of root yield and total plant weight under both very high yielding and low yielding environments. This indicated that harvest index was a highly stable character over a wide range of environments where as yield and total plant weight were not as stable.

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

In a study involving 75 genotypes of cassava, Suthanthirapandian *et al.* (1994) reported that highest genetic advance was noticed for number of leaves. Among the economic characters, highest genetic advance was noticed for tuber yield per plant followed by number of tubers, single tuber weight and tuber length. The highest heritability was found for number of leaves. In taro, estimate of genotypic and phenotypic variance coupled with high heritability was noticed for length of and diameter of cormel. All the characters showed heritability exceeding 60 percent. This indicates the scope for attaining high yielding clones from local population of taro (Apte *et al.*, 1994). Harvest index is closely associated with yield (Sinclair, 1998).

2.5. CORRELATION STUDIES

One of the important objectives in a breeding programme is the incorporation of the genetic potential from high yield in a variety. Since yield is a complex character it is worthwhile to estimate the influence of the association existing between the variable characters and yield. Correlation studies were conducted to determine the interrelationship among various traits, which are useful in making selection. Generally estimates of genetic correlations are of very low precision. A knowledge of the magnitude and sign helps to understand how the improvement in one character will cause simultaneous change in other characters. A comparison of phenotypic and genotypic correlations would give an indication of the effect of environment on the genetic performance of individuals of a population.

Galton (1889) conceived the idea of correlation of variables for the first time. Williams and Gazali (1979) has reported that harvest index of high yielding cassava was very high and that high yield was not necessarily due to the production of large total biomass. They also suggested that difference in yield might be associated with an improved canopy structure with narrow leaves that becomes more vertically oriented at midday. The mean components of yield in tuber crops were the number and mean weight of tubers, which were directly related to the process of tuber initiation and tuber growth (Wilson 1973).

Enyi (1973) reported negative relationship between leaf area and tuber yield in dwarf plants of tapioca. Bulking rate increased with increase in leaf area index, reaching a maximum at a leaf area index of 3.5. In tapioca high yields could be achieved with low leaf production cultivars provided that high harvest index were realized. An investigation with M_4 variety of tapioca revealed that the yield of tubers had a positive correlation with the length of tuber, girth of tuber, number of nodes per plant and height of the plants. Leaf area and tuber yield were negatively correlated while leaf length and breadth were positively correlated. The node number had a positive correlation with characters other than leaf area. The height of plants recorded a positive relationship with length, girth, and yield of tubers while leaf area exhibited negative relationship. (Muthukrishnan *et al.*, 1974). Magron and Krishnan (1973) reported that in tapioca tube length, circumference and number per plant were positively correlated with tuber yield but tuber number per plant was negatively correlated with tuber length and circumference. High leaf number was positively correlated with high yield.

The traits such as starch, dry matter, crude protein and cyanide content were independently inherited. Holmes and Wilson (1974) reported that in cassava, there was significant negative correlation between tuber number and mean tuber weight in high yielding and low yielding cultivars. Workers at IITA Nigeria indicated significant positive correlation between number and size of tubers with yield in tapioca (Anon, 1987). Determination of correlation in sweet potato revealed that a increase in the length of vine causes significant increase in tuber yield, but leaf area had negative correlation with yield (Pushkaran *et al.*, 1976). An investigation with 65 clones of sweet potato indicated the number of tuber per vine, girth of tubers, weight of foliage, number of branches per vine, number of leaves per vine, length of petiole had high degree of positive association between tuber yield both at phenotypic level and genotypic levels while the characters like the girth of stem and length of vine had negative correlation (Thamburaj and Muthukrishnan, 1976).

In a study to estimates correlation on sweet potato, Kamalam *et al.* (1977), found that number of tubers had positive significant correlation with yield. But length as well as the weight of vine showed significant negative correlation with yield in cassava, the harvest index, number of tubers per plant and mean tuber weight showed positive correlation with the yield (Biradar *et al.*, 1978). Kawano *et al.* (1978) reported significant positive correlation between harvest index and yield based on population studies in cassava. Lakshmi and Amma (1980) recorded positive significant correlation of number of shoots, number of branches and 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 and length of tubers had positive correlation with yield. Correlation studies by Sreekumari and Abraham (1985) showed that in *Coleus* tuber yield was positively and significantly correlated with shoot length and number of branches. The harvest index was positively correlated with number of tubers and tuber girth.

Ibrahim (1987) found new significant correlation between tuber yield on sweet potato. Mohankumar *et al.* (1990) indicated that mean weight of cormel; number of cormels per plant and leaf area index was positively and significantly correlated with yield. Correlation studies for 7 characters in cassava showed that tuber yield was positively correlated with all the characters except petiole length (Naskar *et al.* 1991).

Sreekumari and Abraham (1985) reported negative correlation between shading and tuber development and that it was less for shoot and leaf formation. Girth of stem and tuber showed significant positive correlation with tuber yield under shade. Nanda (1994) reported that in sweet potato, marketable tube yield was positively and significantly correlated with number of tubers per plant but neck length was negatively correlated with yield. In sweet potato vine length, number of branches, number of leaves and tuber yield showed high genotypic and phenotypic coefficient of variation from data of eight quantitative characters in 25 genotypes of sweet potato. (Kumar *et al.*, 1996).

2.6. PATH COEFFICIENT ANALYSIS

Path coefficient analysis devised by Wright (1921) is a standardised partial regression coefficient and as such measure the direct influence of one variable upon another and permits the separation of correlation coefficients into components of direct and indirect effects. Working on crested weed grass Dewey and Lu (1959) demonstrated the method of path coefficient on the analysis of correlation in a system of correlated variables which was widely employed by the animal breeders but only rarely by plant breeders. Analysis of seventeen varieties of sweet potato by Pushkaran *et al.* (1976) showed that yield was influenced by the first order components like girth off tubers, number of tubers and length of tubers, the direct effect of last two being more pronounced. An increase in the second order components of vine, length of vine caused a significant increase in the tuber yield but was associated with an increase in the leaf area which had negative correlation with yield. It is concluded that attempt to increase vine length should be coupled with selection of reduced leaf area.

Thamburaj and Muthukrishanan (1976) on sweet potato indicated that weight of foliage, girth of tubers 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. The study to estimate path coefficient using six characters in ten varieties of sweet potato (Kamalam *et al.*, 1977) found that number of tubers showed maximum positive direct as well as indirect effects on yield. Path coefficient analysis in sweet potato for seven characters with 22 genotypes showed that length of tubers had maximum direct effect on yield (Naskar *et al.*, 1986).

Ibrahim (1987) reported that root characters like 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 characters, shoot character will be of little importance. Maximum direct effect was observed for mean weight of cormels with yield in taro by Mohankumar *et al*. (1990).

Rekha *et al.* (1991) reported that path analysis of yield components of eight cassava accessions revealed that single tuber weight contributed maximum direct effect to tuber yield. Single tube weight, girth of the tubers and length of tubers were found to be the three factors exerting considerable influence directly and indirectly on tuber yield in cassava. Path coefficient analysis revealed that the maximum direct effect on tuber yield was through tuber weight in sweet potato (Kumar *et al.*, 1996)

Materials and methods

3. MATERIALS AND METHODS

The present investigation envisages to evaluate eleven selected mutants of *Coleus* at four test sites in the central zone of Kerala, to work out genotype x environment interaction and stability parameters for yield.

The materials for this study comprised 11 promising mutants of *Coleus* obtained through mutation breeding in the Department of Plant Breeding and Genetics along with one local cultivar and two released varieties as check details of which are furnished in table 1.

Table.1. Details of the genotypes used in the study

Sl. No	Name of the cultivar
1	641
2	Sreedhara
3	1041
4	61-b
5	111
6	121-b
7	412
8	112
9	Local cultivar
10	61-a
11	Nidhi
12	1042
13	352
14	121-a

The experiment was conducted at 4 different locations representing Malappuram, Thrissur, Palakkad and Ernakulam district, in the farmer's field in Edavanna, Kodassery, Cherpulassery and Aduvassery representing Malappuram, Thrissur, Palakkad and Ernakulam districts during Kharif 2001.

3.1. MATERIALS

14 genotypes of *Coleus* including 11 mutants evolved through mutation breeding in the Department of Plant Breeding and Genetics, College of Horticulture, Thrissur, two released varieties of *Coleus* and one high yielding local cultivar constituted the materials for the study (table.1)

3.2. METHODS

Selected 11 mutants of *Coleus* along with the two released varieties and one local check were evaluated for genotype x environment interaction in the selected places of four districts of the central zone of Kerala as detailed below.

	District	Place selected
1.	Malappuram	Edavanna
2.	Thrissur	Kodassery
3.	Palakkad	Cherpulassery
4.	Ernakulam	Aduvassery

The experiment at these four districts were laid out in randomised block design with three replications. Each plot was of size 124.7 m^2 with 42 beds per plot. In each bed 10 plants of one variety were planted in 20 cm apart. Uniform care and management was given to the crop as per the Package of Practices Recommendations of the Kerala Agricultural University (KAU, 1996). A random sample of best five plants per bed was selected and observations were recorded for the following characters.

3.3. BIOMETRICAL OBSERVATIONS

Biometrical observations were recorded for the following traits, from 5 plants in each bed and the mean value worked out on per plant basis.

3.3.1. Height of the Plant at Harvest

The length of the vine of individual plants was measured from the base to the tip of the longest vine in centimetres.

3.3.2. Number of Days to Tuberisation

Total days from the date of planting till the tuber initiation for each plant was worked out in each bed and mean for each genotype was worked out.

3.3.3. Number of Days to Flowering

Total number of days from the date of planting till flowering and mean for each genotype was worked out.

3.3.4. Number of Tubers Per Plant

Total number of tubers from each plant was counted and average worked out.

3.3.5. Size and Grade of Tubers

Seven grades were given to the tubers viz. 1.very small, 2. Small and Very Small, 3. Small, 4. Small and Medium, 5. Medium, 6. Medium and large and 7. Large. These grades were given to each plant and average grade per each bed was worked out.

3.3.6. Tuber Yield Per Plant

The total weight of the marketable tubers per plant in grams was recorded and the average worked out.

3.3.7. Harvest Index

Harvest index was calculated as the ratio of the tuber yield to the total biomass.

3.3.8. Pest and Disease Incidence

Three grades were given viz. 1. Mild, 2. severe and 3. resistant. These grades were given to each plant and average was worked for each mound.

3.3.9. Duration of the Crop

Total number of days from the date of planting till the date of harvest was worked out and the average for each mound was worked out.

3.3.10. Chemical Analysis

Chemical analysis of the tubers for the following traits were done and the average was worked out.

3.3.10.1. *Protein Content*

Healthy tubers of each variety were selected from each plot. 500 mg of the sample for each variety was taken and the amount of protein in the samples was estimated using Lowery's method (Lowery *et al.*, 1951). The values were expressed as mg/g of the sample. The values were expressed as % weight of the sample.

3.3.10.2. *Starch Content*

Healthy tubers of each variety were selected from each plot. 0.2 g of the sample for each variety was taken and the percentage of starch in the sample of tuber was estimated using anthron reagent (Hodge and Hofreiter, 1962) and the values were expressed as % weight of the sample.

3.3.11. Organoleptic Evaluation of the Cooked Tubers

The tubers harvested separately from each genotype were washed and stored at room temperature. These tubers were cooked and screened for colour, appearance, texture, flavour and Taste. The organoleptic qualities were calculated as the mean of the rating for these characters. Scoring was done based on a scale of 0 to 10. 10 representing maximum favourable expression of all characters mentioned above. The average values of genotypes were classified into three groups as < 4 = Poor, 4 and <6 = Medium and >6 = good.

3.4. STATISTICAL ANALYSIS

The data obtained from the field experiments, chemical analysis and the organoleptic quality tests were subjected to the following statistical analysis.

The data obtained from the four locations, viz., Aduvassery (location I), Cherpulassery (location II), Kodassery (location III) and Edavanna (location IV) were subjected to location wise analysis of variance followed by stability analysis. Measures like mean, variance, standard deviation, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were calculated as per Snedecor (1961). Heritability, genetic advance (GA), genetic gain (GG), phenotypic and genotypic correlations and path analysis were carried out following methods compiled by Singh and Choudhary (1985).

The model of Eberhart and Russel (1966) were used for stability analysis with 14 genotypes tested in four environments. For carrying out the various statistical analysis the software package SPAR 1 was used.

Results

4. RESULTS

The ultimate aim of any plant-breeding programme is to develop a variety, which will show superiority in economic traits over the available ones. In most of the cases the aim of the breeder will be centered around the development of a variety, which is high yielding.

More over the high yielding genotype that is developed should be stable over different environments. That means a variety, which is superior due to its yield potential or due to some other characters like resistance should show a stable performance over locations and seasons. Then it can be referred as a superior one.

Yield, as it is a quantitative character will depend upon various other component characters. The environment is also having a major role in determining the yield either directly or through other component characters. As the present study envisages to evaluate the yield stability of 14 genotypes of coleus, a location wise picture of the characters for their stability is needed.

The analysis of variance was done for 17 characters in four environments and a detailed result of the analysis is presented below.

4.1. ANALYSIS OF VARIANCE FOR THE 17 CHARACTERS OVER THE ENVIRONMENTS

4.1.1. Location I (Ernakulam)

Mean values of coleus genotypes in location-I for the 17 characters are presented in Table.2 and ANOVA is presented in Table.3.

Mean of the character- Height of the plant at harvest ranges from 31.33 to 47.00cm. This showed significant difference among the genotypes. Number of days to tuberisation did not show any significant difference among the genotypes. It showed a lesser range of variation of 62.33 to 69.00. The same trend is indicated by number of

Table.2. Means of different characters of coleus genotypes at location in Ernakulam

Sl. no.	Treatment	Height of the plant at harvest (cm)	Days to tuberisation	Days to flowering	Pest and disease incidence	No. of marketable tubers	Size and grade of tubers	Tuber yield per plant (gm)	Total biomass (gm)	Harvest index
1	'641'	38	69.00	49.0	2.00	9.73	2.73	104.67	216.67	0.50
2	'Sreedhara'	45.33	62.33	49.0	2.00	8.87	2.33	93.67	243.33	0.44
3	'1041'	37.67	69.00	49.0	2.00	9.00	2.73	115.00	239.67	0.50
4	'61-b'	29.67	69.00	49.0	2.00	7.13	2.33	69.67	147.00	0.47
5	'111'	32.0	62.33	49.0	2.00	9.8	2.33	96.00	197.00	0.50
6	'121-b'	28.67	69.00	49.0	2.00	9.4	2.67	107.00	220.67	0.47
7	'412'	47.0	62.33	49.0	2.00	13.13	2.80	163.33	350.33	0.49
8	'112'	38.33	69.00	49.0	2.00	10.20	2.60	108.33	246.33	0.44
9	Local	31.33	62.33	55.67	2.00	10.93	1.93	73.33	144.00	0.53
10	'61-a'	36.67	69.00	55.67	2.00	10.27	3.33	115.33	253.00	0.46
11	Nidhi	36.00	69.00	55.67	2.00	12.47	2.73	129.67	260.33	0.50
12	'1042'	31.33	69.00	55.67	2.00	10.53	1.53	87.67	181.33	0.51
13	'352'	40.67	69.99	55.67	2.00	0.93	3.00	122.00	259.00	0.48
14	'121-a'	36.33	69.00	55.67	2.00	8.47	3.00	107.33	240.67	0.46

Table.2. Contd.

Sl.no.	Treatment	Duration of crop (Days)	Starch content (%)	Protein content (%)	Colour of the cooked tubers	Appearance of the cooked tubers	Texture of the cooked tubers	Flavour of the cooked tubers	Taste of the cooked tubers
1	'641'	120.00	19.10	0.06	3.00	3.00	2.00	3.00	2.00
2	'Sreedhara'	120.00	14.30	0.04	3.00	3.00	3.00	3.00	3.00
3	'1041'	120.00	15.40	0.10	3.00	3.00	3.00	3.00	3.00
4	'61-b'	120.00	8.20	0.10	2.00	2.00	3.00	3.00	3.00
5	'111'	120.00	14.50	0.10	3.00	3.00	2.00	2.00	2.00
6	'121-b'	120.00	9.70	0.05	2.00	2.00	2.00	2.00	2.00
7	'412'	120.00	11.30	0.09	3.00	3.00	3.00	2.00	2.00
8	'112'	120.00	11.40	0.09	3.00	3.00	3.00	3.00	3.00
9	Local	120.00	8.20	0.09	2.00	2.00	3.00	3.00	3.00
10	'61-a'	120.00	10.50	0.05	3.00	3.00	3.00	3.00	3.00
11	Nidhi	120.00	12.78	0.10	2.00	3.00	3.00	2.00	2.00
12	'1042'	120.00	10.90	0.06	3.00	3.00	3.00	3.00	3.00
13	'352'	120.00	12.90	0.09	3.00	3.00	3.00	3.00	3.00
14	'121-a'	120.00	8.40	0.06	2.00	3.00	3.00	3.00	2.00

Table.3.Analysis of variance for different characters of coleus genotypes at location in Ernakulam

Source of variation	Mean Sum of Squares									
	df	Height of the plant at harvest (cm)	Days to tuberisation	Days to flowering	Pest and disease incidence	No. of marketable tubers	Size and grade of tubers	Tuber yield per plant (gm)	Total biomass (gm)	Harvest index
Replication	2	392.00	152.38	152.38	0.0	3.76	2.78	2.82×10^{-3}	0.29×10^{5}	0.024
Treatment	13	90.99*	29.30	29.30	0.0	9.04*	0.63	1.67×10^{-3}	0.81×10^{4}	0.0021
Error	26	44.17	29.30	29.30	0.0	3.33	0.77	1.21×10^{-3}	0.51×10^{4}	0.0044

Table.3.Contd

Source of variation	Mean Sum of Squares								
	df	Duration of crop (Days)	Starch content (%)	Protein content (%)	Colour of the cooked tubers	Appearance of the cooked tubers	Texture of the cooked tubers	Flavour of the cooked tubers	Taste of the cooked tubers
Replication	2	0.00	0.46×10^{-3}	0.11×10^{-7}	0.21×10^{-5}	0.65×10^{-5}	0.65×10^{-5}	0.65×10^{-5}	0.43×10^{-5}
Treatment	13	0.00	29**	0.0013*	0.74**	0.54**	0.54**	0.65**	0.79**
Error	26	0.00	0.32×10^{-4}	0.65×10^{-9}	0.16×10^{-6}	0.50×10^{-6}	0.50×10^{-6}	0.50×10^{-6}	0.33×10^{-6}

days to flowering with a range of 49.00 to 55.67, with out any significant difference among the genotypes. There was a mild infection of pests and diseases but no significant difference was noticed among the genotypes. Significant difference was noticed in the number tubers per plant among the genotypes with a range of variation of 7.13 to 13.13. There was no significant variation among the genotypes with respect to the size and grade of the tubers, which ranges from 1.53 to 3.33. Even though a high range of variation of 69.67 to 129.67 g was noticed in tuber yield per plant, there was non-significant difference among the genotypes. The same trend was exhibited in the case of total biomass, which has a range of 144.00 to 350.33 g with out any significant difference among the genotypes. The harvest index showed a range of 0.44 to 0.53 with out any significant difference among the genotypes.

Among the qualitative characters starch content, protein content and the organoleptic qualities like colour, appearance, texture, flavour, and taste of the cooked tubers showed significant difference among the genotypes. The range of variation for the starch content and protein content were 6.61 to 19.60 and 0.3 to 0.1 respectively. For the organoleptic characters the range of variation was 2.00 to 3.00.

4.1.2. Location II (Palakkad)

In location II (Palakkad District) among the 17 characters studied, 10 characters showed significant difference among the genotypes. These characters are as follows. Height of the plant at harvest, number of days to flowering, size and grade of the tubers, starch and protein content of the tubers, and the organoleptic qualities like colour appearance, texture, flavour and taste.

Height of the plant at harvest ranges from 38 cm to 55.53 cm. Number of days to flowering and days to tuberisation has the same range of 61.00 to 70.00. In the case of number of tubers per plant the range was 6.00 to 11.40 and its size and grade has a range of 3.07 to 5.07. The tuber weight per plant and total biomass has the range of 103.67 g to 191.67 g and 187.0 to 367.00g respectively. Harvest index ranged from 0.33 to 0.65. The range of qualitative characters where as follows. 7.10 to 17.90 for starch, 0.03 to 0.10 for protein. For the organoleptic qualities like colour, appearance, texture, flavour and taste of the cooked tubers the range was from 2.00 to 3.00.

Mean values for the 17 characters are presented in Table.4 and ANOVA is presented in Table.5.

4.1.3. Location III (Thrissur)

Among the quantitative characters studied the 14 coleus genotypes at location III (Thrissur district) height of the plant at harvest, number of days to flowering, number of tubers per plant, and total biomass showed significant difference among the genotypes. Their mean values ranged as follows. Height of the plant at harvest ranged from 34.00 to 64.00 cm, number of days to flowering ranged from 66.00 to 76.33, number of tubers per plant ranged from 7.13 to 15.93 and for the total biomass, the range was from 199.33 to 285.67 g.

The qualitative characters namely starch content and protein content of the tubers differed significantly among the genotypes with a range of 6.61 to 19.60 % and 0.03 to 0.1 % respectively. The organoleptic qualities namely colour, appearance, texture, flavour and taste of the cooked tubers showed significant difference with a common range of 2.00 to 3.00.

Mean values for the 17 characters are presented in table.6 and ANOVA is presented in table.7

4.1.4. Location IV (Malappuram)

In the location IV (Malappuram District) significant difference were noticed for the quantitative characters namely height of the plant at harvest, number of tubers per plant, size and grade of the tubers, tuber yield per plant and total biomass. Their range of variation were, 34.00 to 59.0 for the height of the plant at harvest, 3.53 to 14.13 for

Table.4. Means of different characters of coleus genotypes at location in Palakkad

Sl. no.	Treatment	Height of the plant at harvest (cm)	Days to tuberisation	Days to flowering	Pest and disease incidence	No. of marketable tubers	Size and grade of tubers	Tuber yield per plant (gm)	Total biomass (gm)	Harvest index
1	'641'	52.67	61.00	61.00	2.00	8.13	4.73	187.33	327.00	0.57
2	'Sreedhara'	49.73	64.00	64.00	2.00	6.53	4.20	164.47	282.00	0.60
3	'1041'	47.20	64.00	61.00	2.00	8.60	3.67	160.67	255.00	0.64
4	'61-b'	48.33	61.00	61.00	2.00	11.40	3.20	152.53	257.33	0.57
5	'111'	49.07	64.00	61.00	2.00	6.67	5.07	186.33	314.67	0.61
6	'121-b'	42.67	64.00	61.00	2.00	7.87	3.33	109.00	187.00	0.59
7	'412'	51.67	64.00	67.00	2.00	11.20	3.07	131.67	323.33	0.43
8	'112'	51.00	70.00	64.00	2.00	7.20	4.33	181.33	373.67	0.50
9	Local	42.67	64.00	64.00	2.00	6.00	3.73	107.00	220.33	0.51
10	'61-a'	50.33	67.00	70.00	2.00	8.33	3.07	103.67	247.67	0.44
11	Nidhi	38.00	64.00	64.00	2.00	9.93	3.67	141.67	223.00	0.65
12	'1042'	42.00	61.00	61.00	2.00	7.67	3.73	184.33	298.00	0.61
13	'352'	53.00	61.00	61.00	2.00	8.47	4.53	191.67	365.67	0.53
14	'121-a'	55.53	64.00	67.00	2.00	7.27	3.53	121.00	367.00	2.53

Table.4. Contd.

Sl.no.	Treatment	Duration of crop (Days)	Starch content (%)	Protein content (%)	Colour of the cooked tubers	Appearance of the cooked tubers	Texture of the cooked tubers	Flavour of the cooked tubers	Taste of the cooked tubers
1	'641'	130.00	14.70	0.07	3.00	3.00	2.00	3.00	2.00
2	'Sreedhara'	130.00	14.50	0.03	3.00	3.00	3.00	3.00	3.00
3	'1041'	130.00	11.40	0.10	3.00	3.00	3.00	3.00	3.00
4	'61-b'	130.00	7.10	0.09	2.00	2.00	3.00	3.00	3.00
5	'111'	130.00	13.20	0.10	3.00	3.00	2.00	2.00	2.00
6	'121-b'	130.00	12.70	0.05	2.00	2.00	2.00	2.00	2.00
7	'412'	130.00	8.10	0.09	3.00	3.00	3.00	2.00	2.00
8	'112'	130.00	8.40	0.09	3.00	3.00	3.00	3.00	3.00
9	Local	130.00	7.50	0.08	2.00	2.00	3.00	3.00	3.00
10	'61-a'	130.00	14.30	0.05	3.00	3.00	3.00	3.00	3.00
11	Nidhi	130.00	9.63	0.10	2.00	3.00	3.00	2.00	2.00
12	'1042'	130.00	14.30	0.05	3.00	3.00	3.00	3.00	3.00
13	'352'	130.00	17.90	0.09	3.00	3.00	3.00	3.00	3.00
14	'121-a'	130.00	8.20	0.05	2.00	3.00	3.00	3.00	2.00

Table.5. Analysis of variance for different characters of coleus genotypes at location in Palakkad

Source of variation	Mean Sum of Squares									
	df	Height of the plant at harvest (cm)	Days to tuberisation	Days to flowering	Pest and disease incidence	No. of marketable tubers	Size and grade of tubers	Tuber yield per plant (gm)	Total biomass (gm)	Harvest index
Replication	2	17	13	25	0.0	3	0.66	0.68×10^{4}	0.24×10^{5}	1.1
Treatment	13	75*	18	25*	0.0	8	1.3**	0.31×10^{4}	0.10×10^{5}	0.84
Error	26	27	17	10	0.0	6.5	0.43	0.15×10^{4}	0.61×10^{4}	0.98

Table.5. Contd.

Source of variation	Mean Sum of Squares								
	Df	Duration of crop	Starch content	Protein content	Colour of the cooked tubers	Appearance of the cooked tubers	Texture of the cooked tubers	Flavour of the cooked tubers	Taste of the cooked tubers
Replication	2	0.00	0.76×10^{-4}	0.28×10^{-7}	0.21×10^{-5}	0.65×10^{-5}	0.65×10^{-5}	0.65×10^{-5}	0.43×10^{-5}
Treatment	13	0.00	0.34×10^{2}**	0.16×10^{-2}**	0.74**	0.54**	0.54**	0.65**	0.79**
Error	26	0.00	0.12×10^{-4}	0.25×10^{-8}	0.16×10^{-6}	0.50×10^{-6}	0.50×10^{-6}	0.50×10^{-6}	0.33×10^{-6}

Table.6. Means of different characters of coleus genotypes at location in Thrissur

Sl. no.	Treatment	Height of the plant at harvest (cm)	Days to tuberisation	Days to flowering	Pest and disease incidence	No. of marketable tubers	Size and grade of tubers	Tuber yield per plant (gm)	Total biomass (gm)	Harvest index
1	'641'	46.67	70.67	66.00	2.00	12.67	3.00	118.67	277.67	0.43
2	'Sreedhara'	45.67	80.00	70.67	2.00	13.20	2.93	107.00	225.67	0.46
3	'1041'	47.33	70.67	75.33	2.00	15.67	3.13	130.33	267.67	0.46
4	'61-b'	51.33	70.67	71.67	2.00	8.80	3.20	91.33	277.67	0.33
5	'111'	67.00	80.00	75.33	2.00	9.40	3.07	105.33	283.33	0.38
6	'121-b'	52.67	75.33	75.33	2.00	7.13	2.87	55.33	204.67	0.25
7	'412'	56.67	80.00	70.67	2.00	15.93	3.13	125.33	285.67	0.43
8	'112'	47.00	80.00	76.33	2.00	7.67	3.20	84.67	199.33	0.42
9	Local	35.67	70.67	67.00	2.00	10.47	3.33	83.67	208.33	0.39
10	'61-a'	35.00	80.00	75.33	2.00	8.87	2.87	98.67	213.67	0.46
11	Nidhi	34.00	80.00	70.67	2.00	12.07	3.07	98.33	210.33	0.48
12	'1042'	54.33	80.00	67.00	2.00	10.73	3.13	111.33	246.33	0.45
13	'352'	54.33	75.33	75.33	2.00	10.93	3.67	98.00	241.00	0.40
14	'121-a'	41.33	70.67	75.33	2.00	8.53	3.87	79.67	217.00	0.37

Table.6.Contd..

Sl.no.	Treatment	Duration of crop (Days)	Starch content (%)	Protein content (%)	Colour of the cooked tubers	Appearance of the cooked tubers	Texture of the cooked tubers	Flavour of the cooked tubers	Taste of the cooked tubers
1	'641'	140.00	15.70	0.06	3.00	3.00	2.00	3.00	2.00
2	'Sreedhara'	140.00	15.00	0.03	3.00	3.00	3.00	3.00	3.00
3	'1041'	140.00	11.40	0.10	3.00	3.00	3.00	3.00	3.00
4	'61-b'	140.00	6.61	0.09	2.00	2.00	3.00	3.00	3.00
5	'111'	140.00	13.80	0.10	3.00	3.00	2.00	2.00	2.00
6	'121-b'	140.00	12.50	0.05	2.00	2.00	2.00	2.00	2.00
7	'412'	140.00	8.70	0.10	3.00	3.00	3.00	2.00	2.00
8	'112'	140.00	8.20	0.09	3.00	3.00	3.00	3.00	3.00
9	Local	140.00	7.80	0.08	2.00	2.00	3.00	3.00	3.00
10	'61-a'	140.00	10.50	0.09	3.00	3.00	3.00	3.00	3.00
11	Nidhi	140.00	10.75	0.10	2.00	3.00	3.00	2.00	2.00
12	'1042'	140.00	14.00	0.05	3.00	3.00	3.00	3.00	3.00
13	'352'	140.00	19.60	0.08	3.00	3.00	3.00	3.00	3.00
14	'121-a'	140.00	7.70	0.05	2.00	3.00	3.00	3.00	2.00

Table.7.Analysis of variance for different characters of coleus genotypes at location in Thrissur

Source of variation	df	Height of the plant at harvest (cm)	Days to tuberisation	Days to flowering	Pest and disease incidence	No. of marketable tubers	Size and grade of tubers	Tuber yield per plant (gm)	Total biomass (gm)	Harvest index
		Mean Sum of Squares								
Replication	2	1.3	0.00	17	0.00	3.1	0.52	0.56×10^{3}	0.29×10^{4}	0.019
Treatment	13	250**	58	40	0.00	23	0.13*	0.11×10^{4}	0.31×10^{4}	0.011*
Error	26	24	35	51	0.00	8.1	0.21	0.79×10^{3}	0.14×10^{4}	0.0057

Table.7. Contd.

Source of variation	df	Duration of crop (Days)	Starch content (%)	Protein content (%)	Colour of the cooked tubers	Appearance of the cooked tubers	Texture of the cooked tubers	Flavour of the cooked tubers	Taste of the cooked tubers
		Mean Sum of Squares							
Replication	2	0.00	0.96×10^{-3}	0.55×10^{-7}	0.21×10^{-5}	0.65×10^{-5}	0.65×10^{-5}	0.65×10^{-5}	0.43×10^{-5}
Treatment	13	0.00	0.41×10^{2}**	0.17×10^{-2}**	0.74**	0.54**	0.54**	0.65**	0.79**
Error	26	0.00	0.74×10^{-4}	0.44×10^{-8}	0.16×10^{-6}	0.50×10^{-6}	0.50×10^{-6}	0.50×10^{-6}	0.33×10^{-6}

number of tubers per plant, 1.00 to 3.60 for size and grade of the tubers, and 189.33 to 408.33 for total biomass.

Among the qualitative characters starch content and protein content of the tubers expressed significant difference among the genotypes with a range of 6.50 to 15.70 and 0.03 to 0.10 % respectively. Here also the organoleptic qualities showed significant difference among themselves with a common range of 2.00 to 3.00.

Mean values for the 17 characters are presented in Table.8 and ANOVA is presented in Table.9

4.2. HERITABILITY, GENETIC ADVANCE, PHENOTYPIC AND GENOTYPIC COVARIANCE

Tuber yield, appearance (30% each) recorded negative heritability. Starch content, protein content, texture, flavour and taste recorded high heritability (60%, 78%, 58%, 62%, 55% respectively.).

Irrespective of the environment, maximum variability both at genotypic and phenotypic level was shown by protein content (52.5% and 59.5%) followed by starch content (32% and 41%).

Tuber yield recorded high variation over the environments at phenotypic level (43%) with comparatively low variability (23.26%) at genotypic level. The maximum genetic gain of 29.03 was obtained by tuber yield with a medium genetic gain of 26.09. Heritability was also medium for this (29.60%).

With respect to the genetic gain the characters, starch content and protein content showed high genetic gain (95.15 and 50.94 respectively). Tuber yield, flavour and taste of the cooked tubers was having medium genetic gain (26.09, 21.37 and 22.64 respectively) where as tuber number, colour, appearance and texture of the cooked tubers exhibited only low genetic gain (12.96, 5.30, 8.97 and 17.59 respectively). The

Table.8. Means of different characters of coleus genotypes at location in Malappuram

Sl. no.	Treatment	Height of the plant at harvest (cm)	Days to tuberisation	Days to flowering	Pest and disease incidence	No. of marketable tubers	Size and grade of tubers	Tuber yield per plant (gm)	Total biomass (gm)	Harvest index
1	'641'	46.67	55.00	62.67	2.00	14.13	2.60	122.00	316.67	0.39
2	'Sreedhara'	47.33	62.67	78.00	2.00	8.40	3.60	106.33	251.67	0.44
3	'1041'	52.00	55.00	55.00	2.00	10.87	3.60	190.67	408.33	0.46
4	'61-b'	41.33	62.67	70.33	2.00	8.13	2.33	77.33	251.67	0.30
5	'111'	59.00	62.67	70.33	2.00	9.00	2.20	67.33	260.00	0.26
6	'121-b'	49.67	55.00	78.00	2.00	10.33	2.27	78.00	265.00	1.34
7	'412'	38.00	62.67	70.33	2.00	8.40	2.60	92.33	245.00	0.36
8	'112'	48.33	62.67	70.33	2.00	10.40	2.47	105.00	286.67	0.36
9	Local	56.00	70.33	78.00	2.00	3.53	1.00	52.00	273.33	0.18
10	'61-a'	57.67	62.67	70.33	2.00	9.67	1.87	74.33	240.00	0.32
11	Nidhi	51.67	62.67	70.33	2.00	9.40	2.73	79.67	252.33	0.29
12	'1042'	34.00	55.00	78.00	2.00	6.20	1.20	37.67	189.33	0.20
13	'352'	49.00	70.33	78.0	2.00	7.53	2.93	91.00	270.33	0.37
14	'121-a'	57.67	55.00	78.00	2.00	8.13	2.13	55.33	231.00	0.23

Table.8.Contd.

Sl.no.	Treatment	Duration of crop (Days)	Starch content (%)	Protein content (%)	Colour of the cooked tubers	Appearance of the cooked tubers	Texture of the cooked tubers	Flavour of the cooked tubers	Taste of the cooked tubers
1	'641'	125.00	14.50	0.06	3.00	3.00	2.00	3.00	2.00
2	'Sreedhara'	125.00	15.50	0.03	3.00	3.00	3.00	3.00	3.00
3	'1041'	125.00	12.30	0.10	3.00	3.00	3.00	3.00	3.00
4	'61-b'	125.00	7.60	0.10	2.00	2.00	3.00	3.00	3.00
5	'111'	125.00	12.90	0.10	3.00	3.00	2.00	2.00	2.00
6	'121-b'	125.00	11.20	0.05	2.00	2.00	2.00	2.00	2.00
7	'412'	125.00	8.60	0.10	3.00	3.00	3.00	2.00	2.00
8	'112'	125.00	8.90	0.10	3.00	3.00	3.00	3.00	3.00
9	Local	125.00	9.70	0.08	2.00	2.00	3.00	3.00	3.00
10	'61-a'	125.00	11.05	0.05	3.00	3.00	3.00	3.00	3.00
11	Nidhi	125.00	10.26	0.09	2.00	3.00	3.00	2.00	2.00
12	'1042'	125.00	14.00	0.05	3.00	3.00	3.00	3.00	3.00
13	'352'	125.00	15.70	0.10	3.00	3.00	3.00	3.00	3.00
14	'121-a'	125.00	6.50	0.06	2.00	3.00	3.00	3.00	2.00

Table.9.Analysis of variance for different characters of coleus genotypes at location in Malappuram

Source of variation	Mean Sum of Squares									
	df	Height of the plant at harvest (cm)	Days to tuberisation	Days to flowering	Pest and disease incidence	No. of marketable tubers	Size and grade of tubers	Tuber yield per plant (gm)	Total biomass (gm)	Harvest index
Replication	2	940.1	201.5	88.1	0.00	13.5	1.3	0.50×10^{4}	0.28×10^{3}	0.25
Treatment	13	144.2*	86.2	140.4	0.00	17.5*	1.6**	41×10^{2}**	74×10^{2}**	0.24
Error	26	65.0	106.5	88.16	0.00	6.07	0.43	0.63×10^{3}	0.17×10^{4}	0.24

Table.9. Contd..

Source of variation	Mean Sum of Squares								
	Df	Duration of crop (Days)	Starch content (%)	Protein content (%)	Colour of the cooked tubers	Appearance of the cooked tubers	Texture of the cooked tubers	Flavour of the cooked tubers	Taste of the cooked tubers
Replication	2	0.00	0.0010	0.28×10^{-7}	0.21×10^{-5}	0.65×10^{-5}	0.65×10^{-5}	0.65×10^{-5}	0.43×10^{-5}
Treatment	13	0.00	25**	0.0017**	0.74**	0.54**	0.54**	0.65**	0.79**
Error	26	0.00	0.83×10^{-4}	0.21×10^{-8}	0.16×10^{-6}	0.50×10^{-6}	0.50×10^{-6}	0.50×10^{-6}	0.33×10^{-6}

values of heritability, genetic advance, genetic gain and phenotypic and genotypic coefficient of variation is given in table. 10

4.3. CORRELATION

Studies on the association of characters is an important tool in plant breeding since it helps to determine the relationship of yield with its components which in turn helps to select superior genotypes from divers genetic populations.

Correlation provides information on the nature and extent of relationship between characters. The estimate of genotypic and phenotypic correlation coefficients between various characters helps to quantify the intensity and to identify the directions of association. Genotypic correlation provides reliable measure of genetic association between characters and helps to differentiate the vital association useful in breeding from non-vital ones (Falconer, 1981). Therefore analysis of yield in terms of genotypic and phenotypic correlation coefficients of component characters helps to identify the characters that can form the basis of selection.

In the present study, association between yield and its contributing traits both in the phenotypic and genotypic level were estimated using the pooled data of the *coleus* genotypes over locations and the genotypic and phenotypic correlation coefficients are given in Table. 11.

4.3.1. Phenotypic Correlation

Tuber yield is significantly and positively associated with tuber number (0.302), protein content of the tubers (0.443), colour of the cooked tubers (0.282) and appearance of the cooked tubers (0.257). The starch content is significantly and negatively correlated with tuber yield (-0.247).

Among the inter correlations of the various yield contributing traits, tuber appearance has the maximum significant positive association (0.700) with colour of the

Table.10. Values of heritability, genetic advance, genetic gain and genotypic and phenotypic coefficient of variation

	h^2 (%)	Genetic advance	Genetic gain	Cov (genotypic)	Cov (Phenotypic)
TY	19.20	1.22	12.96	14.35	32.74
TN	29.60	29.03	26.09	23.26	42.71
SC	60.00	5.07	50.94	31.92	41.20
PC	77.90	0.10	95.15	52.52	59.49
CC	13.70	0.14	5.30	6.78	18.33
AP	29.50	0.25	8.97	8.08	14.88
TeC	57.90	0.49	17.59	11.32	14.88
FC	62.20	0.58	21.37	13.21	16.75
TaC	55.30	0.57	22.64	14.89	20.00

Table.11. Genotypic and Phenotypic correlation of nine characters of *Coleus*

	TY	TN	SC	PC	CC	AP	TeC	FC	TaC
TY		-0.311**	-0.793**	0.814**	0.511**	0.234*	0.100	0.149	0.216*
TN	0.302**		0.313*	-0.420*	0.185	0.246*	0.219*	-0.127	-0.035
SC	-0.247*	0.200*		-0.938**	0.017	0.227*	-0.025	0.099	-0.254**
PC	0.443**	-0.113	-0.670**		-0.131	-0.222*	0.054	-0.069	0.163
CC	0.282**	0.130	0.377**	0.011		0.479**	0.192*	0.265**	0.062
AP	0.257**	0.165	0.272**	0.008	0.700**		0.365**	0.326**	-0.078
TeC	0.002	-0.013	-0.232*	0.078	-0.023	0.155		0.599**	0.741**
FC	0.018	-0.141	0.042	-0.116	0.195*	0.062	0.437**		0.588**
TaC	0.053	-0.111	-0.052	0.054	0.256**	-0.064	0.539**	0.653**	

Upper diagonal – Genotypic correlation
Lower diagonal – Phenotypic correlation

cooked tubers, followed by protein content and starch content of the tubers (-0.670) which is negative. A higher significant positive association was noted between flavour and taste (0.653), and also with its texture (0.539). The starch content is positively associated with the colour (0.377) and appearance (0.272) of the cooked tubers but is negatively associated with its texture (-0.232). The colour of the cooked tuber is positively associated with the taste of the cooked tubers (0.256).

4.3.2. Genotypic Correlation

Tuber yield is positively associated with the protein content of the tubers (0.814), colour of the cooked tubers (0.511) and appearance of the cooked tubers (0.234) and negatively associated with tuber number (-0.311) and starch content (-0.793) respectively. The inter correlations among yield contributing traits was maximum for protein content and starch content (-0.938) which is negative. Taste of the cooked tuber is positively associated with the texture of the cooked tubers (0.588). Flavour of the cooked tuber was positively associated with colour (0.265), appearance (0.326) and texture (0.219) of the cooked tubers and was negatively correlated with the protein content of the tubers (-0.420).

4.4. PATH ANALYSIS

The environmental effects in the expression of various yield-attributing characters determines the quantum of effects on the tuber yield. The significance and the mode of action of the correlated response of the characters also vary with the environment. Hence a simultaneous assessment of the direct and indirect effects of the yield attributing traits both at phenotypic and genotypic level is a pre requisite for assessing various traits on yield. The number of tubers (0.315) at genotypic level and (0.359) at phenotypic level has direct effect on tuber yield. Protein content (3.039) at genotypic level and (0.347) at phenotypic level has the second direct effect in tuber yield. The appearances also contribute directly to the tuber yield at genotypic level and at phenotypic level with 0.744 and 0.167 respectively.

At genotypic level taste has high direct effect (1.545) but its phenotypic direct effect is negligible (0.044). In the genotypic level starch has high direct effect (2.160) where as in the phenotypic level its effect is negative (-0.237). Texture of the cooked tubers has very high negative genotypic direct effect (-1.465) and low negative phenotypic direct effect (-0.176). The starch content has very high positive genotypic direct effect but its genotypic correlation is negative since it is routed through the character protein content and the indirect effect thus is –2.849.

4.5. STABILITY PARAMETERS

The ANOVA for the stability of genotypes for the seven characters revealed that the characters like, number of tubers per plant, weight of the tubers, protein content and the organoleptic qualities such as colour, appearance, texture, flavour and taste has significant difference among the genotypes and the characters such as height of the plant at harvest, days to tuberisation, number of days to flowering, pest and disease incidence, size and grade of the tubers, total biomass, harvest index, duration of the crop, and starch content of the tubers, has no significant difference among the genotypes studied over the locations.

The environment has significant difference over the performance of genotypes in the following characters. Height of the plants at harvest, days to tuberisation, number of days to flowering, number of tubers per plant, total biomass, harvest index, starch content of the tubers and the organoleptic qualities like appearance, texture, flavour and taste. All other characters studied showed no significant difference among the genotypes over the locations.

Genotype x environment interaction found to be significant for the characters such as height of the plants at harvest, starch content and protein content.

In the pooled analysis and its partition into environment + (variety x environment) interactions, environment (linear), variety x environment (linear) and its pooled deviation indicated that environment (linear) significant differed for the characters like, height of the plant at harvest, days to tuberisation, days to flowering, number of tubers per plant, size and grade of the tubers, tuber weight, total biomass, and harvest index. Character such as pests and disease incidence, duration of the crop, starch content, protein content showed no significant difference among the genotypes over the environments.

Variety x environment (linear) differed significantly for the following characters. Size and grade of the tubers, harvest index, starch content of the tubers, and the organoleptic qualities like colour, appearance, texture, flavour and taste. All other characters showed no significant difference among the genotypes.

The pooled deviation for 14 genotypes showed significant difference in the characters such as height of the plants at harvest, number of tubers per plant, total biomass, starch content, protein content and the organoleptic qualities such as colour, appearance texture, flavour and taste, while all other characters showed no significant difference over the locations studied.

Pooled analysis of variance for the seventeen characters of 14 *Coleus* genotypes are shown in the table 12 and parameters namely mean, regression coefficient and mean square deviation are presented in table.13.

The genotypes having the highest mean value followed by regression coefficient and with a lowest mean square deviation are considered to be more stable and adaptable. Accordingly stable genotypes with respect to each character are presented below.

4.5.1. Height of the Plants at Harvest

The genotype '352' having the second highest mean 49.25 cm with a regression coefficient of 0.95 with a low mean square deviation of 3.94 is the most stable. While considering the performance of the genotypes over the locations for this character the genotype '61-a', which has a mean value of 44.92 and a regression coefficient of 1.01

and a deviation of 113.06, can be considered. The genotype '641' ranks third with a minimum deviation of 1.41 with a medium mean height of 46.00cm and a regression coefficient of 0.91.

4.5.2. Number of Days to Tuberisation

The genotype '112' recorded the highest mean value of 70.42 wit a regression coefficient of around one and second lowest mean square deviation of 2.36, was the most stable having maximum days to tuberisation.'641' which has the lowest days to tuberisation with a regression coefficient of around one and a low mean square deviation of 3.57 can be considered as the most stable genotype for number of days to tuberisation.

4.5.3. Number of Days to Flowering

Stability parameters for this character reveals that the genotype '121-a' has the highest mean value of 67.33 with a regression coefficient of 1.22 and a medium mean deviation of 10.59. As far as the stability is considered '61-a' was the most stable with a mean of 66.17 and low mean deviation of 7.45. As far as a low mean value with good stability is concerned the genotype, '641' is having the lowest mean value for this character with a regression coefficient of 0.67 and a deviation of 8.34.

4.5.4. Number of Tubers Per Plant

The highest mean value for this character was reported by the genotype '412' with a regression coefficient of 2.35 and a mean square deviation of 2.85 indicating that the environment influences maximum number of tubers. Nidhi the released variety ranks fourth in high mean values with a regression coefficient of 1.1 and a mean square deviation of 0.82.

4.5.5. Size and Grade of the Tubers

The genotype '352' showed the highest mean value of 3.53 and a regression coefficient of 1.09 with a very low mean square deviation indicating the stability of this genotype, over the locations. With respect to the lowest mean square deviation of 0.03 regression coefficient of 1.39 and a mean value of 3.27 the genotype '641' is the most promising stable cultivar.

4.5.6. Weight of the Tubers Per Plant

The stability parameters of this character showed that the genotype '1041' has the maximum mean value of 149.17 g per plant and has the lowest regression coefficient of 0.05, with a maximum mean square deviation. The second highest mean weight is for the genotype '641' with a regression coefficient of 1.17 and a mean square deviation of 71.97. The local cultivar recorded the lowest mean weight of tubers (79 g) with a regression coefficient of 0.74 and a mean square deviation of 207.82.

4.5.7. Total Biomass

The genotype '412' recorded the maximum biomass of 301.08 g per plant, but with a regression coefficient of 0.46 and mean square deviation of 1707.47. Here also the local cultivar recorded the lowest mean weight of 211.50 with a regression coefficient of 1.31 and very high mean square deviation of 1130.19. While considering the stable performance of the genotypes we can consider the genotype '352' as it possessed a vary stable performance over the environments though it was with the third highest mean value.

4.5.8. Harvest Index

With regard to the favourable environment to express the maximum value of this character the genotype '121-a' recorded the maximum mean value of 0.90 followed by very high regression coefficient and with lowest mean square deviation of 0.03. The local cultivar recorded the lowest mean value and regression coefficient below one (0.72) with a comparatively low mean square deviation.

4.5.9. Starch Content of the Tubers

The genotype '352' showed the highest mean value of 60.52 and a regression coefficient of 5.81 with a mean square deviation of 9.09. The second important genotype to be considered for selection based on stability parameters is '641' which recorded 16.00, 7.69, 0.71 for the parameters mean, regression coefficient and mean square deviation respectively.

4.5.10. Protein Content of the Cooked Tubers

The maximum protein content was shown by the genotypes '1041', '111' and Nidhi with mean values of 0.1. '1041' has a comparatively high regression coefficient of 0.64 among the three. All the genotypes showed zero mean square deviation.

4.5.11. Organoleptic Qualities of the Cooked Tubers (Colour, Appearance, Texture, Flavour and Taste)

While considering these qualitative attributes many of the genotypes showed secular trends in the stability parameters. Many of the mean values were in par among the genotypes. The genotypes '641', 'Sreedhara', '1041', '412', '112', '61-a', '1042' and '352' were in par with respect to colour, appearance and texture and they were better than any other genotypes. Their mean square deviation and regression values were slightly deviating among themselves. The genotypes 'Sreedhara', '1041', '61-b', '112', '61-a', '1042' and '352' and the local cultivar were on par with each other with respect to mean values and other stability parameters for the characters flavour and taste of the cooked tubers.

Table.12. Pooled analysis of variance for different characters of coleus genotypes

Source of variation	Mean Sum of Squares								
	df	Height of the plant at harvest	Days to tuberisation	Days to flowering	No. of marketable tubers	Size and grade of tubers	Tuber yield per plant	Total biomass	Harvest index
Varieties	13	39.8	15.4	19.9	7.3*	0.34	1526.5*	3324.8	0.07
Environments	3	485.6*	593.0*	1602.2*	17.4*	6.5**	10965.6*	10312.1*	0.28*
Variety x Environment	39	50.3*	16.3	17.4	4.0	0.31	627.7	2154.8	0.099
Total	55								
Pooled error	104	40.3	47.2	40.0	6.0	0.46	1054.9	3643.9	0.31
ENV+(VAR.*ENV.)	42	81.1	57.5	130.6	4.9	0.75	1366.1	2737.5	0.11
ENVRON (Linear)	1	1456.9*	1779.0*	4806.6*	52.1*	19.6*	32896.6*	30935.8*	0.84*
VAR x ENVRON (Linear)	13	26.7	16.2	11.7	4.6	0.57*	834.9	1739.1	0.23*
Pooled deviation	28	57.2*	15.2	18.8	3.4*	0.16	486.7	2193.9*	0.03

Table.12.Contd...

Source of variation	Mean Sum of Squares								
	df	Duration of crop	Starch content	Protein content	Colour of the cooked tubers	Appearance of the cooked tubers	Texture of the cooked tubers	Flavour of the cooked tubers	Taste of the cooked tubers
Varieties	13	00	36.3	2.0×10^{-3}*	0.99*	0.73*	0.725*	0.87*	1.05*
Environments	3	1020.8	0.96	1.98×10^{-5}	1.45×10^{-6}	4.36×10^{-6}*	4.3×10^{-6}*	4.3×10^{-6}*	2.9×10^{-6}*
Variety x Environment	39	00	2.5*	4.63×10^{-5}*	1.1×10^{-7}	3.35×10^{-7}	3.35×10^{-7}	3.35×10^{-7}	2.2×10^{-7}
Total	55								
Pooled error	104	00	3.4×10^{-5}	2.1×10^{-9}	1.7×10^{-7}	5.03×10^{-7}	5.03×10^{-7}	5.03×10^{-7}	3.35×10^{-7}
ENV+(VAR.*ENV.)	42	72.9	2.4	4.4×10^{-5}	00	00	00	0.00	0.00
ENVRON (Linear)	1	3062.5	2.9	5.96×10^{-5}	2.6×10^{-13}*	5.84×10^{-13}*	5.8×10^{-13}*	5.8×10^{-13}*	6.5×10^{-14}*
VAR x ENVRON (Linear)	13	00	3.75*	1.7×10^{-5}	31.07*	34.15*	34.15*	32.6*	29.5*
Pooled deviation	28	00	1.74*	5.7×10^{-5}*	14.4*	15.9*	15.9*	15.14*	13.7*

Table.13. Stability parameters of 14 coleus genotypes for different characters

	Height of the plant (cm)			Days to tuberisation			Days to flowering		
Variety	Mean	Regression Coefficient	Mean Square Deviation	Mean	Regression Coefficient	Mean Square Deviation	Mean	Regression Coefficient	Mean Square Deviation
'641'	46.00	0.91	1.41	63.92	0.98	3.57	59.67	0.67	8.34
'Sreedhara'	47.02	0.20	9.38	67.25	1.20	2.36	65.42	1.12	1.53
'1041'	46.05	0.96	7.34	64.67	0.90	7.17	60.08	0.72	89.45
'61-b'	42.67	1.44	17.94	65.83	0.62	6.44	63.00	0.98	12.24
'111'	49.27	1.89	106.28	67.25	1.20	2.36	63.92	1.06	5.33
'121-b'	43.42	1.66	14.99	65.83	1.23	1.53	65.83	1.23	1.83
'412'	48.33	0.09	80.67	67.25	1.20	2.36	64.25	0.94	4.61
'112'	46.17	0.89	9.64	70.42	1.05	9.10	64.92	1.08	5.29
Local	41.42	1.20	85.49	66.83	0.18	9.93	66.17	0.74	19.68
'61-a'	44.92	1.01	113.06	69.67	1.13	14.92	66.17	1.04	7.45
Nidhi	39.92	0.50	69.64	68.92	1.20	14.70	63.50	0.94	12.07
'1042'	40.42	0.96	98.35	66.25	1.64	10.81	63.75	1.04	20.88
'352'	49.25	0.95	3.94	68.92	0.59	15.22	65.83	1.23	1.83
'121-a'	47.72	1.34	58.34	64.67	0.90	7.17	67.33	1.22	10.59

Table.13. Contd.

	Number of tubers			Size and grade of tubers			Weight of tubers (gm)		
Variety	Mean	Regression Coefficient	Mean Square Deviation	Mean	Regression Coefficient	Mean Square Deviation	Mean	Regression Coefficient	Mean Square Deviation
'641'	11.17	0.94	7.49	3.27	1.39	0.03	133.17	1.17	71.97
'Sreedhara'	9.25	2.41	0.91	3.27	0.73	0.46	117.92	1.02	67.77
'1041'	11.03	2.31	3.81	3.28	0.27	0.08	149.17	0.05	1333.40
'61-b'	8.87	0.89	1.50	2.77	0.63	0.06	97.72	1.23	15.55
'111'	8.72	0.97	0.79	3.17	1.91	0.08	113.75	1.79	208.30
'121-b'	8.68	0.49	0.70	2.78	0.63	0.13	87.33	0.59	219.98
'412'	12.17	2.35	2.85	2.90	0.29	0.12	128.17	0.36	763.49
'112'	8.87	0.01	2.16	3.15	1.24	0.15	119.83	1.41	0.93
Local	7.73	2.49	5.62	2.50	1.69	0.24	79.00	0.74	207.82
'61-a'	9.28	0.19	0.98	2.78	0.42	0.34	98.00	0.30	8.22
Nidhi	10.97	1.11	0.82	3.05	0.64	0.15	112.33	0.87	26.09
'1042'	8.78	1.63	0.46	2.65	2.37	0.12	105.25	2.04	356.88
'352'	8.22	0.53	0.02	3.53	1.09	0.15	125.67	1.63	306.71
'121-a'	8.10	0.46	1.89	2.88	0.71	0.01	90.83	0.90	15.97

Table.13. Contd.

	Total biomass (gm)			Harvest index			Duration of the crop (Days)		
Variety	Mean	Regression Coefficient	Mean Square Deviation	Mean	Regression Coefficient	Mean Square Deviation	Mean	Regression Coefficient	Mean Square Deviation
'641'	284.50	1.69	609.50	0.47	0.54	0.10	128.75	1.00	0.00
'Sreedhara'	250.67	0.74	992.45	0.48	0.52	0.10	128.75	1.00	0.00
'1041'	292.67	0.87	7060.24	0.52	0.62	0.10	128.75	1.00	0.00
'61-b'	233.42	1.20	2364.14	0.42	0.81	0.10	128.75	1.00	0.00
'111'	263.75	1.42	276.18	0.44	0.98	0.10	128.75	1.00	0.00
'121-b'	219.33	0.16	432.49	0.66	0.75	0.22	128.75	1.00	0.00
'412'	301.08	0.46	1707.47	0.43	0.10	0.10	128.75	1.00	0.00
'112'	276.50	2.43	481.02	0.43	0.36	0.10	128.75	1.00	0.00
Local	211.50	1.31	1130.19	0.40	0.72	0.08	128.75	1.00	0.00
'61-a'	238.58	0.14	780.97	0.42	0.17	0.10	128.75	1.00	0.00
Nidhi	236.50	0.22	427.55	0.48	0.90	0.09	128.75	1.00	0.00
'1042'	228.75	1.29	1413.38	0.44	0.97	0.09	128.75	1.00	0.00
'352'	284.00	1.76	15.60	0.44	0.49	0.10	128.75	1.00	0.00
'121-a'	263.92	1.99	1640.31	0.90	7.57	0.03	128.75	1.00	0.00

Table.13. Contd.

	Starch content			Protein content			Colour of the tubers		
Variety	Mean	Regression Coefficient	Mean Square Deviation	Mean	Regression Coefficient	Mean Square Deviation	Mean	Regression Coefficient	Mean Square Deviation
'641'	16.00	7.69	0.71	0.06	1.68	0.00	3.00	44040192.00	18.00
'Sreedhara'	14.82	1.76	0.11	0.03	2.40	0.00	3.00	44040192.00	18.00
'1041'	12.62	5.64	2.12	0.10	0.64	0.00	3.00	44040192.00	18.00
'61-b'	7.38	1.27	0.53	0.09	1.87	0.00	2.00	29360128.00	8.00
'111'	13.60	2.56	0.07	0.10	0.09	0.00	3.00	44040192.00	18.00
'121-b'	11.53	3.09	1.90	0.05	0.06	0.00	2.00	29360128.00	8.00
'412'	9.18	4.74	0.80	0.09	1.74	0.00	3.00	44040192.00	18.00
'112'	9.23	4.49	1.20	0.09	2.15	0.00	3.00	44040192.00	18.00
Local	8.30	1.81	1.09	0.05	0.20	0.00	2.00	29360128.00	8.00
'61-a'	11.59	1.65	4.72	0.06	6.13	0.00	3.00	44040192.00	18.00
Nidhi	10.85	4.41	0.78	0.10	0.45	0.00	2.00	29360128.00	8.00
'1042'	13.30	5.39	0.87	0.05	2.78	0.00	3.00	44040192.00	18.00
'352'	16.52	5.81	9.09	0.09	0.48	0.00	3.00	44040192.00	18.00
'121-a'	7.70	2.70	0.34	0.05	0.43	0.00	2.00	29360128.00	8.00

Table.13. Contd.

variety	Appearance of the tubers			Texture of the tubers			Flavour of the tubers		
	Mean	Regression Coefficient	Mean Square Deviation	Mean	Regression Coefficient	Mean Square Deviation	Mean	Regression Coefficient	Mean Square Deviation
'641'	3.00	29360124	18	2.00	19573418	8	3.00	29360124	18
'Sreedhara'	3.00	29360124	18	3.00	29360124	18	3.00	29360124	18
'1041'	3.00	29360124	18	3.00	29360124	18	3.00	29360124	18
'61-b'	2.00	19573418	8	3.00	29360124	18	3.00	29360124	18
'111'	3.00	29360124	18	2.00	19573418	8	2.00	19573418	8
'121-b'	2.00	19573418	8	2.00	19573418	8	2.00	19573418	8
'412'	3.00	29360124	18	3.00	29360124	18	2.00	19573418	8
'112'	3.00	29360124	18	3.00	29360124	18	3.00	29360124	18
Local	2.00	19573418	8	3.00	29360124	18	3.00	29360124	18
'61-a'	3.00	29360124	18	3.00	29360124	18	3.00	29360124	18
Nidhi	3.00	29360124	18	3.00	29360124	18	2.00	19573418	8
'1042'	3.00	29360124	18	3.00	29360124	18	3.00	29360124	18
'352'	3.00	29360124	18	3.00	29360124	18	3.00	29360124	18
'121-a'	3.00	29360124	18	3.00	29360124	18	3.00	29360124	18

Table.13. Contd.

Variety	Taste of the cooked tubers		
	Mean	Regression Coefficient	Mean Square Deviation
'641'	2.00	58720256	8
'Sreedhara'	3.00	88080384	18
'1041'	3.00	88080384	18
'61-b'	3.00	88080384	18
'111'	2.00	58720256	8
'121-b'	2.00	58720256	8
'412'	2.00	58720256	8
'112'	3.00	88080384	18
Local	3.00	88080384	18
'61-a'	3.00	88080384	18
Nidhi	2.00	58720256	8
'1042'	3.00	88080384	18
'352'	3.00	88080384	18
'121-a'	2.00	58720256	8

Discussion

5. DISCUSSION

The concept of any plant breeding programme is to evolve a variety having superiority in the economic traits over the popular variety in that location. *Coleus* is an under exploited vegetable tuber crop which fetches premium price in the market. Since it is a vegetatively propagated crop lack of variability is the main limiting factor in the genetic improvement of this crop. An attempt was made in the Department of Plant Breeding and Genetics to induce variability in *Coleus* through mutation breeding and 11 promising mutants were identified. It is inevitable to study the stable performance of these mutants for many of the economic traits over different environments. With this objective the study has been conducted with 11 promising mutants two released varieties and one local cultivar as check, in four locations in four districts namely Palakkad, Thrissur, Malappuram and Ernakulam.

The results obtained in this study over the locations are discussed below.

5.1. GENETIC VARIABILITY

The analysis of variance of four locations namely Palakkad, Thrissur, Malappuram and Ernakulam revealed highly significant differences among the mutants for many of the economic traits like tuber yield, tuber number, starch and protein content of the tubers and in the organoleptic qualities like colour, appearance, texture, flavour and taste of the cooked tubers, over the locations. The extent of heritability expressed by the above characters over locations is graphically represented in figure 1.

Protein content followed by flavour of the cooked tubers showed maximum heritability and lowest was recorded by the colour of the cooked tubers, indicating that protein content and flavour of the cooked tubers are comparatively stable in the their performance over the locations.

Tuber yield and tuber number showed low heritability indicating that it is influenced by the environment significantly.

Generally high phenotypic coefficient of variation was expressed by the significantly differing characters when compared to its genotypic coefficient of variation. Here also maximum phenotypic and genotypic coefficient of variations was expressed by the protein content. The extent of genotypic and phenotypic coefficients of variation expressed by the above characters are graphically expressed in figure.2

Tuber number and starch content showed medium range of variations over locations, indicating that the mutants selected for study have high range of variation over location and the mutants taken for study for identifying the stable one are justified.

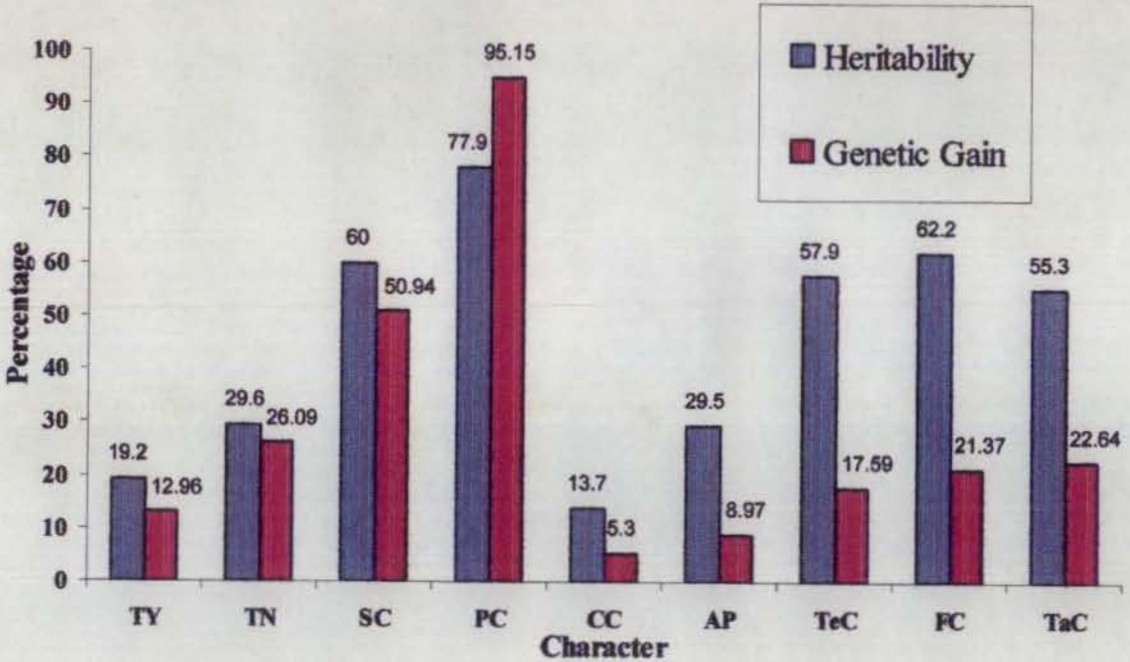
Variability with in *Coleus* was reported by Sreekumari and Abraham (1985), but Vimala (1994) and Prakash (1996) reported that tuber characters like tuber yield, tuber length and tuber girth did not show any significant difference among the genotypes of *Coleus*.

5.2. ASSOCIATION OF CHARACTERS

The association between different characters of economic traits over location is an important factor while assessing the stability of a genotype. Though a number of studies in this line were conducted in various other crops including tuber crops only a very few studies are reported in *Coleus*.

In the present study it is revealed that tuber yield was positively correlated with protein content, colour, appearance and taste of the cooked tubers and negatively associated with starch content and tuber number. Sreekumari and Abraham (1985) reported positive significant correlation for tuber yield with shoot length and number of branches. Correlated response of different characters and its inter responses has been diagrammatically shown in figure.3

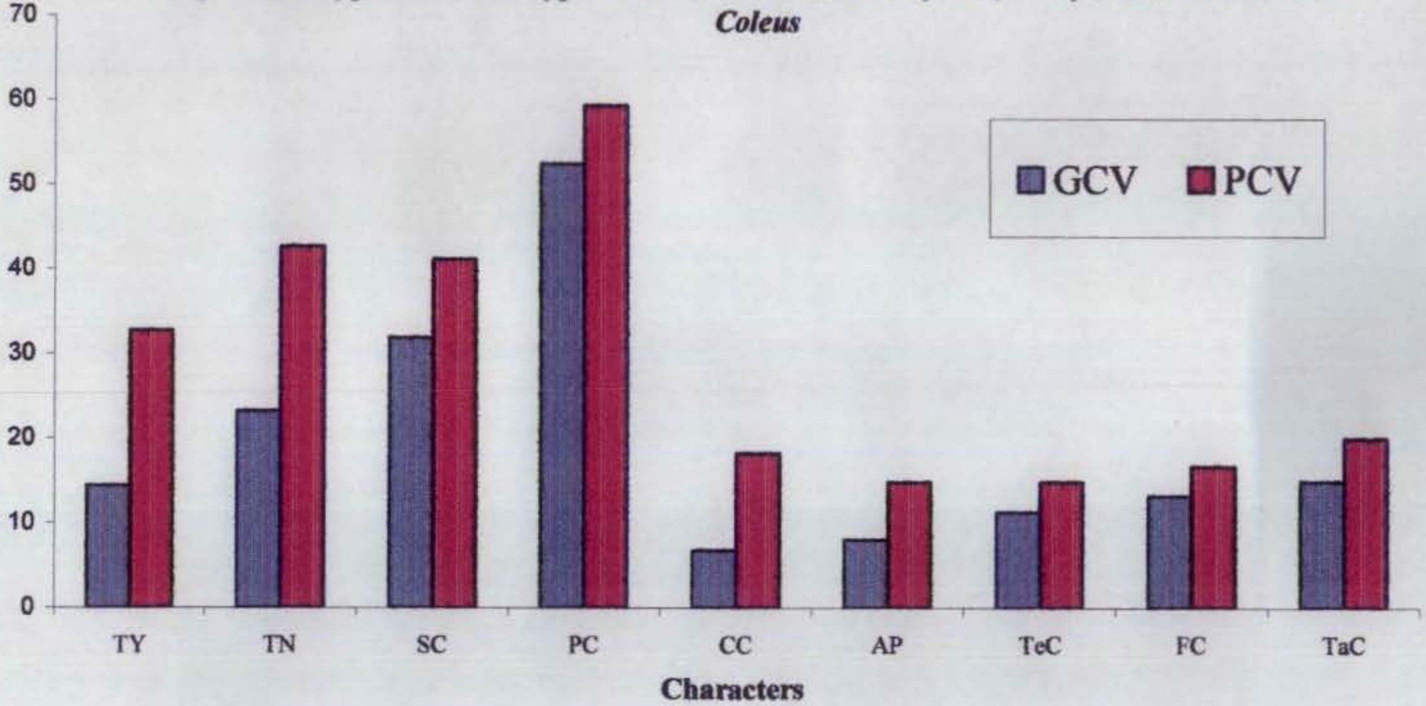
Tubers that are white coloured non-groovy, smooth and without any black mark with delicious taste and high protein content will increase the tuber yield per plant, Figure. 1. Heritability and Genetic gain for nine characters of Coleus



TY – Tuber Yield
TN – Tuber Number
SC – Starch Content
PC – Protein Content
CC – Colour of the Cooked tubers

AP – Appearance of the cooked tubers
TeC – Texture of the Cooked tubers
FC – Falvour of the Cooked tubers
TaC – Taste of the Cooked tubers

Fig. 2. Genotypic and Phenotypic Coefficient of Variation (GCV, PCV) of nine characters of *Coleus*



TY – Tuber Yield
TN – Tuber Number
SC – Starch Content
PC – Protein Content

CC – Colour of the Cooked tubers
AP – Appearance of the cooked tubers
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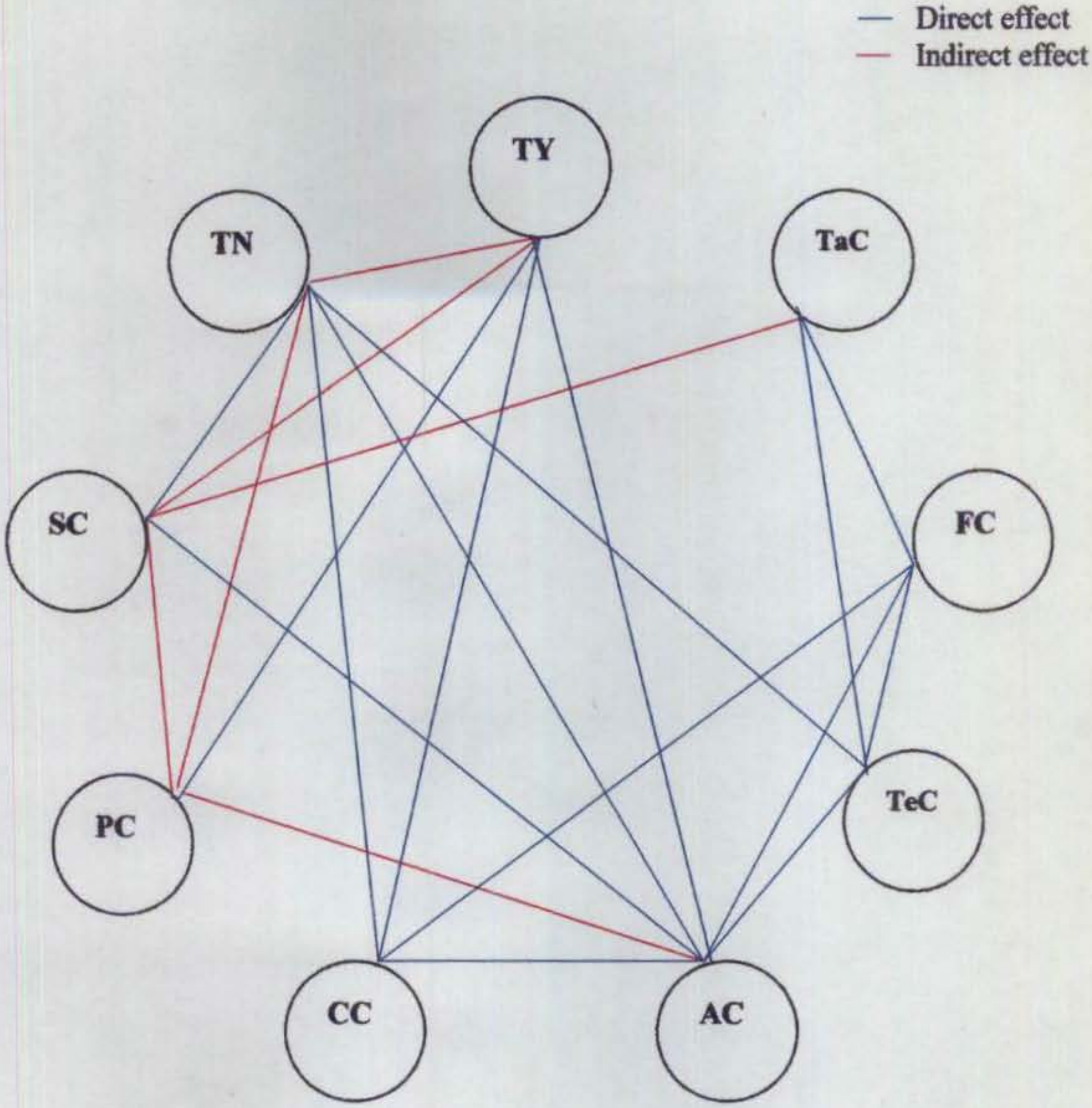
TaC – Taste of the Cooked tubers

Figure 3. Genotypic correlation diagram of nine characters of *Coleus*



TY – Tuber yield

TN – Tuber number

SC – Starch content

PC- Protein Content

CC- Colour of the cooked tubers

AC- Appearance of the cooked tubers

TeC-Texture of the cooked tubers

FC- Flavour of the cooked tubers

TaC- Taste of the cooked tubers

where as, tuber number and correspondingly low starch content is favoured for increase in the tuber yield. Holmes and Wilson (1974) in cassava had reported negative significant correlation between tuber number and mean tuber weight but Anon (1987) reported positive correlation between number and size of the tubers with the tuber yield.

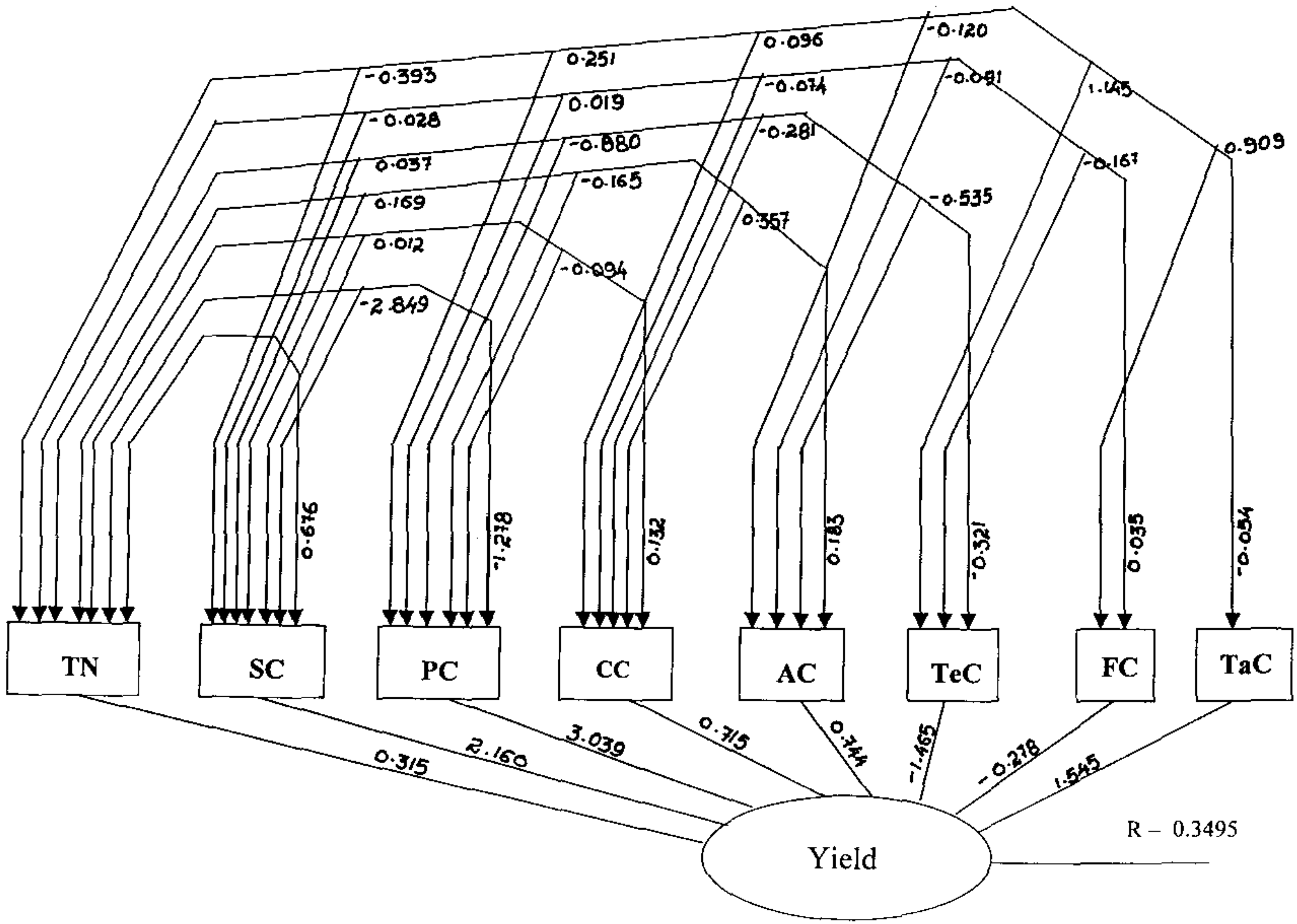
The direct influence and the indirect influence of various yield contributing traits has been depicted in the path diagram (Figure. 4)

Maximum direct effect was given by the protein content followed by starch content. This emphasises the importance to be given to the character protein content in increasing the yield. Even though a negative genotypic association was recorded, its direct effect was comparatively high and positive. This is because it has a high indirect negative effect towards yield through other component characters. This relation ship indicates that to increase yield there should be an optimum level of starch content and protein content.

Tuber number has a positive direct effect on yield even though it has a negative significant genotypic correlation. This is because it has a negative indirect effect towards yield through protein content, texture of the cooked tubers and taste of the cooked tubers. This also indicates that an optimum tuber number is a must in the increase of yield in *Coleus*.

The study has given an insight of the plant architecture to increase the yield over locations. Optimum tuber number, optimum starch and protein content, good texture and optimum flavour and white coloured, smooth groove less tubers with delicious taste were identified as the selection criteria for a better tuber yielding *Coleus* genotype.

Figure 4. Path diagram of nine characters with yield in *Coleus* genotypes



5.3. STABILITY

All plant types can make a physiological adjustment, which permits them to cope with the fluctuations in their immediate environments, which is collectively known as adaptations. This phenomenon is also known as individual buffering and it is specific to genotypes. The individual buffering in response to environments is generally termed as genotype x environment interaction. Lerner (1954) coined the term 'Genetic homeostasis' for the mechanism by which genotypes are flexible and can adjust their genotypic and phenotypic states in response to the different environmental conditions.

To asses the genotype x environment interaction or varietal adaptations mainly three parameters are used namely mean performance of the character, its regression coefficient and deviation from the regression environmental index. Kamalam *et al.*, (1978) in sweet potato reported that the linear regression is important in the difference in stability, but Mahajan and Khehra (1992) in maize reported that it is the deviations from the regression line which is important than the regression itself.

The performance of genotypes for each character in response to environments are discussed below.

5.3.1. Height of the Plant at Harvest

The mutant '352' was showed to be stable in performance over locations with a good height. With a comparatively medium height having a stable performance the genotype '61-a' can also be selected.

5.3.2. Number of Days to Tuberisation

As the main concern while considering the number of days to tuberisation is that the genotype should have a minimum number of days to tuberisation with stability in their performance over the locations, the genotype '641' can be selected since it had the least number of days to tuberisation and with a good stability over the environments.

5.3.3. Number of Days to Flowering

With respect to this character, also a minimum value is preferred for a good genotype and with this concern the genotype '641' again can be selected as it has recorded the lowest mean value with fairly good stability over the environments. Though the genotype '352' was having a very good stability over the environments, the mean values for the number of days to tuberisation and flowering was very high and hence it can not be recommended.

5.3.4. Number of Tubers Per Plant

As implied by the correlation studies a genotype with optimum tuber number should only be selected. While considering this the genotype '111' can be selected as this posses the qualities of medium tuber number and good stability over the environments.

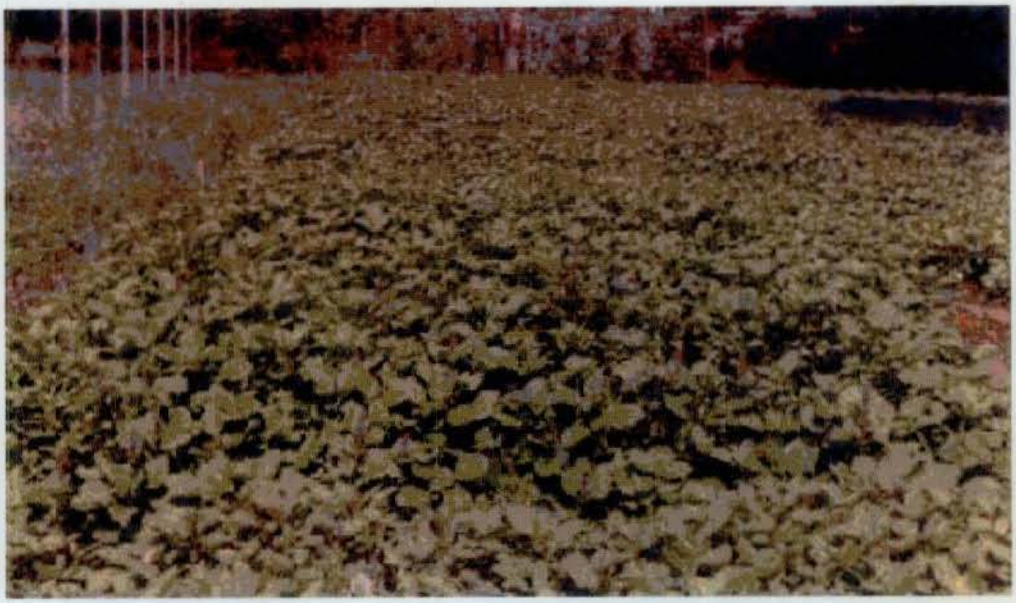
5.3.5. Size and Grade of the Tubers

In this character with respect to the maximum value, the genotype '352' is to be selected, as this was the genotype with highest mean value and a very stable performance over the environments.

5.3.6. Weight of the Tubers Per Plant

As this character implies total yield, any plant breeding programme will be aimed at a genotype with the highest value for this character combined with high stability over the locations. Considering this the genotype '641' can be recommended as it was with high stable performance over the locations and with the second highest mean value. The genotype '1041' cannot be recommended in spite of its highest mean

PLATE: 1 FIELD VIEW OF *COLEUS* GENOTYPES



value as it lacks stability over locations. Srivastava and Kamalesh Ram (1998) working with Sesame suggested that breeding objective should be to combine the high yield potential of genotypes with stability.

5.3.7. Total Biomass

The genotype '352' can be recommended based on this character as it was possessed with the third highest mean value but with high stability of the character over the environments.

5.3.8. Harvest Index

Mahajan and Khehra (1992) in maize have reported that the deviation from the regression line must be given priority in assessing the stability than the regression coefficient. In view of this the genotype '121-a' can be recommended based on this character as it was coupled with the highest mean value and a very low deviation from the regression line, though it possessed a high value for the regression coefficient.

5.3.9. Starch Content of the Tubers

As the correlation studies implies the importance of optimum starch content for a high yielding variety, the genotype '61-a' can be selected which had an average mean value and fairly good stability over the locations.

5.3.10. Protein Content of the Tubers

This also should be in an optimum range and hence the genotype '61-b' can be selected as it had an average mean value with stability over the locations.

5.3.11. Organoleptic Qualities (Colour, Appearance, Texture, Flavour and Taste of the Cooked Tubers)

White coloured tubers, which were indicated by a high mean value must be selected in the case of colour of the cooked tubers. Similarly in the case of appearance, texture and taste a high mean value is preferred. So the genotypes, which can be recommended, are '641', '1041', '412', '112', '61-a', '1042' and '352' as these were all in par with each other in having a high mean value and good stability.

In the case of flavour of the cooked tubers an optimum value is preferred for selection the recommended varieties are '111', '121-b' and '412'.

The relative contributions of the stability parameters of the 17 characters of all the 11 mutants over the locations are presented in the Table 14.

Results showed that two mutants, which scored high values for the relative contributions to stability parameters, were '641' and '352', but while considering the most economic character, that is the yield, mutant '641' was the best and hence the mutant '641' can be selected as the most stable, high yielding and well adapted for the locations followed by '352' and then by '61-a' and '412'.

Table.14. Relative contribution of stability parameters of 16 characters on eleven mutants of *Coleus*

Genotypes	He.P	Num. T	Num. F	T.N	S&G	T.Y	B.M	H.I	S.C	P.C	CC	AC	Te.C	FC	Ta.C	Total
'641'		✓	✓			✓					✓	✓	✓		✓	7
'1041'											✓	✓	✓		✓	4
'61-b'										✓						1
'111'				✓										✓		2
'121-b'														✓		1
'412'											✓	✓	✓	✓	✓	5
'112'											✓	✓	✓		✓	4
'61-a'								✓	✓		✓	✓	✓		✓	6
'1042'											✓	✓	✓		✓	4
'352'	✓				✓		✓				✓	✓	✓		✓	7
'121-a'								✓								1

He.P – Height of the plant
Num.T-Number of days to tuberisation
Num.F- Number of days to flowering
T.N- Tuber number
S&G-Size and grade of the tubers
T.Y.- Tuber yield
B.M.- Total biomass

H.I. Harvest index
SC- Starch content
Pc Protein content
CC- Colour of the cooked tubers
AP – Appearnce of the cooked tuberas
Te.C- Texture of the cooked tubers
F.C- Flavour of the cooked tubers
Ta.C- Taste of the cooked tubers

PLATE: 2 PROMISING *COLEUS* MUTANTS

Summary

SUMMARY

The present investigation on 'Stability analysis of selected mutants of Coleus (*Solenostemon rotundifolius* (Poir.) J.K. Morton.) was conducted in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during Khariff, 2001.

Eleven promising mutants, two released varieties and one local cultivar as check were the materials for the study and the experiment was laid out in four locations in four districts of central Kerala, namely Palakkad, Thrissur, Malappuram and Ernakulam where *Coleus* Cultivation is under taken.

The salient findings of the experiments are summarised below.

i. The mutants selected for the study significantly differed for many of the economic traits like tuber yield, tuber number, starch and protein content and organoleptic qualities.

ii. Protein content and flavour of the cooked tubers are comparatively stable characters where as tuber yield and tuber number were highly influenced by environments of different locations

iii. White coloured, delicious non-groovy tubers, which are smooth and with out any black marks, having high protein content, low tuber number and low starch content will increase the tuber yield

iv. Maximum direct effect in increasing the tuber yield was given by protein content followed by starch content.

v. Direct and indirect studies indicates that the ideal plant type for *Coleus* should have optimum tuber number, white coloured delicious non-groovy tubers, optimum starch and protein content, good texture and medium flavour.

vi. The stability analysis indicates that the mutant '641' followed by '352' were the most stable, well adapted for many of the economic traits over locations and can be recommended for wide cultivation in these four locations.

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STABILITY ANALYSIS OF SELECTED MUTANTS OF COLEUS *(Solenostemon rotundifolius* [Poir.] J.K. Morton*)*

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ABSTRACT OF THE THESIS

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ABSTRACT

Stability analysis of fourteen mutants of *Coleus* comprising of eleven promising mutants, two released varieties and one local cultivar was conducted at four locations in four districts of Kerala, namely, Palakkad, Malappuram, Thrissur and Ernakulam during Khariff, 2001.

The selected mutants showed significant differences for many of the economic traits over locations. For increasing the tuber yield in *Coleus*, selection should be based on low tuber number, low starch content and high protein content. Further the tubers should be white coloured, delicious, non-groovy and smooth. The study revealed that the ideal plant architecture in *Coleus* should have optimum tuber number, white coloured delicious non-groovy tubers with optimum starch and protein content, good texture and medium flavour.

The stability analysis identified mutants '641' and '352' as the most stable high yielding well adapted genotype for many of the economic traits over locations.