A STUDY OF GENETIC DIVERSITY IN DESSERT AND CULINARY TYPES OF BANANA VARIETIES

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "A STUDY OF GENETIC DIVERSITY IN DESSERT AND CULINARY TYPES OF BANANA VARIETIES" is a bonafide record of research work done by me during the course of research and that the thesis has not been 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.

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CERTIFICATE

Certified that this thesis, entitled " A STUDY OF GENETIC DIVERSITY IN DESSERT AND CULINARY TYPES OF BANANA VARIETIES" is a record of research work done independently by Miss. K.A. MERCEY, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

Banana is one of the oldest and the most popular fruits of the World. Mention has been made of it in ancient Sanskrit works and sages are said to have lived entirely on it. It is an important fruit of the tropical countries. It is available throughout the year in India which has a second position in the World for production of banana, with its cultivation in more than two lakh hectares. The chief banana growing States in the country are Kerala, Tamil Nadu, Maharashtra, Andhra Pradesh, Karnataka, Orissa, Bihar and West Bengal. Of the total area under cultivation 54% is being shared by Kerala, Tamil Nadu and Maharashtra. Kerala ranks first among these States with an area of 50,000 hectares and a production of 615,227 tonnes (Anon, 1980).

The original home of the banana is the tropical forests of Asia. Bananas are monocotyledons of the genus *Musa* in the plant family Musaceae. A large number of varieties are grown in India under a tremendously large number of varietal names. The important varieties of banana are dessert or table varieties and culinary varieties. Examples for the first are Poovan, Mauritius, Kunnan, Palayan, Ney poovan, Red banana and Gros Michel. Examples for the second are Nenthran and Nendran. These varieties vary so much in size, disposition of inflorescence, arrangement of 'fingers', the colour, taste, odour and consistency of the pulp of the ripe fruits. It would be desirable to have a comprehensive study of the diversities of these banana varieties. It is not sure that whether these diversities are only an environmental variation or is due to genetic constitution of the varieties. This is a matter of great concern. It is indeed a difficult task to assess the varibability among the different varieties of banana.

We know that no two individuals are exactly the same. In some cases the variation may be so slight as to be unimportant or it may be sufficient enough to deserve special attention. Variation among closely related plants are usually negligible. The more distant the relationship the greater is the variation to be expected. The reason attributable to the diversity in genotypes of the same species is that through the course of evolution the genotypes of the same species can change due to mutation, natural selection and artificial selection. Thus changes in the species are in varying magnitudes under varying situations. Inspite of the availability of some excellent genetic variability in our population we are not able to generate the right kind of interaction between heredity and environment for the full exploitation of our genetic resources. In other words we fail to develop quite often the available genetic potential for lack of right kind of environment for the expression of this potential. The high yielding varieties of wheat which have been released in the country have doubled the production making an addition of more than 1900 crores of rupees to our national economy. Geneticists at the Indian Agricultural Research Institute believe that India's other crop plants including the various cereals, oil-seeds, pulses, fibre plants, plantation crops, spices and fruits offer a similar scope for their genetic upgrading.

Plant and animal breeding is a slow and difficult process. Planned research on problems of economic importance in bananas is only of recent undertaking in India is started with the establishment of the Banana Research Stations in Tamil Nadu, Maharashtra and West Bengal, with financial assistance of the Indian Council of Agricultural Research.

The improvement in Indian bananas with a view to infuse keeping, non-shedding and other desirable qualities, lacking in some of the varieties can be effected in two ways (1) by hybridisation (2) by selection. Improving by hybridisation is an exceedingly difficult problem. Because the parents which do not develop normal seeds should be made to produce seeds and finally the type evolved again be made seedless. Exhaustive survey has to be carried out to procure material likely to be of use for crossing. But after all this trouble owing to the inconstant nature of characters inherent in the banana the variety bred may not retain the desirable qualities for long.

Selection work is less laborious and might yield quicker results. But before taking up the question of improvement the importance of exhaustive survey and detailed study of all the varieties available in the country cannot be emphasised too much for it is simple waste of time and money to try to evolve a variety which might be already in existence.

At present the Indian Institute of Horticultural Research, Hessarghatta is engaged in the improvement of banana through selection, hybridisation and mutation breeding. Early research confined to selection of varieties from indigenous and exotic sources, choices of appropriate methods of propagation, use of plant growth regulators for regulation of fruiting, experiments on fertilisation and control of diseases.

The precise information about the extent of genetic divergence is crucial for a breeding programme. This information is frequently sought for picking the well nicking heterotic crosses. Very often in most of the plants geographic or phenotypic diversity has been taken as an index of the genetic diversity. This being only an inferential criterion as such it could not be practicable in quantifying or genetically discriminating between populations.

Many workers have found that Multivariate analysis is a powerful tool in quantifying the degree of divergence between biological populations. Estimation of genetic diversity in banana varieties were not attempted so far in detail. Banana being an important fruit crop in Kerala, new high yielding, diseases resistant and delicious banana varieties with keeping qualities are to be developed for the benefits of the banana cultivators. The present study is directed with the following objectives:

1. To find the genetic diversity among the different varieties of banana.
2. To find the character which contributes maximum towards genetic divergence.
3. To form clusters of banana varieties which are genetically diverse and can be used for exploiting heterosis.
4. To perform a comparative study of the clusters formed through the D^2 analysis and through canonical analysis.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The importance of genetic diversity in a programme of plant breeding has been emphasised by several workers. Many statistical procedures have been developed to measure genetic divergence, among populations. Among them multivariate analysis has proved to be a potent tool.

Theoretical studies

Rao (1952) has presented multivariate analysis as a body of techniques indispensable to applied research. Multivariate analysis permits the simultaneous statistical treatment of several characters.

Most of the multivariate tests developed have special reference to problems considered under the category of discriminant functions. Research in this direction originated with Wishart's (1928) distribution of the estimated variances and covariances and Hotelling's (1931, 1936) T^2 test and canonical correlations. Hotelling's generalised T^2 is essentially a multivariate 't' test for two samples. The technique of canonical analysis described by him, requires the partitioning of the p-variates into two groups $X^{(1)}$ and $X^{(2)}$ each containing p_1 and p_2 variates such that $p_1 + p_2 = p$ and finding linear functions of the p_1 variates in $X^{(1)}$ and p_2 variates in $X^{(2)}$ such that the correlation coefficient between the two linear function is the maximum. This procedure is continued by forming further linear combinations with the maximum possible correlation coefficients.

Wilks (1932), following the likelihood ratio method (Neyman and Pearson, 1928, 1931; Pearson and Neyman, 1930), obtained suitable generalisations in the analysis of variance applicable to several variables. The statistic Λ proposed by him has been found useful in a variety of problems. Bartlett (1934) applied it for testing the significance of treatments with respect to two variables in a varietal trial and indicated its general use in multivariate tests of significance. Wilks (1935) and Hotelling (1935) found it useful in testing the independence of several groups of variates. Wilks statistic supplied some of the basic tests in multivariate analysis. Karl Pearson's coefficient of racial likeness (.C.R.L.) Thildesley (1921), Pearson (1926) has been used by anthropologists for purpose of classifying skeletal remains. Pearson's C.R.L. is a test and not a measure of group divergence.

The concept of a measure of divergence between populations was first introduced and further developed on the theoretical side by Mahalanobis. He found for the uncorrelated case the first four moments of what may be called the classical D^2 and also some approximate results for the 'studentised' form of the statistic (Mahalanobis, 1936). The exact distribution as well as the moments of classical D^2 for the correlated case where obtained by Bose (1936) and a series of the properties of these moment functions were brought out by Bose. The classical D^2 involved the population variances which in actual practice had to be estimated from the data itself.

The approximate generalisations of the D^2 statistic in the case of more than two populations and suitable statistic to test the equality of means of each character for a given number of populations were given by Fisher (1938).

The distribution of the ratio of D^2 calculated on p and p + r characters has been found by Rao (1946). The test based on this is useful to decide whether the inclusion of 'r' more characters to 'p' basic characters results in an increase in the divergence measure between populations.

Mahalanobis D^2 statistic is a distance in a Euclidian space whose axes are oblique since it allows for the variance and covariance among the characters. It also satisfies the triangle law of distances.

Mahalanobis D^2 is intimately related to the linear discriminant function (Fisher, 1936) being infact the distance between population means along the axis of the discriminant function. This permits significant tests to be performed on the distances. D^2 is maximal with respect to the ratio of variance among groups over variance within groups. The coefficient is useful in cases where each group is represented by a sample and the distances between the groups are desired.

The application of D^2 statistic to classificatory problems was limited to anthropology and psychology in the earlier days of development of the method and later on the technique was used in diverse fields of study.

Mahalanobis (1928) employed the concept of distance between two statistical populations as a measure of divergence in his "statistical study of the chineese head measurements".

An anthropometric survey of the United States was conducted by Mahalanobis *et al.* (1949). They had classified 12 castes and tribes of the united provinces using D^2 statistic based on 9 characters. They classified into five clusters, one containing four and the other four clusters each containing two. It was analysed by canonical analysis also. The same clustering pattern was obtained.

Applied studies

A review of the works that had been done so far in various crops by geneticists and biometricians reflects the considerable importance of multivariate analysis.

Multivariate analysis by means of Mahalanobis D^2 statistic was found to be a powerful tool in the hands of plant breeders for quantifying the degree of divergence between biological populations, to understand the trend on evolutionary pattern, to assess the relative contribution of different characters towards total divergence and the associations between genetic divergence and geographic divergence.

Generally geographic diversity has been considered as an index of genetic variability in crop plants.

However this may not be true for every case as many workers have postulated that geographic diversity is not necessarily directly related to genetic diversity.

Vegetables

Sachan and Sarma (1971), Peter and Rai (1976) examined the genetic diversity of tomatos and found that genetic divergence was not related to geographic divergence. Also the group constellations obtained by D^2 was confirmed by canonical analysis.

Singh and Singh (1976), Nair (1981), studied the genetic divergence in chillies. They also reported the same result as that of Sachan and Sarma (1971), Peter and Rai (1976).

Joseph (1981) studied the genetic diversity in sweet potato through D^2 analysis and canonical analysis and obtained confirmatory results of the group constellations.

Murthy *et al*. (1966) in *Brassica campestris* var. brown sarson, Murthy and Arunachalam (1966) in *Brassica campestris* var. brown sarson, Mital *et al*. (1975) in brinjal, Ramachandran (1978) in bitter gourd, Chaubey and Katiyar (1979) in *Brassica campestris* var. toria, Bhaskar *et al*. (1980) in egg plant studied the genetic diversity and formed the clusters using D^2-statistic. They also indicated the maximum and minimum contributing characters towards divergence.

Mital *et al*. (1975), Chaubey and Katiyar (1979) confirmed through their study that the clustering pattern was not following geographical distribution.

Cereals

Ram *et al*. (1970), Maurya *et al*. (1977) studied the genetic diversity in rice. Their study also confirmed the relationship between geographical diversity and genetic diversity.

Somayajulu *et al*. (1970), Yadav *et al*. (1974), Chaudhary and Singh (1975), Sethi *et al*. (1978) studied genetic diversity in wheat through D^2 and canonical analysis and came out with the result that the clustering pattern had no influence of the pedigree relationship of the genotypes.

Arunachalam and Jawahar Ram (1967), Mehndiratta *et al*. (1971), Chandrasekhariah *et al*.(1974) studied the genetic diversity in sorghum and brought out the same result as that of Sechan and Sarma and Peter and

Rai towards the genetic diversity and geographic diversity.

Pulses

Shaw *et al.* (1972) in soybean, Malhotra *et al.* (1974) in greengram, Chaudhary *et al.* (1975) in cluster bean, Sagar *et al.* (1976) in urdbean, Chandrasekhar Azad (1978) in chickpea, Narsinghani *et al.* (1978) in peas, Pillai (1980) in blackgram reported that clustering pattern was not following geographical distribution.

Malhotra and Singh (1971) revealed the presence of wide genetic diversity in blackgram. In horsegram Ramakrishnan *et al.* (1979) reported that 100 seed weight and dry weight of nodular tissue were the chief contributors towards total divergence.

In greengram Gupta and Singh (1970) found that the clustering pattern was influenced by the parentage. Asawa *et al.* (1981) studied the divergence in pigeon pea (*Cajanus cajan* (Linn.) Mill sp.). Based on divergence some varieties which can be crossed are found out.

Mehndiratta and Singh (1971) and Jayaprakash *et al.* (1974) studied the genetic divergence in cowpea and reported the important characters responsible for genetic divergence.

<u>Oil yielding crops</u>

Sanga (1971) and Shwe <u>et al.</u> (1972) studied genetic divergence in groundnut and obtained the same results with regard to the genetic divergence and geographic divergence as that of Sachan and Sarma.

In linseed Anand and Murthy (1968), Jeswani <u>et al.</u> (1970) found that the number of primary branches had contributed maximum towards divergence.

Singh and Srivastava (1978) found that in castor the genetic divergence and geographic divergence were in close relationship.

<u>Tobacco</u>

Murthy <u>et al.</u> (1965) in <u>Nicotiana rustica</u> L. found that the geographical distribution of the varieties and their genetic divergence could not be related. The same conclusion was obtained by Narasimhayayya <u>et al.</u> (1974) in <u>Nicotiana tabacum</u> L.

<u>Cotton</u>

Singh and Gupta (1968) estimated the genetic divergence in 33 strains of upland cotton (<u>Gossypium hirsutum</u> L.) and found that clustering pattern of the varieties was influenced by their pedigrees. Singh <u>et al.</u> (1971) found that the distribution of varieties in different clusters were not according to the geographic origin.

Arecanut

George (1976) studied the genetic diversity among the arecanut varieties and confirmed the cluster constellations through D^2 and canonical approaches.

Teak

Nair and Mukherjee (1960) used Multivariate analysis in the classification of natural and plantation teaks. The same clustering pattern was obtained by canonical analysis.

Millets

In fiftyone inbreds of pearl millet (Mukerji et al. 1981) found that geographical distance was not related to genetic divergence. Upadhyay et al. (1970) also came to the same conclusion.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was based on the crop raised at the Banana Research Station, Kannara, during the last two years. The number of varieties selected; 56 in dessert and 30 in culinary groups. All the cultural treatments given to the above groups were quite uniform. Within each group of varieties the application of manures, fertilisers and chemicals, irrigation and other management practices were managed time to time so that there is uniformity in all respects. The different morphological characters measured from these plants are given below:

1. Height
2. Girth
3. Leaves per plant
4. Hand weight
5. Finger weight
6. Bunch weight
7. Fingers per bunch
8. Finger length
9. Finger thickness
10. Hands per bunch
11. Fingers per hand
12. Peduncle length
13. Roots per plant

In the dessert varieties it was possible to get only an incomplete set of observations in regard to the thirteenth character, number of roots. Only the remaining 12 characters were taken for the statistical analysis. All the 13 characters were included in the culinary varieties.

3.1. Varieties selected

The dessert bananas included five different groups. They were Kunnan, Kadali, Poovan, Dwarf and Miscellaneous. Seven varieties were obtained from Kunnan, 7 from Poovan, 6 from Kadali, 15 from Dwarf and 21 from the Miscellaneous (total 56). Thirty different varieties were included in the culinary group. The different varieties of the two groups along with their genotype is given below (*Musa acuminata* is represented by AA and *Musa balbisiana* by BB).

Dessert bananas.

I.

Kunnan Group	Genotypes
1. Nendra Kunnan	AAB
2. Pey Kunnan	ABB
3. Valiya Kunnan	AB
4. Kodupilla Kunnan	AAB
5. Thean Kunnan	AAB
6. Poocha Kunnan	AAB
7. Adukka Kunnan	AAB

II.	Poovan Group	Genotypes
	8. KNR 1/76	AAB
	9. KNR 2/75	AAB
	10. Rasthali	AAB
	11. Tongate	AAB
	12. Njali poovan	AB
	13. Ayiramka poovan	AAB
	14. Poovan	AAB
III.	Kadali Group	
	15. Chenkadali	AAA
	16. Red banana	AAA
	17. Ambala kadali	AA
	18. Vadakkan kadali	AA
	19. Chakkara kadali	AAB
	20. Kanni kadali	AAB
IV.	Dwarf varieties.	
	21. Mons Marie	AAA
	22. Amrit sagar	AAA
	23. Robusta	AAA
	24. Peddapacha Arathi	AAA
	25. Giant cavendish	AAA
	26. Wather	AAA
	27. Harichal	AAA
	28. High gate	AAA
	29. Gros Michel	AAA
	30. Sapumal anamalu	AA
	31. Mauritus	AAA
	32. Dwarf cavendish	AAA

	33. Prinkabel	AAA
	34. Lacatan	AAA
	35. Vamanakeli	ABA
V.	Miscellaneous	
	36. Preban	AAA
	37. Martaman	AAB
	38. Poochachingan	AAA
	39. Sikumani	AA
	40. Chingan	AA
	41. Pilian	AB
	42. Pacha Nadan	AAB
	43. Sirumalai	AAB
	44. Chirapunchi	ABB
	45. Charapadathi	AAB
	46. Thiruvananthapuram	AAB
	47. Lady's finger	AB
	48. Nendra padathi	AAB
	49. Pirija	AAB
	50. Radja	AAB
	51. Chinali	ABB
	52. Krishna vazhai	AAB
	53. Saina	AAA
	54. Virupakshy	AAB
	55. Redrajah	AAA
	56. Adukkan	AB

Culinary Bananas

1. Nallabakshe	ABB
2. Nangneri payan	ABB
3. Java	ABB
4. Hybrid sawai	ABB
5. Gloria	ABB

6. Erachi vazhai AA
7. Boodi ABB
8. Ennabenian ABB
9. Sawai ABB
10. Pisang awak ABB
11. Peykunnan ABB
12. Neyvannan ABB
13. Alukkel ABB
14. Bising ABB
15. Bluggoe ABB
16. Malai Monthan ABB
17. Sambrani Monthan ABB
18. Nalla bontha ABB
19. Monthan ABB
20. Kanchikela ABB
21. Ashybatheesa ABB
22. Pachabontha batheesa ABB
23. Karibontha ABB
24. Ashmonthan ABB
25. Kayur AAB
26. Walha ABB
27. Chetty ABB
28. Neyvannan ABB
29. Vannan AAB
30. Mannan AAB

3.2. Lay out of the experiment

The experiment was laid out in RBD with three replications.

3.3. Statistical analysis

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

3.3.1. Analysis of variance and covariances

Before proceeding with detailed statistical analysis of plant characters and varieties the data were analysed for the analysis of variance for randomised block design. The model utilised in the analysis of this design is:

$$Y_{ij} = \mu + b_i + t_j + e_{ij}$$

$$i = 1 \ldots r$$

$$j = 1 \ldots t$$

where Y_{ij} = performance of j^{th} genotype in the i^{th} block.

μ = general mean

b_i = true effect of i^{th} block

t_j = true effect of j^{th} genotype

and e_{ij} = random error

restrictions are $\sum_{i=1}^{r} b_i = 0$

$$\sum_{j=1}^{t} t_j = 0$$

The actual break up of the total variance into variances due to replications, genotypes and error are given in table.

Analysis of variance

Source	df	SS	M.SS.	F
Replication	(r-1)	R(r-1)	R	$\frac{R}{E}$
Varieties	(t-1)	V(t-1)	V	$\frac{V}{E}$
Error	(r-1)(t-1)	E(r-1)(t-1)	E	
Total	rt-1			

Analysis of variance were carried out for all the characters. F test is conducted to test the significant differences among varieties for all the characters studied.

Analysis of covariance was also carried out for all the characters to obtain the common dispersion matrix which is useful for further analysis.

3.4. Multivariate analysis

Wilks' 'Λ' criterion (Wilks, 1932) was used to test the significance of the difference between the varieties with regard to the mean values of all the characters simultaneously as follows:

$$= \frac{|E|}{|E+V|}$$ where E is the matrix of error

sum of squares and V is the matrix of the sum of squares due to varieties.

$$= \frac{|E|}{|E + V|}$$

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

From the value of Λ the V statistic was calculated using the relation $V = - m \log_e \Lambda$

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

n = df for error + varieties

$= N_1 + N_2 + .. + N_k - r$

p = number of characters

q = number of varieties − 1

$N_1, N_2, \ldots N_k$ are sample sizes from $A_1, A_2, \ldots A_k$ population (varieties) from which the correlated characters are selected.

The 'V' statistic follows a χ^2 distribution with pq degrees of freedom. Since the degrees of freedom in the present study exceeds 30, the expression $Z = \sqrt{2\chi^2} - \sqrt{2n-1}$ was used as a normal deviate (Singh and Chaudhary, 1977). The significance of the 'V' statistic shows that the difference between the mean in respect of the effect of p characters between different populations are significant. Hence further analysis to estimate the D^2 values are made.

3.4.1. D^2 analysis

The genetic divergence between the varieties was estimated by using Mahalanobis D^2 (Mahalanobis, 1936). He explained the distance between the two populations as estimated from a sample on the basis of p characters as

$$D_p^2 = \sum_{i=1}^{p} \sum_{j=1}^{p} S^{ij} \; (\overline{X}_{i1} - \overline{X}_{i2}) \; (\overline{X}_{j1} - \overline{X}_{j2})$$

$$= \sum_{i=1}^{p} \sum_{j=1}^{p} S^{ij} \; d_i d_j \text{ where}$$

$\overline{X}_{i1}$ = sample mean for the i^{th} character from the first sample.

$\overline{X}_{i2}$ = sample mean for the i^{th} character from the second sample.

S^{ij} = inverse of the variance covariance matrix

$$d_i = \overline{X}_{i1} - \overline{X}_{i2}$$
$$d_j = \overline{X}_{j1} - \overline{X}_{j2}$$

The significance of the total D^2 between any two varieties was tested. For testing the significance of the mean values of p characters for any two populations the statistic $\frac{N_1 N_2 \; (N_1 + N_2 - p - 1)}{(N_1 + N_2) \; (N_1 + N_2 - 2) \; P} \; D^2$ is used. It follows an F with degrees of freedom p and $N_1 + N_2 - p - 1$ d.f. Here N_1 is the sample size for the first population, N_2 is the sample size for the second population. Hence pairwise comparison between the different varieties was conducted and tested for its significance.

The computation for finding D^2 is very tedious, since it requires the inversion of a higher order matrix. The computation is simplified by working with a set of transformed uncorrelated variables (y's) obtained from the original variables (x's) by pivotal condensation of the common dispersion matrix (Rao, 1952). By using this transformation the problem can be studied in some detail and we can judge the importance of various characters used for discrimination. Using the relation between y's and x's the mean values of different varieties for the different characters were transformed into the mean values of a set of uncorrelated linear combinations (y's).

The theory of the method of construction is as follows. Suppose $x_1, x_2, \ldots x_p$ be the original characters and w_{ij} be the covariance between the

i^{th} and j^{th} variates. The transformed variables, $y_1, y_2 \ldots y_p$ are defined by

$$y_1 = x_1$$

$$y_2 = x_2 - a_{21}\, y_1$$

$$y_3 = x_3 - a_{32}\, y_2 - a_{31}\, y_1$$

$$\cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot$$

$$y_p = x_p - a_{pp-1}\, y_{p-1} - \cdot \cdot \cdot - a_{p1}\, y_1$$

The constants a_{ij} are chosen such that y_i's are independent. The actual evaluation of these coefficients is carried out in successive stages so that if the coefficients in $y_1 \ldots y_i$ are known any coefficient in y_{i+1} can be calculated in a simple manner.

To find a_{21}, $\mathrm{Cov}\,(y_1 y_2) = 0$

$$\mathrm{Cov}\,(y_1, y_2) = \mathrm{Cov}\,(x_1, x_2) - a_{21}\, V\,(y_1)$$

$$= u_{12} - a_{21}\, u_{11} = 0$$

$$\therefore a_{21} = \frac{u_{12}}{u_{11}}$$

For y_3, a_{31}, a_{32} are to be calculated in order. We introduce constants b_{ij} to facilitate computation.

$$b_{31} = u_{31}$$

$$b_{32} = u_{32} - a_{21}\, b_{31}$$

$$a_{31} = \frac{b_{31}}{v(y_1)}$$

$$a_{32} = \frac{b_{32}}{v(y_2)}$$

with $y_1 \cdot \cdot \cdot y_{i-1}$ are known the steps for the evaluation of y_i are $b_{i1} = u_{i1}$

$$b_{i2} = u_{i2} - a_{21}\, b_{i1}$$

$$b_{i3} = u_{i3} - a_{32}\, b_{i2} - a_{31}\, b_{i1}$$

$$\cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot$$

$$b_{ij} = u_{ij} - \sum_{t = i-1}^{1} a_{jt}\, b_{it}$$

$$a_{i1} = \frac{b_{i1}}{v(y_1)}$$

$$a_{i2} = \frac{b_{i2}}{v(y_2)}$$

$$a_{i3} = \frac{b_{i3}}{v(y_3)}$$

$$\cdot \cdot \cdot \cdot \cdot \cdot$$

$$a_{ij} = \frac{b_{ij}}{v(y_j)}, \; j \leq i - 1$$

So $v(y_i) = u_{ii} - \sum_{j=1}^{i-1} a_{ij}\, b_{ij}$

The method needs checking at each stage since the constants derived at any stage depend on those previously calculated. Errors may accumulate due to rounding off in earlier calculations, but the accuracy can be maintained by retaining a sufficient number of decimal places at each stage. On the computational side this is done by pivotal condensation method. The D^2 between the i^{th} and j^{th} variety for p characters is calculated separately as $D^2_{ij} = \sum_{t=1}^{p} (y_{it} - y_{jt})^2$

where y_{it} = the mean value of the t^{th} linear combination for the i^{th} variety and y_{jt} is the t^{th} linear combination for the j^{th} variety. Thus D^2_{ij} can be considered as the sum of the p component D^2 values corresponding to t = 1, 2 . . . p.

3.4.2. Ranking of D^2 values

The p component D^2 values for each combination were ranked in the descending order of magnitude, equal values, if they occur which are very rare receiving same ranks. The ranks were added up for each component D^2 over all combinations to obtain the rank totals.

3.4.3. Cluster formation

Tocher's method

To find out the genetic diversity of banana the first method adopted is Tocher's method. The method suggested by Tocher is that any two groups belonging to the same cluster should at least on the average show a smaller D^2 value than those belonging to two different clusters. This is the method of minimum generalised distance. First we started with two closely associated groups and found out a third group which has the smallest average D^2 from the first two. If at any stage the average D^2 of a group does not fit in with the former group it is taken to be outside the former cluster. Thus the clusters are formed.

Computational scheme for finding clusters

Group added to a cluster (1)	D^2 (2)	No. of terms (n) (3)	Increase in $\frac{D^2}{\text{Increase in } n}$ (4)	Ave. D^2 $\frac{\Sigma D^2}{n}$ (5)	Cluster (6)

3.4.4. Intra and Intercluster distance

After forming clusters next step is to find the intra and intercluster distance. It is as follows. Intra cluster D^2 will be average of possible D^2 values that can be obtained from within a cluster. Suppose A_1, A_2, A_3, A_4 form a cluster then intra cluster D^2 will be the average of the distance A_1 & A_2, A_1 & A_3, A_1 & A_4, A_2 & A_3, A_2 & A_4, A_3 & A_4.

Intercluster D^2 will be the average of the possible D^2 values that can be obtained between the two clusters. Suppose A_1, A_2, A_3, A_4 and B_1, B_2 be the two clusters. The intercluster D^2 is calculated as the average of the distance between A_1 & B_1, A_2 & B_1, A_3 & B_1, A_4 & B_1, A_1 & B_2, A_2 & B_2, A_3 & B_2, A_4 & B_2.

This type of clusters and their relationship can be shown in a multi-dimensional graph in a two dimensional space.

When intracluster distance is least we can say that variability within the clusters is least or in other words there is homogeneity among the varieties within the clusters. Intercluster distance will be more compared to intracluster distance. That is an indication of the heterogeneity between the clusters. By looking at the distance we can say which of the clusters has got minimum divergence and maximum divergence. That is the method of D^2 for assessing diversity.

3.5. Canonical analysis of biological data

Canonical analysis helps in confirming the group of constellations arrived at by the D^2 statistic.

In this case we are representing the clusters with respect to two or three suitably chosen functions of the p characters. The problem is to find the best t (< p) linear combinations of the p - variates which make the sum of all possible D^2 values a maximum.

Let

$$\begin{array}{ccc} m_{11} & \cdots\cdot & m_{p1} \\ m_{12} & \cdots\cdot & m_{p2} \\ \cdots & \cdots & \cdots \\ m_{1k} & \cdots\cdot & m_{pk} \end{array}$$

represent the mean values of p characters for the first, second, . . k^{th} populations, and Λ the common dispersion matrix. Suppose that t = 1 and the required linear function is $l_1x_1 + l_2x_2 + \ldots + l_px_p$ with its variance $l \Lambda l^1$, where l is the vector ($l_1, l_2 \ldots,$ l_p). The D^2 with respect to $l_1x_1 + \ldots + l_px_p$ between the i^{th} and j^{th} populations is $[l_1(m_{1i} - m_{1j}) + \ldots$ $+ l_p (m_{pi} - m_{pj})]^2$. The sum of all possible D^2 values is proportional to $\sum\sum l_i l_j b_{ij}$

where $b_{ij} = \sum (m_{ir} - \overline{m_i}) (m_{jr} - \overline{m_j})$ and $\overline{m_i} = \sum \frac{m_{ir}}{k}$. This is nothing but between populations variance with respect to the chosen linear compounds.

To find the best linear function $\Sigma\Sigma l_i l_j b_{ij}$ is maximised, subject to the condition $\Sigma\Sigma l_i l_j \lambda_{ij} = 1$ Introducing the lagrangian multiplier, the vector I is obtained as the solution of $I(B - \lambda \Lambda) = 0$ where $B = (b_{ij})$

$\Lambda = (\lambda_{ij})$ and λ is the greatest root of the equation, $|B - \lambda\Lambda| = 0$

Suppose that we want the best two functions lx' and mx' where l and m can be choosen to satisfy the condition $I \Lambda I' = 1 = m \Lambda m'$ and $I \Lambda m' = 0$. Introducing lagrangian multipliers, c_1, c_2, c_3 the expression to be differentiated is

$$IBI' + mBm' - c_1 I \Lambda I' - 2 C_3 I \Lambda m' - C_2 m \Lambda m'$$

The equations are

$$IB - C_1 I \Lambda - C_3 m \Lambda = 0$$
$$mB - C_2 m \Lambda - C_3 I \Lambda = 0$$

The value of $C_3 = 0$ by solving the equations. This shows that C_1 and C_2 are roots of the equation $|B - \lambda\Lambda| = 0$. Since the maximised value of $IBI' + mBm'$ is $c_1 + c_2$ it follows that c_1 and c_2 correspond to the first two largest roots. Also the vectors corresponding to any two roots satisfy the condition $I \Lambda m' = 0$ so that lx' and mx' are uncorrelated. The best two linear functions are thus the first two canonical vectors associated with the matrices B and Λ.

Similarly the first t canonical variates give the best t linear functions. The sum of all possible D^2 values with respect to all the p characters is proportional to sum of the roots $\lambda 1 + \ldots + \lambda p$ and the corresponding sum for the t largest canonical variates is $\lambda_1 + \lambda_2 + \ldots + \lambda_t$ so that the adequacy of the fit is judged by the smallness of the sum of the residual roots $\lambda_{t+1} + \ldots + \lambda_p$ or its ratio to the total.

Canonical analysis facilitates in many cases the representation of the population in a two dimensional chart. The magnitude of the coefficients in the successive canonical vectors indicate the relative importance of the characters in the major and secondary axis of differentiation.

The first two canonical roots and the first two canonical vectors were computed by the iteration method described by Rao (1952). The computation method consisted of the following steps. The original variables has already transformed to an uncorrelated set so that if the transformed values are used the problem reduces to the determination of latent roots and vectors of the between product sum matrix.

(1) starting from the matrix of y values ie., the mean values of the uncorrelated linear combinations for all the characters and for all the varieties (used in the computation of D^2 values) the between sum product matrix was calculated (matrix A).

2. The second power of matrix A was computed to quicken the iterative process. Canonical vectors associated with a symmetric matrix A and A^{2p}, a suitable power of A are the same. If I is the vector associated with the root   of A then $I(A - \lambda I) = 0$ multiplying by A +   I the equation reduces to

$I(A^2 - \lambda^2 I) = 0$

multiplying by $(A^2 + \lambda^2 I)$

$I(A^4 - \lambda^4 I) = 0$ and so on. Hence the result stated above is true.

3. Column totals of this matrix is found out.

4. Divided the column totals by the highest quantity in the set.

5. Multiplied each row of A^2 by this vector to get a second approximation.

6. The operations are continued till stable vectors are obtained or till the sum of the absolute values of the difference between the corresponding elements of two consecutive eigen vectors calculated is less than or equal to .0000001. The highest value used in the last stage of division gives the second

7. The vector is standardised by dividing each element of the vector by the square root of sum of squares of all the elements of the vector.

Thus we get the first eigen value and first eigen vector.

To get the second eigen vector the steps are as follows: From the $(i, j)^{th}$ element of the matrix A^2 is subtracted the product $\lambda 1^2 \times i^{th}$ element $\times j^{th}$ element of the first vector to obtain the reduced matrix. The above process of chosing trial vector and finding better approximations are repeated on this reduced matrix. Thus we got the second vector and second root.

Suppose the first two canonical roots that is $t = 2$ together account the largest proportion of the total. Then the first two canonical vectors supply the best two linear functions Z_1 and Z_2 for y_1, y_2 . . . . , the standardised variables corresponding to each variety under each character. From the mean values of y_1, y_2 . . . . . the mean values of Z_1, Z_2 to each variety can be calculated. If the two roots together account for a 90% of the total a two dimensional representation with the canonical variate will

will give almost true picture of the configuration of the groups. The magnitude of the canonical vector will say about the variability contributed by each character viz: a greater value in absolute terms for the character under study accounts the maximum variation of the varieties.

RESULTS

RESULTS

The results obtained in the present investigation are presented below

4.1. Culinary varieties of banana

4.1.1. Analysis of variance and covariance

The mean values of the 30 varieties of culinary type of banana for 13 characters are given in Table 1. The data were analysed for the analysis of variance. The analysis of variance table obtained were as given in Table 2. It was found from Table 2 that the varieties were highly significant for all characters.

A partial analysis of covariance of the data for all the 13_{c_2} combinations of the characters were carried out. The results obtained were shown in appendix I. Error variance covariance matrix calculated from the analysis of variance and covariance are given in Table 3.

4.1.2. Wilk's Λ criterion

The Wilk's Λ criterion was worked out as follows:

$$\Lambda = 1.975 \times 10^{-17}$$

v statistic was calculated as v = 2519.36. This follows a χ^2 distribution with 13 x 29 d.f. since the d.f.

in the present case exceeds 30, the z variate was worked out as

$$z = 57.79$$

As z is greater than 2.58 we can conclude that V statistic was highly significant which in other words proved that the varieties on the whole were highly significant among themselves, when all the characters were considered simultaneously.

4.1.3. D^2 analysis

The means of the 30 varieties for the 13 characters presented in Table 1 were transformed into standardised uncorrelated means. The uncorrelated mean values were presented in Table 4. Using this uncorrelated mean values for the 13 characters of the 30 varieties the genetic distance (D^2 of Mahalanobis) were calculated. The 435 (30_{c_2}) such squares of differences (D^2 values) were obtained by taking these 30 varieties, two at a time. The D^2 values thus obtained were as shown in Table 5.

4.1.4. Ranking of D^2 values

The rank totals as explained in section 3.4.2. for the various characters were worked out as shown in Table 6. From this table it could be observed that the yield (bunch weight) followed by hand weight was contributing to the maximum towards divergence whereas girth (cm) followed by height (cm) was having the least contribution to divergence.

4.1.5. Cluster formation

The D^2 values as shown in Table 5 were used to group the different varieties into different clusters which were heterogeneous between and homogeneous within by Tocher's method. The 30 varieties of culinary type of banana were grouped into 12 clusters out of which the first cluster included eleven varieties, the second and third clusters five varieties each and the remaining nine only one variety each. The clusters thus obtained were as given below:

First cluster

1. Neymannan
2. Nenuan
3. Alukhel
4. Sawai
5. Boodi
6. Hybrid sawai
7. Sambrani Monthan
8. Neyvannan
9. Vannan
10. Gloria
11. Nanabanian.

Second cluster

1. Kapur
2. Jawa
3. Sangmari payan
4. Nallabaksha
5. Ashybabatheesa.

Third cluster

1. Bluggoe
2. Karibontha
3. Malai Monthan
4. Monthan
5. Bising.

Fourth cluster

1. Erachi Vazhai.

Fifth cluster

1. Pisang awak.

Sixth cluster

1. Pey Kunnan.

Seventh cluster

1. Nallabontha

Eighth cluster

1. Kanchikela

Ninth cluster

1. Pachabontha batheesa

Tenth cluster

1. Ashmonthan.

Eleventh cluster

Twelfth cluster

1. Chetty

4.1.6. Intra and inter cluster D^2 values

The intra and inter cluster D^2 and D values of these 12 clusters worked out were presented in tables 7 and 8 respectively. From these tables it could be observed that the intra cluster D^2 values were the least within each cluster in comparison to inter cluster D^2 values of that cluster with other clusters.

A two dimensional representation of these D values of the different clusters were given in Fig.1 to have an approximate idea about the clusters and their interrelationships. Since the accurate representation would have been in a multidimensional space, the relative distance between all the clusters could not be shown accurately in a two dimensional space.

A study of the pairwise comparison of the different varieties by taking the 13 characters simultaneously were made. It was found that the D^2 values obtained by making a pairwise comparison of the varieties within the cluster were much less than that of between clusters.

Clusters and their interrelationship - a two dimensional representation (Culinary type of banana)

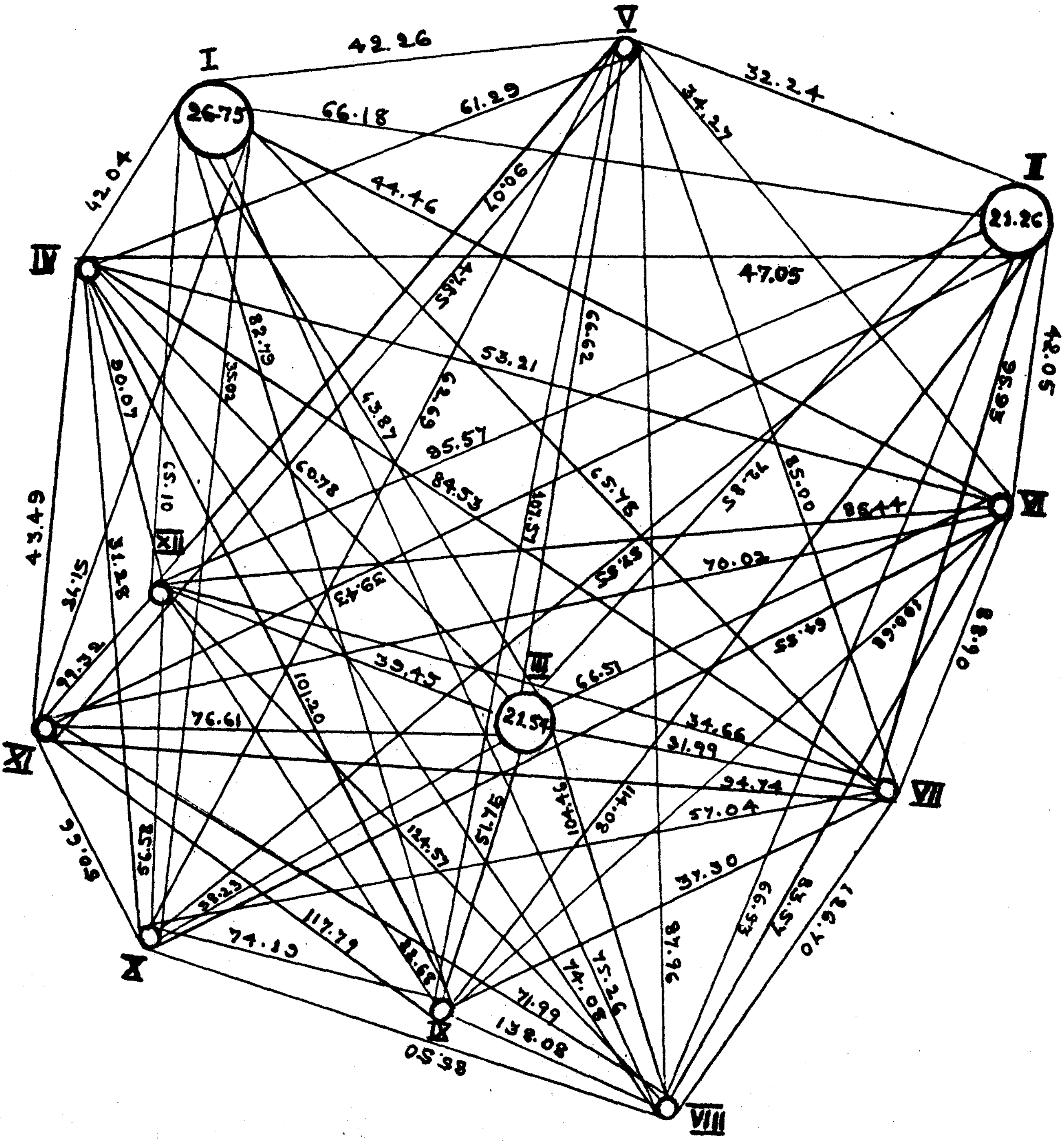

FIG. 1

4.1.7. Canonical analysis

The first two canonical roots with their relative contribution obtained as explained by Rao (1952) were as presented in Table 9. It was observed from Table 9 that the first two roots together contributes 93.89%. This showed that these two roots together accounts 93.89% of the total variability involved in the data. Hence it was enough to use only these two roots to represent the 30 varieties when these 13 characters were considered simultaneously for all practical purposes. Thus the canonical vectors corresponding to the first two canonical roots for all the characters were calculated and was as shown in Table 10.

From Table 10, it could be observed that the values corresponding to bunch weight (yield) and hand weight were larger in magnitude (absolute terms) than that of the other characters. Similarly the values of the canonical vector corresponding to girth and height were the minimum. The mean values of these two canonical roots were worked out for all the 30 varieties as shown in Table 11.

A scatter diagram showing the positions of the 30 varieties on the basis of mean values of canonical

Scatter diagram showing the positions of 30 varieties of Culinary type of banana on the basis of the first two sets of canonical variates.

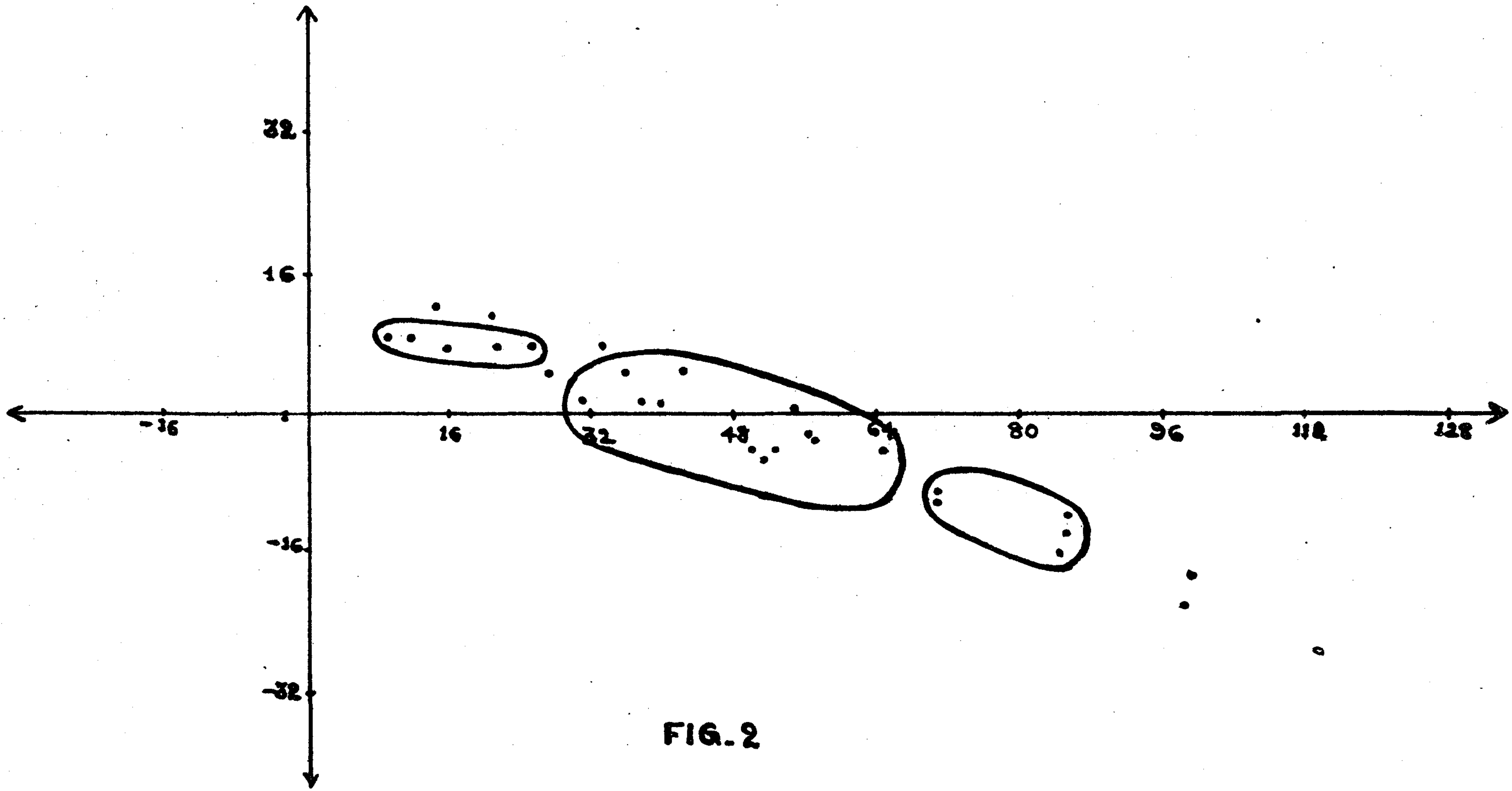

FIG. 2

variates was plotted as shown in Fig.2.

4.2. Dessert varieties of banana

4.2.1. Analysis of variance and covariance

The mean values of the 56 varieties of culinary type of banana for 12 characters are given in Table 12. The data were analysed for the analysis of variance. The analysis of variance table obtained were as given in Table 13. It was found from Table 13 that the varieties were highly significant for all characters.

A partial analysis of covariance of the data for all the 12_{c_2} combinations of the characters were carried out. The results obtained were shown in appendix II. Error variance covariance matrix calculated from the analysis of variance and covariance were given in Table 14.

4.2.2. Wilk's Λ criterion

The Wilk's Λ criterion was worked out as follows:

$$\Lambda = .2037 \times 10^{-13}$$

v statistic was calculated as

$$v = 4086.36$$

This follows a χ^2 distribution with 12 x 55 d.f.

Since the d.f. in the present case exceeds 30 the z variate was worked out as

$$z = 75.27$$

As z is greater than 2.58 we can conclude that v statistic was highly significant which in other words proved that the varieties on the whole were highly significant among themselves, when all the characters were considered simultaneously.

4.2.3. D^2 analysis

The means of the 56 varieties for the 12 characters presented in Table 12 were transformed into standardised uncorrelated means. The uncorrelated mean values were presented in Table 15. Using this uncorrelated mean values for the 12 characters of the 56 varieties the genetic distance (D^2 of Mahalanobis) were calculated by taking these 56 varieties, two at a time. The 3080 (56_{c_2}) D^2 values thus obtained were shown in Table 16.

4.2.4. Ranking of D^2 values

The rank totals as explained in section 3.4.2. for the various characters were as shown in Table 17. From this table it could be observed that finger length followed by pedunele length was contributing to the maximum towards divergence. Whereas leaves per plant and girth were having the lowest contribution to divergence.

4.2.5. Cluster formation

The D^2 values as shown in Table 16 were used to group the different varieties into different clusters. The 56 varieties of dessert type of banana were grouped into 7 clusters out of which the first cluster included 13 varieties, second and third clusters included 17 and 20 varieties and the third and fourth clusters included two varieties each respectively. Remaining two clusters were single variety clusters. The clusters thus obtained were as given below:

First cluster

1. Thaen Kunnan
2. Tongate
3. Harthman
4. Adukkan
5. Ambala Kadali
6. Rasthali
7. KNR 2/75
8. Krishna Vazhai
9. Chirapunchi
10. Njali Poovan

11. Pey Kunnan
12. Poocha Kunnan
13. Vadakkan Kadali.

Second cluster

1. Pacha Nadan
2. Virupakshy
3. Charapadathi
4. Valiya Kunnan
5. Thiruvananthapuram
6. KMR 1/76
7. Chakara Kadali
8. Nendra Kunnan
9. Sirumalai
10. Radja
11. Preban
12. Poovan
13. Mons Marie
14. High Gate
15. Kodupilla Kunnan
16. Chingan
17. Pilian.

Third cluster

1. Giant Cavendish
2. Mauritus
3. Lacatan
4. Vannankeli
5. Gros Michel
6. Chinali
7. Mauritus
8. Amrit Sagar

9. Sapumal anamalu
10. Kanni Kadali
11. Pirija
12. Pachachingan
13. Nendra Padathi
14. Lady's finger
15. Prinkchal
16. Peddapacha Arathi
17. Harichal
18. Sikusani
19. Redrajah
20. Robusta

Fourth cluster

1. Wather
2. Saina.

Fifth cluster

1. Chenkadali
2. Red banana.

Sixth cluster

1. Adakka Kunnan.

Seventh cluster

1. Ayiranka Poovan

4.2.6. Intra and inter cluster D^2 and D values

The intra and inter cluster D^2 and D values of these 7 clusters worked out were presented in tables 18 and 19 respectively. From these tables it could be observed that the intra cluster D^2 values were

Clusters and their interrelationship - a two dimensional representation. (Dessert type of banana)

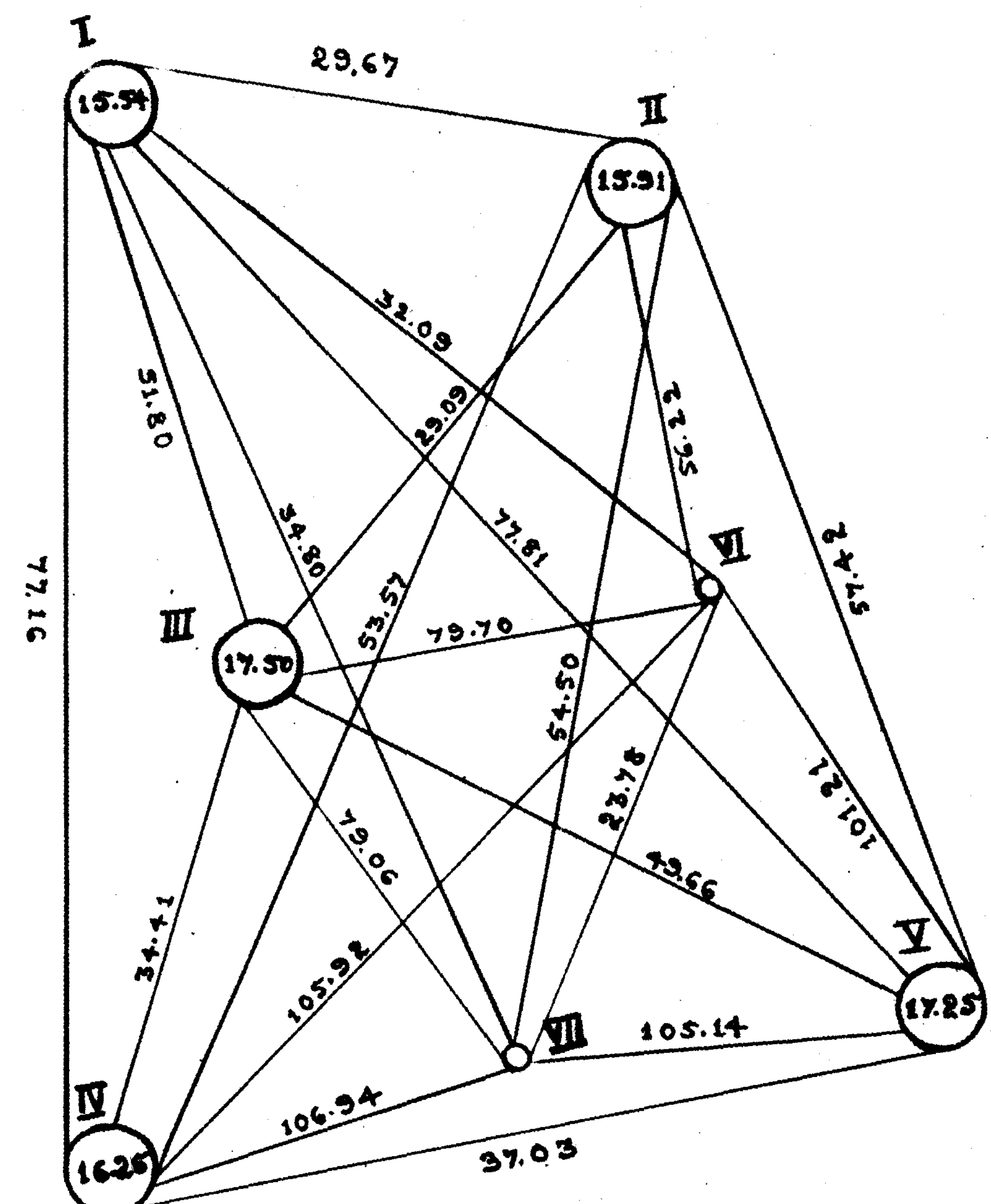

FIG. 3

the least within each cluster in comparison to inter cluster D^2 values of that cluster with other clusters.

A two dimensional representation of these D values of the different clusters were given in Fig.3 to have an approximate idea about the clusters and their interrelationships.

A study of the pairwise comparison of the different varieties by taking the 12 characters simultaneously were made. It was found that the D^2 values obtained by making a pairwise comparison of the varieties within the cluster were much less than that of between clusters.

4.2.7. Canonical analysis

The first two canonical roots with their relative contribution obtained as explained by Rao (1952) were as presented in Table 20. It was observed from Table 20 that the first two roots together contributes 93.21% of the total variability involved in the data. Hence it was enough to use only these two roots to represent the 56 varieties when those 12 characters were considered simultaneously for all practical purposes. Thus the canonical vectors corresponding to the first two canonical roots for all the characters were calculated and was as shown in Table 21.

From Table 21 it could be observed that the

Scatter diagram showing the positions of 56 varieties of Dessert type of banana on the basis of the first two canonical variates.

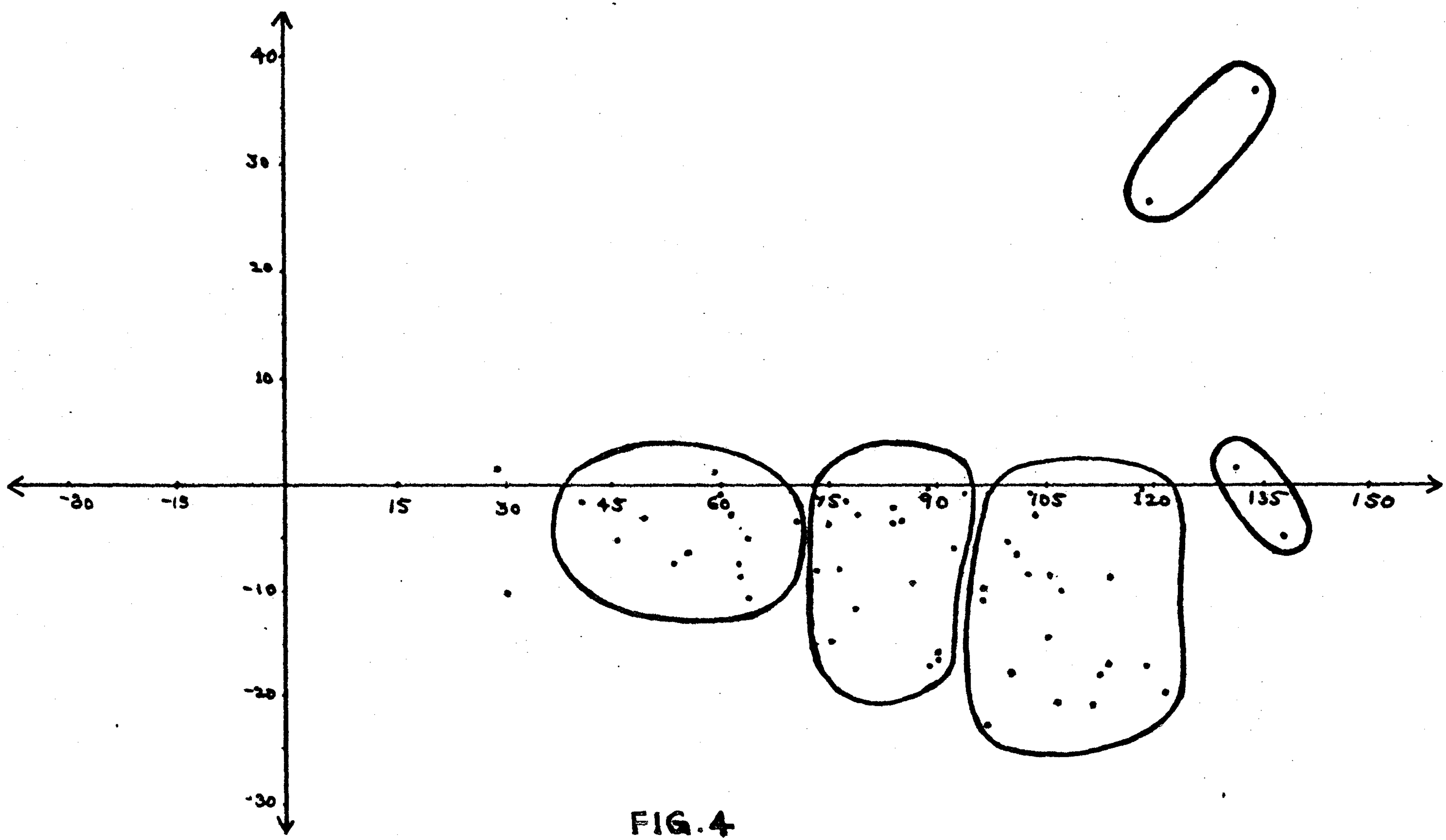

FIG. 4

values corresponding to finger length and peduncle length were larger in magnitude (absolute terms) than that of the other characters. Similarly the values of the canonical vector corresponding to leaves per plant and girth (cm) were the minimum.

The mean values of these two canonical roots were worked out for all the 56 varieties as shown in Table 22.

A scatter diagram showing the positions of the 56 varieties on the basis of mean values of the canonical variates was as shown in Fig.4.

From this scatter diagram it could be easily verified that the 7 clusters formed on the basis of D^2 values were fully in agreement with the points shown in the scatter diagram.

Table 1. Mean values of the 13 characters of 30 varieties of culinary type of banana.

Var.	ch.1	ch.2	ch.3	ch.4	ch.5	ch.6	ch.7	ch.8	ch.9	ch.10	ch.11	ch.12	ch.13
1.	270.67	70.00	33.00	612.67	47.59	12.33	221.67	11.05	8.79	16.33	13.74	96.67	204.67
2.	267.67	79.00	34.67	701.27	49.68	11.90	114.67	10.05	9.98	9.00	13.66	70.33	292.00
3.	284.67	80.00	30.67	607.39	31.09	9.33	155.67	10.35	8.07	9.33	16.96	65.33	277.67
4.	290.00	76.67	31.67	1597.17	99.01	13.00	133.00	10.92	11.42	8.67	13.85	78.67	199.33
5.	300.33	73.67	32.00	1149.27	73.61	13.50	129.00	13.57	10.93	9.67	13.76	82.67	315.00
6.	212.00	62.67	30.67	1058.67	69.63	7.40	90.33	19.00	10.00	6.67	19.13	79.17	122.00
7.	209.33	78.00	33.00	1080.07	91.23	14.50	151.67	11.38	10.41	9.33	16.47	82.50	188.33
8.	264.33	69.67	30.00	880.37	64.01	5.33	80.00	14.25	10.55	7.67	11.35	74.33	205.33
9.	288.00	80.00	32.00	1218.18	95.70	11.17	96.00	11.45	13.85	7.00	13.71	54.00	187.67
10.	299.67	76.67	32.33	884.12	55.79	13.67	221.67	10.04	8.80	12.67	17.52	95.00	347.67
11.	331.67	81.00	31.67	1003.78	68.73	20.17	275.33	10.27	8.57	15.00	18.36	134.67	285.67
12.	272.67	78.00	33.33	1348.33	98.57	15.17	133.67	13.42	11.26	8.00	16.71	64.50	191.33
13.	262.00	77.33	33.67	1309.00	105.50	10.33	80.67	14.50	12.63	6.33	12.71	72.67	256.33
14.	340.00	73.33	30.33	1688.07	145.00	13.85	77.33	16.50	14.42	6.00	12.69	103.00	310.00
15.	295.67	68.67	33.33	1802.97	152.05	11.17	58.33	16.33	14.35	5.00	11.67	78.85	260.00
16.	285.67	73.33	31.00	1806.78	153.32	13.33	79.00	20.00	13.13	6.00	13.50	68.33	270.00
17.	275.00	72.67	31.67	1382.83	119.50	8.50	94.67	15.60	13.50	5.00	10.93	92.17	205.00
18.	346.67	73.00	28.33	2058.27	189.18	14.00	73.00	16.74	15.82	6.00	12.50	101.33	277.00
19.	343.33	73.67	30.67	1548.60	141.43	13.17	79.67	17.40	14.57	6.67	11.86	77.83	268.00
20.	303.33	73.00	31.00	136.03	124.50	14.50	105.33	18.13	13.43	8.00	13.17	81.83	197.00
21.	306.67	73.33	30.00	945.33	74.67	16.83	185.00	13.92	11.31	14.00	13.50	102.83	268.33
22.	311.67	73.00	27.67	2369.00	217.17	12.17	61.00	19.83	25.33	5.00	12.13	74.67	241.67
23.	335.00	71.33	30.67	1733.47	155.05	13.17	73.33	16.00	14.56	6.33	11.77	64.33	277.33
24.	340.00	73.33	31.67	1447.33	117.00	9.85	56.67	17.85	14.30	5.33	10.69	98.17	138.67
25.	321.33	69.67	29.00	535.40	28.36	8.33	131.67	11.66	8.43	7.33	15.88	65.33	235.67
26.	317.33	75.67	32.33	887.27	76.00	16.85	201.00	13.39	10.00	13.33	15.46	138.67	167.00
27.	322.00	75.00	31.67	2177.33	175.33	11.33	57.00	18.37	24.67	5.33	10.77	79.00	221.33
28.	302.67	75.33	32.00	979.17	55.00	9.00	90.33	12.38	10.22	7.33	12.32	63.17	228.33
29.	285.67	70.00	29.00	1014.17	71.33	6.50	68.00	13.20	12.33	6.00	12.75	83.83	234.67
30.	292.33	74.00	30.33	1161.93	77.04	7.67	108.33	12.49	9.58	8.00	13.59	48.00	210.67

Characters and varieties mentioned in the section 3.1 for the culinary bananas.

Table 2. Analysis of variance of 30 varieties of culinary type of banana under 13 characters.

Source	d.f.	Mean Squares						
		ch.1	ch.2	ch.3	ch.4	ch.5	ch.6	ch.7
Replications	2	1178.411	42.253	0.811	1632.182	34.217	6.369	290.453
Varieties	29	2519.479**	48.040**	7.309**	787600.425**	6884.224**	33.079**	9834.201**
Error	58	374.986	16.915	1.811	655.088	9.881	1.904	180 .410

Mean Squares					
ch.8	ch.9	ch.10	ch.11	ch.12	ch.13
0.265	0.810	1.044	0.684	17.807	99.478
29.186**	49.153**	29.908**	16.043**	1244.357**	7070.569**
0.148	0.203	1.500	4.851	4.065	36.248

** significant at 1 percent level of probability.

Table 3. Error variance covariance matrix of 13 characters of 30 varieties of culinary type of banana.

Chara-cters	1	2	3	4	5	6	7	8	9	10	11	12	13
1.	374.9658	27.3957	8.7542	43.8022	1.8602	2.4786	-25.4891	1.0754	0.7595	-2.0682	-1.1892	9.5539	4.7812
2.		16.9115	1.0806	-19.7666	1.0961	0.1657	- 9.6632	-0.0988	0.1116	-0.2828	-0.5413	0.8877	0.0516
3.			1.8111	1.5655	-0.0497	-0.2050	0.6540	-0.0501	0.0064	-0.2475	0.4378	-0.0377	-0.9155
4.				655.0875	46.3388	23.4236	118.5916	4.4664	7.2865	7.2818	-4.2779	16.0468	12.6112
5.					9.8809	2.9519	15.3849	0.6665	0.8531	0.8839	0.3848	2.8539	4.6055
6.						1.9044	9.0865	0.2539	0.3568	0.8065	-0.3757	1.1384	2.3414
7.							180.4103	2.0569	1.4886	10.0655	-0.0519	9.8520	5.6822
8.								0.1480	0.0941	0.1094	0.2070	0.2115	0.6875
9.									0.2028	0.1295	-0.1101	0.3580	0.6631
10.										1.4996	-1.0987	0.6725	1.2763
11.											4.8506	-0.3814	-1.1390
12.												4.0648	1.2588
13.													36.2479

Table 4. Uncorrelated mean values of 30 varieties of culinary type of banana on the basis of 13 characters.

Var.	ch.1	ch.2	ch.3	ch.4	ch.5	ch.6	ch.7	ch.8	ch.9	ch.10	ch.11	ch.12	ch.13
1.	13.98	13.01	19.96	25.81	-1.92	-9.94	16.31	23.67	-3.01	12.91	2.74	48.01	38.50
2.	14.86	15.02	20.79	29.74	-4.35	-13.82	7.81	21.94	-1.75	11.17	3.31	33.46	43.92
3.	14.70	15.33	17.64	26.17	-8.91	-10.87	13.33	25.06	-4.12	8.20	3.25	32.68	53.23
4.	14.90	14.37	18.42	64.22	-11.28	-46.28	11.33	9.51	-20.67	17.58	9.14	32.21	40.09
5.	15.92	13.25	18.45	47.40	-8.37	-29.22	9.65	25.56	-14.01	15.38	1.64	39.20	62.24
6.	10.95	12.22	19.27	43.91	-6.94	-32.25	7.56	47.04	-20.23	17.26	-6.86	43.96	23.62
7.	14.94	14.73	19.46	45.01	0.55	-29.62	10.34	15.61	-13.10	13.88	4.63	35.32	38.59
8.	13.65	13.04	17.70	36.73	-3.87	-29.20	7.94	32.45	- 8.52	16.53	-2.85	37.19	39.19
9.	14.87	15.27	18.64	50.75	-2.20	-38.40	7.63	15.17	-5.57	15.49	6.21	16.82	39.30
10.	15.48	14.70	18.74	37.07	-7.66	-18.14	17.47	16.63	-9.09	10.10	6.51	45.15	69.50
11.	17.13	14.70	17.62	41.80	-6.21	-17.02	19.87	12.85	-14.58	9.20	7.42	66.38	44.17
12.	14.08	15.04	19.90	55.97	-4.99	-37.59	9.16	20.20	-19.66	15.68	3.04	25.40	41.28
13.	13.53	15.07	20.46	54.42	-0.94	-43.31	6.11	24.18	-15.63	18.74	-0.41	30.98	48.06
14.	17.56	13.08	16.56	66.61	5.44	-57.17	5.38	20.36	-21.90	21.94	0.26	43.26	45.63
15.	15.27	12.19	19.83	73.53	3.20	-65.42	4.23	18.73	-26.34	24.88	-0.26	29.49	57.14
16.	15.27	13.40	17.86	74.05	3.12	-63.93	5.71	30.32	-34.77	25.25	-5.50	24.82	55.34
17.	16.27	12.86	18.10	55.49	3.92	-49.98	4.85	24.47	-16.13	20.70	-2.08	40.86	41.72

(Table 4 contd.)

(Table 4 contd.)

Var. No.	ch.1	ch.2	ch.3	ch.4	ch.5	ch.6	ch.7	ch.8	ch.9	ch.10	ch.11	ch.12	ch.13
18.	17.90	12.35	14.91	83.83	9.91	-78.21	5.86	10.14	-30.15	27.39	3.27	35.99	60.46
19.	17.73	12.58	16.81	63.02	6.65	-54.74	5.51	24.52	-19.98	22.30	-1.81	28.35	32.60
20.	15.66	13.17	17.76	7.34	43.46	-11.26	1.29	39.61	8.57	12.77	-12.58	31.85	19.11
21.	15.84	13.19	16.90	39.14	-1.56	-20.32	12.49	26.52	-8.19	14.41	1.45	49.13	30.19
22.	16.09	13.01	14.98	96.69	11.62	-94.58	5.79	14.31	-11.27	29.28	5.99	13.59	52.86
23.	17.30	12.13	17.00	70.06	6.49	-62.66	5.15	16.30	-23.77	24.10	1.25	18.03	37.17
24.	17.56	12.56	17.66	59.15	0.02	-50.72	5.13	31.48	-17.39	21.19	-4.10	45.30	29.08
25.	16.59	11.96	15.95	22.35	-7.17	-9.48	11.37	30.01	-1.80	7.21	0.16	32.80	43.19
26.	16.39	13.59	18.51	35.65	1.70	-17.90	13.36	24.99	-9.27	12.95	0.94	71.06	32.09
27.	16.63	13.33	17.93	88.87	0.44	-80.99	5.81	18.57	-4.92	26.34	6.25	21.56	48.60
28.	15.63	13.78	18.50	40.68	-10.72	-25.90	8.17	26.73	-9.81	13.96	0.67	30.66	45.76
29.	14.65	12.76	16.57	42.02	-5.08	-33.35	7.01	26.54	-5.24	15.26	1.28	40.55	46.27
30.	15.10	13.63	17.39	48.12	-7.59	-37.18	10.64	21.48	-17.19	16.99	2.18	17.81	44.85

Table 5. D^2 values of 30 varieties of culinary type of banana by considering 13 characters simultaneously.

Var. No.	1	2	3	4	5	6	7	8	9	10	11
1.		369.39	566.32	3830.46	1703.49	2129.34	1134.13	858.86	2586.10	1312.76	1011.85
2.			195.55	2914.99	1130.71	2207.33	724.73	559.71	1440.20	1065.50	1672.35
3.				3377.76	1091.92	2780.20	1237.72	912.10	2029.36	738.02	1874.48
4.					1199.73	3064.35	1017.32	2039.70	927.49	2454.25	2707.41
5.						2143.97	775.79	777.39	1370.17	557.28	1985.56
6.							1574.59	735.92	2518.77	7756.38	2891.36
7.								472.47	530.68	[illegible]	1349.28
8.									1085.89	[illegible]	1794.56
9.										2465.33	3312.59
10.											1174.36

continued ...

Table 5 continued.

Var. No.	12	13	14	15	16	17	18	19	20	21
1.	2554.98	2692.28	4625.31	6943.48	7482.49	2977.30	10074.73	4592.65	3895.95	489.88
2.	1672.24	1792.62	4002.42	3666.05	6188.03	2454.30	8017.87	3532.73	4142.45	540.86
3.	2149.20	2265.91	4782.10	6311.16	6707.64	3173.84	9632. 15	4100.12	5056.89	679.13
4.	440.25	578.20	796.78	1068.19	1660.44	861.77	2295.84	852.10	10656.92	2207.90
5.	856.68	617.99	1792.61	2573.71	2920.37	1143.16	4751.80	1557.84	7515.21	484.15
6.	1675.85	1638.25	2618.14	4384.58	3568.36	1501.43	7145.34	2758.68	5488.19	1624.32
7.	392.50	537.80	1589.19	2855.34	3562.57	792.48	4994.63	1521.82	5419.20	618.16
8.	905.29	785.42	3227.47	3702.36	3846.97	1080.36	6415.22	1968.06	4358.01	478.05
9.	351.90	564.71	1795.85	2954.40	2867.16	1067.03	4455.22	1238.02	6443.17	1815.81
10.	2169.43	2001.22	3656.71	4851.26	5556.78	2739.13	7225.72	3347.05	7771.41	608.33
11.	1534.25	2107.64	4416.64	5024.79	5258.17	3289.20	7903.85	3356.41	6984.41	2448.46
12.		190.35	1038.00	1585.42	1801.01	586.03	3535.46	730.08	7438.43	1438.40
13.			656.52	1149.64	1395.85	255.46	2927.40	362.36	7110.73	1844.68
14.				492.74	857.27	280.37	1246.58	317.67	9470.38	2534.72
15.					268.15	1094.80	308.47	368.35	12356.99	4855.50
16.						1399.17	1085.39	[illegible]22.99	12406.86	4695.21
17.							2500.31	[illegible].69	7000.08	1497.02
18.								[illegible]79.48	16053.89	6733.44
19.									8797.41	2532.04
20.										5162.67

continued ...

Table 5 continued

Var. No.	22	23	24	25	26	27	28	29	30
1.	14889.34	6866.03	3401.29	422.38	816.18	10172.30	1060.56	1056.73	2487.92
2.	12227.70	5312.77	3127.13	221.68	1768.04	8467.12	430.34	666.56	1434.89
3.	13407.97	9914.54	4036.66	182.95	2286.67	9506.84	604.54	996.85	1722.46
4.	4556.16	1119.86	1436.12	4427.18	4004.31	2510.02	1486.30	1391.07	778.09
5.	8262.77	2635.90	1945.33	1671.53	2329.22	5260.12	341.01	404.41	867.30
6.	10241.42	4758.74	978.53	2328.19	1891.05	6911.17	1364.99	1269.40	1956.13
7.	7945.57	2703.95	1277.18	1429.19	1670.76	5109.54	394.31	758.99	550.87
8.	9403.94	3656.81	1274.96	813.28	1480.24	6146.25	227.30	173.34	846.49
9.	5865.76	1856.54	1708.92	2512.33	3844.58	3519.73	732.72	886.43	275.25
10.	11971.05	4801.30	3929.58	1471.24	2289.35	8112.17	1110.86	1109.35	2044.88
11.	10195.95	4064.75	4166.82	1856.02	4905.46	7300.18	1189.19	2111.35	892.84
12.	5765.63	1432.94	1006.26	2515.44	3170.02	3429.25	599.24	740.36	160.97
13.	5187.71	1155.94	750.31	2669.63	3005.30	2966.85	674.82	519.91	358.84
14.	3497.93	844.05	570.23	5260.36	3785.05	1916.10	2352.38	1662.91	1646.18
15.	2035.30	166.48	1753.31	7172.33	6591.42	1135.31	3442.96	2951.08	2096.15
16.	2613.43	445.28	1844.40	7439.86	7171.57	1743.84	3601.53	3394.67	2202.33
17.	4864.39	1707.41	268.61	3739.31	2613.14	2768.79	1857.91	732. 97	969.73
18.	1791.09	859.38	3853.88	10721.32	8975.45	1201.82	6175.09	5261.91	4281.95
19.	3848.27	343.43	981.17	4658.43	4640.38	1806.09	1889.30	1521.67	1006.09
20.	19965.20	11865.89	7310.69	3878.46	5182.46	19516.97	5709.48	5455.70	7119.40
21.	10696.32	4384.09	2031.56	887.20	848.80	7208.36	325.61	320.82	1389.90
22.		1973.89	5504.31	14436.20	13873.62	514.33	9075.55	8166.05	6355.04
23.			2150.50	6757.45	7154.73	1185.90	3243.48	2975.19	1666.20
24.				3963.41	2565.95	3200.85	1754.76	1168.13	1563.08
25.					2052.00	10325.07	774.41	1144.65	2076.59
26.						9064.16	2142.91	1535.03	3704.30
27.							5097.34	5075.32	3958.02
28.								229.54	444.28
29.									764.02

Table 6. Rank total on the basis of D^2 values for 13 characters of the culinary type of banana.

Character	Rank total
1. Height	4699
2. Girth	4972
3. Leaves per plant	4651
4. Hand weight	1363
5. Finger weight	2773
6. Bunch weight	1176
7. Fingers per bunch	3689
8. Finger length	2713
9. Finger thickness	2465
10. Hands per bunch	3098
11. Fingers per hand	3593
12. Peduncle length	2119
13. Number of roots	2274

Table 7. Average intra and inter cluster D^2 values of 12 clusters for culinary type of banana on the basis of 13 characters simultaneously.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	715.36	4380.05	1984.32	1767.60	1786.09	1976.48	4386.80	5663.85	6054.51	1226.42	2681.57	4237.38
II		451.93	5307.72	2213.92	1039.19	1768.06	9201.98	4486.08	13013.53	3312.01	1554.34	9134.74
III			463.84	3693.70	4438.62	4423.95	1023.45	10911.00	2678.22	1461.52	5868.63	1556.65
IV				0	3756.39	2891.26	7145.34	5488.19	10841.42	978.53	1891.05	6911.17
V					0	1174.36	7225.75	7757.41	11571.05	3929.58	2289.35	8112.17
VI						0	7903.85	6984.41	10135.95	4166.82	4903.46	7300.18
VII							0	16053.89	1391.09	3253.82	6975.45	1801.62
VIII								0	19065.20	7310.62	5182.65	15516.97
IX									0	3504.31	13873.62	514.53
X										0	2565.93	3200.85
XI											0	9064.16
XII												0

Table 8. Average intra and inter cluster D values of 12 clusters for culinary type of banana on the basis of 13 characters simultaneously.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	26.75	66.18	43.87	42.04	42.86	44.46	65.78	75.26	82.79	35.02	51.78	75.10
II		21.26	72.85	47.05	32.24	42.05	95.93	66.53	114.08	57.55	39.43	95.57
III			21.54	60.78	66.62	66.51	31.99	104.46	51.75	38.23	76.61	39.45
IV				0	61.29	53.21	84.53	74.08	101.20	31.28	43.49	90.07
V					0	34.27	85.00	87.96	107.57	62.69	47.88	90.07
VI						0	88.90	85.57	100.68	64.95	70.02	85.44
VII							0	126.70	37.30	57.04	94.74	34.66
VIII								0	138.08	85.50	71.99	124.57
IX									0	74.19	117.79	22.68
X										0	50.66	56.58
XI											0	99.32
XII												0

Table 9. Canonical roots and their relative contribution of 30 varieties of culinary type of banana by taking 13 characters simultaneously.

Canonical root	λ_1	λ_2	$\lambda_3 + - - - + \lambda_{13}$	Total
Value	24823.54	18299.03	2806.27	45928.84
Percentage contribution	54.05	39.84	6.11	100

Table 10. Canonical vectors based on the first two canonical roots of 13 characters of culinary type of banana.

Character	Vector-1	Vector-2
1. Height	.0171	.0092
2. Girth	-.0096	.0055
3. Leaves per plant	-.0170	.0104
4. Hand weight	.6613	.4948
5. Finger weight	-.0294	-.1384
6. Bunch weight	-.4521	.7582
7. Fingers per bunch	-.4023	-.2899
8. Finger length	-.1488	.2101
9. Finger thickness	-.2213	.0761
10. Hands per bunch	.1934	-.0884
11. Fingers per hand	.0327	-.0051
12. Peduncle length	-.2457	.1292
13. Number of roots	.1577	-.0488

Table 11. Mean values of the canonical variates for the 30 varieties of culinary type of banana on the basis of first two canonical roots.

Sl. No.	Y_1	Y_2
1.	8.85	8.85
2.	20.76	8.41
3.	16.13	7.48
4.	65.50	-4.25
5.	43.26	4.77
6.	34.03	7.60
7.	39.58	0.62
8.	31.42	2.07
9.	51.95	-4.13
10.	27.29	5.07
11.	21.39	10.16
12.	54.97	0.02
13.	56.37	-3.48
14.	70.10	-8.57
15.	85.24	-13.98
16.	85.84	-11.74
17.	50.34	-4.47
18.	99.35	-21.71
19.	70.26	-10.00
20.	-2.56	-0.08
21.	26.49	8.24
22.	115.03	-28.80
23.	84.80	-15.82
24.	56.45	-2.68
25.	10.69	9.32
26.	14.71	11.05
27.	98.85	-17.46
28.	36.23	5.04
29.	37.59	1.10
30.	51.19	-4.65

Table 12. Mean values of the 12 characters of 56 varieties of dessert type of banana.

Var.no.	ch.1	ch.2	ch.3	ch.4	ch.5	ch.6	ch.7	ch.8	ch.9	ch.10	ch.11	ch.12
1.	305.00	70.67	32.33	1300.53	79.67	9.67	99.00	12.80	9.63	7.33	13.43	87.00
2.	331.67	81.00	26.67	1038.27	70.97	17.67	154.67	10.90	8.77	13.33	13.80	132.33
3.	263.67	67.33	32.67	1058.20	75.83	10.33	114.67	12.67	11.03	7.67	15.30	76.33
4.	278.67	68.67	27.00	766.40	76.20	9.47	118.00	15.33	10.77	11.00	10.77	84.00
5.	268.67	72.33	31.33	655.67	42.47	8.90	156.67	11.07	8.70	10.67	14.03	84.67
6.	297.67	80.00	28.00	529.67	33.33	6.33	214.00	9.40	8.47	12.67	16.90	86.33
7.	277.00	74.67	29.33	480.67	26.13	5.67	175.33	6.33	6.67	10.33	16.87	62.33
8.	267.33	65.00	31.00	897.00	59.07	6.17	138.33	12.17	10.73	8.33	16.93	73.67
9.	288.00	75.33	30.33	1135.51	79.13	16.47	176.33	11.27	9.93	10.00	17.73	102.33
10.	284.67	83.33	28.67	519.97	46.93	6.83	126.00	10.10	8.43	8.33	15.13	97.00
11.	246.00	63.67	30.00	731.33	47.93	10.17	153.33	11.20	9.07	10.00	13.33	88.33
12.	321.67	72.00	32.67	728.37	47.53	12.33	177.33	10.10	9.33	10.67	16.67	78.33
13.	300.00	65.67	31.00	697.05	53.77	18.00	281.00	10.47	6.87	21.33	12.27	108.00
14.	294.67	72.67	30.67	858.65	77.90	10.53	109.67	11.73	9.80	7.67	14.33	89.00
15.	354.33	87.33	29.33	3284.00	205.67	19.50	85.00	17.87	15.23	5.33	15.80	77.67
16.	325.67	77.00	29.00	2758.33	170.40	19.00	94.33	16.70	15.17	6.00	15.73	84.00
17.	366.67	66.67	31.67	780.67	45.73	9.67	164.33	10.33	9.67	9.67	16.87	88.00
18.	348.33	70.33	32.67	610.00	32.33	9.83	290.33	9.23	8.30	12.67	18.17	78.33
19.	234.00	61.33	29.33	810.27	48.07	8.00	87.00	12.43	9.10	7.00	12.43	56.00
20.	252.33	58.00	30.67	921.87	74.00	8.17	89.00	16.50	8.37	6.67	13.33	80.00
21.	182.67	58.00	29.33	813.70	65.53	10.33	97.33	15.47	9.77	7.67	12.73	53.33
22.	188.33	63.67	27.00	1043.00	94.20	6.50	58.67	17.43	10.43	5.00	11.73	61.67
23.	220.00	72.00	28.33	1213.17	104.67	13.57	115.00	19.60	12.57	8.33	13.83	105.67
24.	232.67	65.67	27.00	1380.00	96.50	12.17	118.67	18.63	10.37	8.00	13.20	115.67
25.	181.00	57.33	30.00	1459.67	115.47	12.73	104.33	17.17	9.80	7.00	14.70	83.67
26.	259.67	68.33	26.67	1920.00	185.51	12.83	78.00	19.00	16.30	5.67	13.63	84.67
27.	260.00	60.33	29.00	1071.53	70.57	11.00	182.67	17.43	10.00	8.00	14.07	115.33
28.	244.00	68.00	28.00	1450.50	85.10	12.85	120.00	16.13	11.17	10.00	15.00	65.00

continued ...

Table 12 continued

Var.no.	ch.1	ch.2	ch.3	ch.4	ch.5	ch.6	ch.7	ch.8	ch.9	ch.10	ch.11	ch.12
29.	305.00	66.00	30.67	1268.25	89.53	11.33	105.33	17.05	10.30	8.00	13.13	59.33
30.	258.33	57.67	28.00	858.75	63.63	7.67	98.33	16.2	9.60	7.67	12.87	73.33
31.	173.33	62.33	29.00	1284.73	91.53	12.93	107.00	15.93	8.90	7.67	13.77	74.33
32.	166.67	61.00	29.67	1408.33	105.27	13.33	118.00	16.87	10.87	8.00	14.77	81.67
33.	170.00	68.33	29.00	1145.63	96.13	12.85	117.67	16.10	11.70	8.00	14.77	81.67
34.	270.00	69.33	28.33	1404.00	85.83	9.50	116.33	17.67	10.30	6.33	18.60	75.00
35.	156.00	61.67	30.33	1135.00	81.67	10.85	105.67	18.60	10.63	7.67	13.87	72.33
36.	300.00	66.67	30.33	1158.90	71.00	9.33	113.00	14.67	10.17	8.00	14.20	67.00
37.	234.00	74.00	32.33	606.33	40.93	7.33	130.67	10.97	8.67	9.00	14.50	82.00
38.	310.00	71.00	30.33	1198.37	61.83	10.33	101.33	15.90	11.23	7.00	14.47	61.00
39.	172.33	55.67	25.33	686.93	37.70	5.67	93.67	16.10	7.60	6.67	14.10	61.33
40.	205.33	70.67	29.00	553.73	53.03	4.50	77.67	14.37	8.90	6.67	11.70	51.33
41.	129.00	39.00	24.00	425.00	38.50	3.33	60.67	11.33	8.43	3.00	12.13	[illegible]
42.	281.00	72.33	30.00	956.70	76.13	8.17	87.67	12.83	11.57	6.67	13.17	[illegible]
43.	316.67	70.33	27.33	985.57	57.23	5.85	85.67	11.93	10.50	6.67	12.00	80.00
44.	319.33	87.67	33.33	1071.13	64.70	14.33	211.00	11.77	10.73	12.33	17.20	85.00
45.	290.33	67.33	26.33	988.57	73.87	6.85	82.33	12.20	11.00	6.67	12.40	81.67
46.	246.33	70.33	27.00	995.00	70.20	8.00	89.67	13.47	10.70	7.33	12.25	82.33
47.	288.67	68.67	30.00	1121.60	76.87	8.67	.88	14.53	11.1	6.33	13.9	89.67
48.	288.33	70.33	29.67	1433.63	101.93	8.83	98.00	15.00	11.83	7.33	13.37	86.00
49.	288.67	74.33	32.67	1158.30	87.53	10.90	97.33	15.77	10.50	7.33	13.30	111.67
50.	302.00	79.67	31.67	1115.50	63.10	11.17	135.33	13.00	9.93	8.33	16.20	62.67
51.	294.33	73.00	32.67	1567.20	121.17	11.83	114.33	15.17	9.90	7.67	14 .90	112.00
52.	284.00	77.00	31.00	875.47	65.63	8.00	100.00	10.87	8.63	6.33	18.17	79.00
53.	200.67	57.00	25.33	1699.67	126.97	5.83	56.00	19.57	12.33	4.33	12.80	27.67
54.	291.33	70.00	31.00	1045.43	72.80	8.57	88.00	12.63	11.13	6.30	13.83	66.00
55.	294.00	69.67	31.33	1692.57	173.43	10.50	83.67	16.60	12.60	6.00	13.90	87.33
56.	243.67	69.00	30.00	707.83	53.17	6.50	116.33	11.00	9.03	8.00	14.57	49.00

Characters and varieties mentioned in the section 3.1 for the dessert banana.

Table 13. Analysis of variance of 56 varieties of dessert type of banana under 12 characters.

Source	d.f	Mean Squares					
		ch.1	ch.2	ch.3	ch.4	ch.5	ch.6
Replications	2	997.238	35.524	3.375	3269.408	132.386	2.149
Varieties	55	8649.463**	204.422**	16.860**	770116.185**	4147.395**	37.353**
Error	110	195.929	21.197	3.278	3372.111	118.462	1.739

Source	Mean Squares					
	ch.7	ch.8	ch.9	ch.10	ch.11	ch.12
Replications	15.875	0.667	0.087	0.363	0.354	20.220
Varieties	5904.067**	28.805**	10.974**	21.292**	9.223**	960.260**
Error	138.499	0.094	0.125	0.436	3.402	28.704

** Significant at 1% level of probability.

Table 14. Error variance covariance matrix of 12 characters of 56 varieties of dessert type of banana.

Characters	1	2	3	4	5	6	7	8	9	10	11	12
1.	193.9290	13.5030	7.9965	49.8814	17.4938	.9942	.0807	-.8691	-.0355	.2370	-1.1741	.5623
2.		21.1965	1.6119	39.6756	2.7778	.5519	3.4695	.1584	.2780	.5887	-.2755	2.8738
3.			3.2780	13.0821	2.2351	.5049	-2.9279	-.0519	-.1116	.0495	-.1179	-1.2985
4.				3372.1114	390.9501	56.8275	153.9597	7.8555	6.3873	7.0300	5.4720	197.6886
5.					118.4618	7.9077	9.9193	.9683	.7856	.5300	.4742	17.2097
6.						1.7335	2.4250	.2402	.2192	.1639	-.0867	2.5957
7.							138.4992	1.9033	.1336	3.2915	2.4053	23.1423
8.								.0936	.0405	.0813	.0352	.2024
9.									.1246	.0340	.0111	.3691
10.										.4358	-.5146	1.0996
11.											3.4021	.2433
12.												28.7859

Table 15. Uncorrelated mean values of 56 varieties of dessert type of banana on the basis of 12 characters.

Var. no.	ch.1	ch.2	ch.3	ch.4	ch.5	ch.6	ch.7	ch.8	ch.9	ch.10	ch.11	ch.12
1.	21.90	10.98	10.10	18.89	-10.07	-14.26	4.78	67.51	27.89	-10.74	-7.14	55.10
2.	23.82	12.87	5.87	14.31	-7.46	.68	9.74	46.43	30.27	1.36	4.99	46.90
3.	18.93	10.88	11.32	14.74	-6.95	-9.90	7.48	63.54	32.99	-10.43	-5.32	50.43
4.	18.57	11.26	8.05	9.91	-2.77	-4.87	8.56	76.39	29.07	-6.89	-5.74	60.21
5.	19.29	11.91	10.26	7.62	-3.31	-3.85	12.66	52.30	25.91	-4.14	.54	44.81
6.	21.38	13.17	7.43	5.38	-4.71	-3.45	17.80	41.35	26.87	-0.64	4.58	35.62
7.	19.89	12.31	8.85	4.60	-4.84	-3.53	14.82	27.47	22.40	0.11	6.67	22.61
8.	19.20	10.31	10.32	12.07	-6.76	-8.74	10.10	60.63	33.10	-9.32	-5.36	47.81
9.	20.68	12.28	9.16	15.99	-7.64	-5.23	11.95	47.84	26.86	-5.96	1.07	41.96
10.	20.44	14.11	8.01	5.08	-2.84	-5.07	10.19	49.52	24.39	-6.46	0.18	37.98
11.	17.67	10.34	10.25	9.27	-5.65	-3.31	12.02	51.77	26.63	-4.94	0.20	[illegible]
12.	23.10	11.02	9.69	8.82	-6.14	-0.61	14.03	44.62	27.23	-3.79	2.77	[illegible]
13.	21.54	9.95	9.58	7.50	-4.07	7.52	21.72	36.20	16.73	13.73	13.01	[illegible]
14.	21.16	11.59	9.29	11.19	-4.10	-5.47	7.60	58.32	27.73	-8.89	-3.28	[illegible]
15.	24.01	14.23	7.18	53.28	-22.50	-28.66	-5.73	94.51	46.22	-21.38	-20.23	[illegible]
16.	23.24	12.10	7.53	44.40	-19.31	-29.65	-2.57	86.32	42.03	-18.33	-16.06	56.63
17.	26.33	9.14	8.47	9.93	-7.48	-4.38	12.52	50.24	29.85	-5.69	0.77	43.51
18.	25.01	10.24	9.35	6.79	-6.54	-1.11	19.20	39.13	23.98	-0.85	5.68	31.24
19.	16.80	10.01	10.19	10.76	-6.65	-7.22	5.81	64.07	26.09	-9.71	-5.62	48.12
20.	18.12	8.98	10.68	12.73	-5.34	-9.57	5.85	86.61	21.66	-14.48	-9.78	69.51
21.	13.12	10.06	11.43	10.95	-4.54	-5.11	6.98	76.57	26.18	-11.72	-7.64	55.07
22.	13.52	11.23	9.76	14.90	-3.98	-13.82	2.54	92.89	28.37	-17.93	-14.60	69.72
23.	15.80	12.59	9.59	17.56	-5.20	-8.58	6.51	96.67	31.98	-16.39	-12.55	78.71
24.	16.71	10.99	8.72	20.73	-8.62	-12.76	5.91	93.49	25.69	-15.53	-12.46	78.54
25.	13.00	9.94	11.88	22.21	-7.26	-14.53	5.02	85.64	25.76	-14.98	-10.96	65.22
26.	18.36	11.23	7.93	30.12	-5.65	-22.82	0.40	99.57	46.58	-20.47	-18.71	72.40
27.	18.67	9.38	9.45	15.37	-7.78	-8.50	6.85	88.41	25.47	-14.05	-9.60	77.37
28.	17.52	11.33	8.98	21.84	-10.99	-13.07	8.28	78.33	30.38	-10.69	-7.74	51.27

continued ...

Table 15 continued

Var. no.	ob.1	ob.2	ob.3	ob.4	ob.5	ob.6	ob.7	ob.8	ob.9	ob.10	ob.11	ob.12
29.	21.90	9.95	9.27	18.55	-8.52	-11.82	5.40	88.25	26.75	-13.95	-10.54	60.91
30.	17.11	9.13	9.43	11.78	-5.55	-8.62	6.64	84.05	25.94	-12.79	-9.10	65.25
31.	12.45	11.17	11.31	19.07	-7.54	-10.67	8.71	77.62	22.38	-12.32	-8.35	57.77
32.	11.97	10.97	11.89	21.23	-7.59	-12.72	6.33	82.02	29.36	-13.56	-9.87	61.53
33.	12.20	12.55	11.20	16.46	-4.97	-8.44	7.30	77.10	32.00	-13.00	-8.50	59.73
34.	19.39	11.23	8.56	20.97	-10.45	-16.07	5.58	91.71	27.24	-17.96	-10.78	67.19
35.	11.20	11.29	12.49	16.40	-6.55	-10.59	6.50	92.78	28.10	-15.70	-11.92	69.25
36.	21.54	10.62	9.10	16.58	-9.12	-11.87	6.45	76.16	28.45	-11.85	-7.75	55.48
37.	16.80	12.82	11.57	6.66	-4.54	-4.57	10.81	53.22	26.31	-6.31	-1.10	47.15
38.	22.26	10.98	8.80	17.20	-8.42	-11.53	5.22	82.92	30.68	-14.81	-9.98	58.89
39.	12.37	9.70	9.38	9.00	-5.75	-7.49	6.81	82.89	19.30	-13.58	-8.11	65.21
40.	14.74	12.53	10.35	6.05	-2.18	-7.02	6.32	75.64	25.12	-12.28	-8.22	57.28
41.	9.86	6.67	10.06	4.97	-2.70	-5.84	5.35	59.74	26.16	-10.08	-5.59	50.88
42.	20.18	11.72	9.21	12.96	-5.47	-9.88	5.23	67.35	34.29	-11.85	-7.60	51.01
43.	22.74	10.73	6.91	6.66	-2.95	-5.43	6.33	63.95	30.70	-10.41	-5.40	55.69
44.	22.95	74.34	9.85	14.33	-8.55	-4.42	15.37	50.52	30.84	-4.43	.99	38.00
45.	20.85	10.47	7.00	13.86	-6.34	-11.54	4.25	65.60	32.60	-10.64	-7.30	54.63
46.	17.69	11.82	8.27	12.81	-5.66	-9.40	5.26	69.60	30.47	-10.85	-7.51	57.43
47.	20.73	10.79	9.15	15.95	-7.83	-12.13	4.48	76.97	31.71	-14.00	-9.53	64.14
48.	20.70	11.17	8.91	21.38	-9.11	-17.76	4.06	79.74	34.66	-13.45	-10.97	62.05
49.	20.73	12.05	10.55	16.28	-7.02	-10.61	5.38	81.38	28.30	-13.89	-9.69	72.13
50.	21.670	13.03	9.50	15.43	-9.31	-8.83	8.50	64.04	27.70	-10.30	-4.21	45.40
51.	21.14	11.67	10.46	23.47	-6.71	-17.21	5.23	78.06	27.32	-13.06	-9.17	66.36
52.	20.39	12.71	9.59	11.35	-5.63	-8.51	6.66	56.00	25.14	-10.16	-1.54	47.86
53.	14.41	9.56	8.71	26.67	-9.28	-26.37	-.63	107.80	35.28	-21.92	-20.30	74.90
54.	20.92	11.05	9.64	14.52	-7.28	-10.95	4.85	66.75	33.05	-12.19	-7.47	51.34
55.	21.11	10.95	9.79	25.84	-4.30	-21.68	2.34	88.94	36.61	-17.15	-14.44	67.79
56.	17.06	11.48	10.03	8.71	-4.65	-7.26	8.95	55.61	27.60	-7.61	-2.48	39.76

Table 17. Rank total on the basis of D^2 values for 12 characters of the dessert type of banana.

Character	Rank total
1. Height	11084
2. Girth	15276
3. Leaves per plant	15294
4. Hand weight	7849
5. Finger weight	12694
6. Bunch weight	8808
7. Fingers per bunch	11655
8. Finger length	3393
9. Finger thickness	10243
10. Hands per bunch	9810
11. Fingers per hand	8612
12. Peduncle length	5202

Table 18. Average intra and inter cluster D^2 values of 7 clusters for dessert type of banana on the basis of 12 characters simultaneously.

	I	II	III	IV	V	VI	VII
I	241.41	880.36	2683.24	5953.51	6054.40	1029.49	1211.36
II		253.04	846.02	2870.09	3305.42	3161.02	2970.61
III			306.11	1184.20	2465.93	6352.66	6250.14
IV				264.05	1371.21	11219.22	11437.09
V					297.45	10242.98	11054.43
VI						0	565.38
VII							0

Table 19. Average intra and inter cluster D values of 7 clusters for dessert type of banana on the basis of 12 characters simultaneously.

	I	II	III	IV	V	VI	VII
I	15.54	29.67	51.80	77.16	77.81	32.09	34.80
II		15.91	29.09	53.57	57.42	56.22	54.50
III			17.50	34.41	49.66	79.70	79.06
IV				16.25	37.03	105.92	106.94
V					17.25	101.21	105.14
VI						0	25.78
VII							0

Table 20. Canonical roots and their relative contribution of 56 varieties of dessert type of banana by taking 12 characters simultaneously.

Canonical root	λ_1	λ_2	$\lambda_3 + - - - + \lambda_{12}$	Total
Value	36502.01	5332.64	2978.67	43913.32
Percentage contribution	81.07	12.14	6.79	100

Table 21. Canonical vectors based on the first two canonical roots of 12 characters of dessert type of banana.

Character	Vector-1	Vector-2
1. Height	-.0494	.2148
2. Girth	-.0080	.0570
3. Leaves per plant	.0028	-.0501
4. Hand weight	.2456	.5856
5. Finger weight	-.0549	-.2625
6. Bunch weight	-.2390	.4216
7. Fingers per bunch	-.1643	-.1227
8. Finger length	.7084	-.1992
9. Finger thickness	.1130	.3654
10. Hands per bunch	-.2266	-.0451
11. Fingers per hand	-.2567	-.0557
12. Peduncle length	.4670	-.4112

Table 22. Mean values of the canonical variates for the 56 varieties of dessert type of banana on the basis of first two canonical roots.

Var. No.	Y_1	Y_2	Var. No.	Y_1	Y_2
1.	87.65	-1.07	29.	105.67	-9.43
2.	56.39	-7.05	30.	101.44	-18.10
3.	80.07	-2.91	31.	95.46	-10.34
4.	89.91	-16.96	32.	102.75	-8.14
5.	61.69	-8.99	33.	95.72	-10.78
6.	46.25	-4.74	34.	113.88	-9.04
7.	29.56	1.20	35.	113.09	-17.89
8.	74.76	-3.55	36.	92.97	-5.53
9.	59.65	-0.81	37.	64.60	-10.65
10.	56.35	-7.73	38.	101.04	-6.85
11.	62.31	-8.23	39.	98.10	-22.55
12.	50.96	-5.46	40.	89.49	-18.75
13.	30.33	-10.13	41.	74.15	-15.20
14.	73.11	-8.19	42.	85.96	-3.82
15.	132.33	36.19	43.	79.39	-12.32
16.	118.87	25.79	44.	59.07	1.60
17.	60.79	-3.17	45.	84.67	-3.88
18.	41.82	-2.13	46.	87.85	-9.08
19.	77.36	-8.22	47.	99.13	-8.39
20.	105.87	-20.68	48.	103.49	-0.97
21.	89.85	-15.67	49.	105.11	-14.56
22.	115.42	-16.84	50.	76.98	-1.52
23.	120.57	-20.40	51.	103.08	-4.43
24.	119.30	-17.27	52.	70.51	-5.58
25.	108.06	-9.99	53.	138.21	-4.81
26.	131.18	2.26	54.	84.25	-2.49
27.	111.42	-21.09	55.	116.72	-0.75
28.	94.02	-0.67	56.	65.15	-4.59

DISCUSSION

DISCUSSION

D^2 - statistic being a numerical estimate has the added advantage over other criteria of permitting precise comparisons among all possible pairs of populations in any given group. In recent works D^2-statistic is being used as a powerful tool for measuring quantitative divergence in economic crops.

5.1. Culinary varieties of banana

5.1.1. Analysis of variance

Analysis of variance of culinary varieties on the basis of individual characters showed significant difference for all the varieties indicating significant difference among the varieties as far as the characters height, girth, leaves per plant, hand weight, finger weight, bunch weight, fingers per bunch, finger length, finger thickness, hands per bunch, fingers per hand, peduncle length and roots per plant were concerned.

Wilk's 'Λ' criterion calculated for the culinary type of varieties by considering all the 13 characters simultaneously showed a highly significant difference. From this result it could be concluded that the varieties were heterogeneous among themselves when all the characters were taken simultaneously.

5.1.2. D^2 analysis

D^2 values presented in Table 5 gave an idea of the genetic distance of the different varieties taken pairwise. From this table it could be observed that the maximum divergence (genetic distance) 19065.20 was between Kanchikela and Pachabontha bathessa (varieties 20 and 22). The next maximum, 16053.89 was between Nallabontha and Kanchikela (varieties 18 & 20). Similarly the minimum divergence (genetic diversity) 160.95 was between Neymannan and Mannan (varieties 12 and 30). The next minimum was 102.95 between Java and Kapur (varieties 3 and 25).

The D^2 values calculated as the difference between the uncorrelated mean values were ranked under each character by taking the varieties pairwise. From the ranks, as shown in Table 6 it could be concluded that the character bunch weight (yield) showed the maximum variability followed by hand weight. In the same manner the minimum contribution of the variability was through girth (cm) followed by height (cm).

The intra and inter cluster grouping made on the basis of Tocher's method as stated in section 4.1.5 and the distance given in Table 8 of the culinary type of banana were most appropriate in the sense that the intra cluster D values in each cluster was the least in comparison with the inter cluster D values. The diagrammatic representation of the intra and inter cluster distance in a two dimensional space, as depicted in Fig.1. also gave an idea of the genetic divergence of the various clusters of varieties.

5.1.3. Canonical analysis

The canonical roots calculated from the uncorrelated mean values of the culinary type of banana on the basis of 13 characters were shown in Table 9. From this it could be seen that 93.89% of the total variability was accounted by the first two canonical roots. Hence the two roots together represented the 30 varieties when all the 13 characters were considered simultaneously.

From the table of canonical vectors calculated out of the first two canonical roots (Table 10) it could be observed that the characters bunch weight (yield) and hand weight respectively accounted the maximum variability. Similarly the characters girth (cm) and height (cm) respectively accounted the lowest variability. This was in confirmity with the result of D^2 analysis already obtained.

From the scatter diagram (Fig.2) it could be easily verified that the 12 clusters formed on the basis of D^2 analysis were almost in agreement with the points shown in the scatter diagram. The only exception was the variety Ashmonthan. This variety was not coming in the first cluster on the basis of D^2 analysis whereas this was having a closer approximation to the varieties in the first cluster on the basis of canonical analysis which may be viewed as an exception.

Through D^2 analysis and canonical analysis one could easily justify the appropriateness of the clusters formed. These varieties, from each cluster can be used for breeding varieties of better qualities through the exploitation of maximum heterosis.

5.2. Dessert varieties of banana

5.2.1. Analysis of variance

Analysis of variance of dessert varieties on the basis of individual characters showed significant difference for all the varieties. This showed that there was considerable difference among the different varieties, so far as the characters height, girth, leaves per plant, hand weight, finger weight, bunch weight, fingers per bunch, finger length, finger thickness, hands per bunch, fingers per hand and peduncle length were concerned.

Wilk's '$\wedge$' criterion calculated for the dessert type of varieties by considering all the 12 characters simultaneously showed a highly significant difference. From this result it could be concluded that the varieties were heterogeneous among themselves when all the characters were considered simultaneously.

5.2.2. D^2 analysis

D^2 values presented in Table 16 gave an idea of the genetic distance of the different varieties taken pairwise. From this table it could be observed that the maximum divergence (genetic distance) 12758.67 was between Ayiramka Poovan and Chenkadali (varieties 13 and 15). The next maximum (11851.97) was between the varieties Adakka Kunnan and Chenkadali (varieties 7 and 15). Similarly the minimum divergence (10.33) was between Theem Kunnan and Tongat, Pachenadan and Viroopakshy (varieties 5 and 11, 42 and 54). The next minimum (28.07) was between Theem Kunnan and Morthman (varieties 5 and 37).

The D^2 values calculated as the difference between the uncorrelated mean values were ranked under each character, by taking the varieties pair-wise. From the ranks as shown in Table 17 it could be concluded that the characters finger length and peduncle length were contributing maximum towards divergence. The minimum contribution to the variability was through the characters leaves per plant and girth (cm).

The intra and inter cluster grouping made on the basis of Tocher's method as stated in section 4.2.4. and the distance (D values) given in Table 19 of the dessert type of banana were most appropriate in the sense that the intra cluster D values in each cluster was the least in comparison with the inter cluster D values. The diagramatic representation of the intra and inter cluster distance in a two dimensional space, as depicted in Fig. 3 also gave an idea of the genetic divergence of the various clusters of varieties.

5.2.3. Canonical analysis

The canonical roots calculated from the uncorrelated mean values of the dessert type of banana on the basis of 12 characters were shown in Table 20. From this it could be seen that 93.21% of the total variability was accounted by the first two canonical roots. Hence the two roots together can represent the 56 varieties when all the 12 characters were considered simultaneously.

From the table of canonical vectors calculated out of the first two canonical roots (Table 21) it could be observed that the characters finger length and peduncle length were contributing maximum towards divergence. In the same way it could be seen that the canonical vector corresponding to leaves per plant and girth (cm) were the minimum meaning thereby having the least contribution towards the divergence. These results are fully in agreement with the results obtained by ranking method.

From the scatter diagram (Fig.4) it could be easily verified that the 7 clusters formed on the basis of D^2 analysis were fully in agreement with the points shown in the scatter diagram.

Through D^2 analysis and canonical analysis one could easily justify the appropriateness of the clusters formed. These varieties, from each cluster can be used for breeding varieties of better qualities through the exploitation of maximum heterosis.

Through the D^2 analysis and canonical analysis of the data on 30 varieties of culinary type of banana on the basis of 13 characters and 56 varieties of dessert type of banana on the basis of 12 characters one could easily observe that the character girth (cm) was contributing minimum towards divergence. Whereas the maximum contributor to the divergence in the case of culinary type of banana was bunch weight and that in dessert varieties it was finger length. This may be due to the different purpose by which the varieties were meant for.

SUMMARY

SUMMARY

The data taken from the Banana Research Station, Kannara for 30 culinary varieties for 13 morphological characters and 56 dessert varieties for 12 morphological characters of banana were analysed for the analysis of variance. Significant difference were shown for all the varieties in the culinary type as well as the dessert type.

Wilk's '$\wedge$' criterion calculated for the culinary type of varieties by considering all the 13 characters and dessert type of varieties by considering all the 12 clusters showed a highly significant difference which showed that the varieties were heterogeneous among themselves in each case when all the characters were taken simultaneously.

By using D^2 analysis the 30 varieties of culinary type of banana were grouped into 12 clusters including 9 single variety clusters which were homogenous within and heterogenous between. In the same manner the 56 varieties of dessert type of banana were grouped into 7 clusters including two single variety clusters which were homogenous within and heterogeneous between.

By ranking method of D^2 values the characters which were contributing maximum towards divergence were bunch weight (yield) and hand weight in the case of culinary varieties. In the case of dessert varieties they were finger length and peduncle length.

By ranking D^2 values the characters which were contributing minimum towards divergence were girth (cm) and height (cm) in the case of culinary varieties. In the case of dessert varieties they were leaves per plant and girth (cm).

In both cases canonical analysis were performed using the uncorrelated mean values. In each case the first two canonical roots accounted more than 90% of the total variability. So a two dimensional representation was made by using the mean values of the canonical variates. The clustering pattern was the same as that of D^2 analysis in both cases. But in the case of culinary varieties the variety Ashmonthan was also coming in the first cluster by canonical analysis which was not in the first cluster by D^2 analysis.

From the canonical vectors calculated out of the first two canonical roots in the case of culinary varieties showed that bunch weight (yield) and hand weight accounted the maximum variability. Whereas in the case of dessert varieties finger length and peduncle length were contributing maximum to the genetic diversity. The characters which were contributing minimum towards divergence in the case of culinary varieties were girth (cm) and height (cm). In the case of dessert varieties they were leaves per plant and girth (cm). The same results were obtained in this aspect by the method of D^2 analysis.

While considering the culinary varieties and dessert varieties, jointly the character girth (cm) was contributing minimum towards divergence.

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* Original not seen.

APPENDIX

Appendix I

Analysis of covariance table (partial) for $^{15}C_2$ character combinations of 30 varieties of culinary type of banana.

Source	df	MSP of Height with Girth	Leaves per plant	Hand weight
Replications	2	211.585	8.961	92.860
Varieties	29	86.494	-58.260	15348.201
Error	58	27.394	8.734	43.502

Source	df	MSP of Height with Finger weight	Bunch weight	Fingers per bunch
Replications	2	-13.352	-24.513	-374.463
Varieties	29	1884.826	120.868	-288.207
Error	58	1.860	2.749	-23.489

Source	df	MSP of Height with Finger length	Finger thickness	Hands per bunch.
Replications	2	-5.100	-14.629	-64.169
Varieties	29	43.494	120.927	-23.854
Error	58	1.075	0.740	-2.068

Source	df	MSP of Height with		
		Fingers per hand	Peduncle length	Roots per plant
Replications	2	-23.329	7.853	145.678
Varieties	29	-80.513	616.105	1264.203
Error	58	-1.189	9.554	4.781

Source	df	MSP of Girth with		
		Leaves per plant	Hand weight	Finger weight.
Replications	2	-0.167	99.711	9.222
Varieties	29	8.724	-429 .841	-70.977
Error	58	1.080	-19.766	1.096

Source	df	MSP of Girth with		
		Bunch weight	Fingers per bunch	Finger length
Replications	2	0.565	-40.267	0.134
Varieties	29	18.912	273.879	-19.727
Error	58	0.164	-9.663	-0.099

Source	df	MSP of Girth with		
		Finger thickness	Hands per bunch	Fingers per hand.
Replications	2	0.993	-9.133	-3.218
Varieties	29	-5.193	10.707	6.255
Error	58	0.112	-0.283	-0.541

Source	df	MSP of Girth with		
		Peduncle length		Roots per plant
Replications	2	10.090	44.750	44.750
Varieties	29	18.935		95.862
Error	58	0.888		0.032

Source	df	MSP of leaves per plant with		
		Hand weight	Finger weight	Bunch weight
Replications	2	-34.039	-5.145	-2.273
Varieties	29	-718.489	-80.467	3.404
Error	58	1.565	-0.050	-0.205

Source	df	MSP of leaves per plant with		
		Fingers per bunch	Finger length	Finger thickness
Replications	2	-14.133	-0.048	-0.795
Varieties	29	83.888	-6.161	-6.788
Error	58	0.654	-0.050	0.006

Source	df	MSP of Leaves per plant with		
		Hands per bunch	Fingers per hand	Peduncle length
Replications	2	-1.469	-0.584	-3.572
Varieties	29	4.782	2.115	2.590
Error	58	-0.248	0.438	-0.038

Source	df	MSP of Leaves per plant with
		Roots per plant
Replications	2	-6.672
Varieties	29	-38.376
Error	58	-0.919

Source	df	MSP of Hand weight with		
		Finger weight	Bunch weight	Fingers per bunch
Replications	2	233.889	95.638	498.266
Varieties	29	62853.841	385.676	-47078.245
Error	58	46.332	23.424	118.592

Source	df	MSP of Hand weight with		
		Finger length	Finger thickness	Hands per bunch.
Replications	2	20.144	30.813	41.743
Varieties	29	2786.158	4842.394	-2660.828
Error	58	4.466	7.268	7.282

Source	df	MSP of Hand weight with		
		Fingers per hand	Peduncle length	Roots per plant
Replications	2	17.158	170.467	375.314
Varieties	29	−1508.794	−2080.595	10946.690
Error	58	−4.277	16.046	12.611

Source	df	MSP of Finger weight with		
		Bunch weight	Fingers per bunch	Finger length
Replications	2	14.440	81.301	3.040
Varieties	29	94.358	−4791.068	346.750
Error	58	2.952	15.365	0.669

Source	df	MSP of Finger weight with		
		Finger thickness	Hands per bunch	Fingers per hand
Replications	2	4.818	7.018	3.056
Varieties	29	504.707	−858.195	−177.648
Error	58	0.853	0.884	0.385

Source	df	MSP of Finger weight with	
		Peduncle length	Roots per plant
Replications	2	24.470	50.717
Varieties	29	5.225	686.142
Error	58	2.834	4.603

Source	df	MSP of Bunch weight with		
		Fingers per bunch	Finger length	Finger thickness
Replications	2	39.482	1.340	2.224
Varieties	29	329.104	-2.382	0.408
Error	58	9.066	0.256	0.357

Source	df	MSP of Bunch weight with		
		Hands per bunch	Fingers per hand	Peduncle length
Replications	2	4.146	1.626	10.036
Varieties	29	16.456	6.874	118.972
Error	58	0.806	-0.376	1.138

Souce	df	MSP of Bunch weight with
		Roots per plant
Replications	2	18.817
Varieties	29	74.046
Error	58	2.341

Source	df	MSP of Fingers per bunch with		
		Finger length	Finger thickness	Hands per bunch
Replications	2	8.294	15.032	35.600
Varieties	29	-356.154	-434.907	508.351
Error	58	2.057	1.489	10.066

Source	df	MSP of Fingers per bunch with		
		Fingers per hand	Peduncle length	Roots per plant
Replications	2	15.584	52.675	71.805
Varieties	29	275.938	1781.635	612.074
Error	58	-0.052	9.632	5.682

Source	df	MSP of Finger length with		
		Finger thickness	Hands per bunch	Fingers per hand
Replications	2	0.467	0.870	0.341
Varieties	29	26.261	-17.855	-10.285
Error	58	0.094	0.109	0.207

Source	df	MSP of Finger length with	
		Peduncle length	Roots per plant
Replications	2	2.114	3.970
Varieties	29	-4.904	-49.682
Error	58	0.212	0.628

Source	df	MSP of Finger thickness with		
		Hands per bunch	Fingers per hand	Peduncle length
Replications	2	1.718	0.665	3.244
Varieties	29	-21.397	-16.453	-22.360
Error	58	0.129	-0.110	0.338

Source	df	MSP of Finger thickness with
		Roots per plant
Replications	2	5.349
Varieties	29	24.375
Error	58	0.665

Source	df	MSP of Hands per bunch with		
		Fingers per hand	Peduncle length	Roots per plant
Replications	2	1.818	4.464	2.544
Varieties	29	11.272	99.277	28.171
Error	58	-1.099	0.672	1.274

Source	df	MSP of Fingers per hand with	
		Peduncle length	Roots per plant
Replications	2	1.830	1.370
Varieties	29	24.299	-33.477
Error	58	-0.381	-1.139

Source	df	MSP of Peduncle length with
		Roots per plant
Replications	2	39.003
Varieties	29	-365.834
Error	58	1.259

Appendix II

Analysis of covariance table (partial) for 12_{C_2} character combinations of 56 varieties of dessert type of banana.

Source	df	MSP of Height with		
		Girth	Leaves per plant	Hand weight
Replications	2	40.533	-3.643	-598.293
Varieties	55	905.515	170.773	11892 .050
Error	110	13.503	7.997	49.881

Source	df	MSP of Height with		
		Finger weight	Bunch weight	Fingers per bunch
Replications	2	272.461	-35.063	121.893
Varieties	55	204.692	159.067	2823.229
Error	110	17.497	0.994	0.081

Source	df	MSP of Height with		
		Finger length	Finger thickness	Hands per bunch
Replications	2	-1.767	-6.795	-14.369
Varieties	55	-203.572	36.202	137.741
Error	110	-0.869	-0.036	0.237

Source	df	MSP of Height with	
		Fingers per hand	Peduncle length
Replications	2	8.020	141.905
Varieties	55	113.172	820.128
Error	110	-1.174	0.562

Source	df	MSP of Girth with		
		Leaves per plant	Hand weight	Finger weight
Replications	2	-10.821	-538.273	-33.296
Varieties	55	19.850	2817.940	136.153
Error	110	1.612	39.676	2.778

Source	df	MSP of Girth with		
		Bunch weight	Fingers per bunch	Finger length
Replications	2	-6.998	-0.821	-4.780
Varieties	55	32.459	375.780	-22.602
Error	110	0.552	3.469	0.158

Source	df	MSP of Girth with		
		Finger thickness	Hands per bunch	Fingers per bunch
Replications	2	-1.495	-2.881	3.455
Varieties	55	9.893	17.293	17.609
Error	110	0.278	0.586	-0.276

Source	df	MSP of Girth with Peduncle length
Replications	2	4.774
Varieties	55	98.504
Error	110	2.674

Source	df	MSP of leaves per plant with		
		Hand weight	Finger weight	Bunch weight
Replications	2	101.100	12.962	1.865
Varieties	55	-236.490	-29.576	8.397
Error	110	13.062	2.253	0.505

Source	df	MSP of leaves per plant with		
		Fingers per bunch	Finger length	Finger thickness
Replications	2	1.366	1.489	0.396
Varieties	55	176.311	-7.037	-2.685
Error	110	-2.928	-0.052	-0.112

Source	df	MSP of leaves per plant with		
		Hands per bunch	Fingers per hand	Peduncle length
Replications	2	0.777	-1.015	-0.214
Varieties	55	9.459	4.375	26.649
Error	110	0.090	-0.118	-1.232

Source	df	MSP of Hand weight with		
		Finger weight	Bunch weight	Fingers per bunch
Replications	2	247.204	72.674	-19.832
Varieties	55	52180.119	332.994	-21261.710
Error	110	390.950	56.828	153.960

Source	df	MSP of hand weight with		
		Finger length	Finger thickness	Hands per bunch
Replications	2	44.691	15.011	29.932
Varieties	55	29 26.867	2412.454	-1496.667
Error	110	7.856	6.3[illegible]7	7.030

Source	df	MSP of hand weight with	
		Fingers per hand	Peduncle length
Replications	2	-33.880	-76.189
Varieties	55	425.176	4700.892
Error	110	5.472	137.689

Source	df	MSP of Finger weight with		
		Bunch weight	Fingers per bunch	Finger length
Replications	2	-2.294	40.823	5.674
Varieties	55	212.285	-2009.279	238.226
Error	110	7.908	9.919	0.968

Source	df	MSP of Finger weight with		
		Finger thickness	Hands per bunch	Fingers per hand
Replications	2	-0.314	-0.919	1.902
Varieties	55	185.188	-122.285	-1.419
Error	110	0.786	0.530	0.474

Source	df	MSP of finger weight with
		Peduncle length
Replications	2	40.033
Varieties	55	411.436
Error	110	17.210

Source	df	MSP of bunch weight with		
		Fingers per bunch	Finger length	Finger thickness
Replications	2	-5.340	0.836	0.433
Varieties	55	161.852	7.839	8.448
Error	110	2.425	0.240	0.219

Source	df	MSP of bunch weight with		
		Hands per bunch	Fingers per hand	Peduncle length
Replications	2	0.883	-0.797	-4.831
Varieties	55	9.979	5.904	105.908
Error	110	0.164	-0.089	2.596

Source	df	MSP of fingers per bunch with		
		Finger length	Finger thickness	Hands per bunch
Replications	2	0.385	-0.630	-1.366
Varieties	55	-289.452	-308.222	331.042
Error	110	1.903	0.134	3.292

Source	df	MSP of Fingers per bunch with	
		Fingers per hand	Peduncle length
Replications	2	0.449	17.509
Varieties	55	104.154	708.299
Error	110	2.403	25.142

Source	df	MSP of Finger length with		
		Finger thickness	Hands per bunch	Fingers per hand
Replications	2	0.176	0.345	-0.449
Varieties	55	10.785	-12.385	-3.281
Error	110	0.040	0.081	0.035

Source	df	MSP of Finger length with
		Peduncle length
Replications	2	-0.117
Varieties	55	11.369
Error	110	0.202

Source	df	MSP of Finger thickness with		
		Hands per bunch	Fingers per hand	Peduncle length
Replications	2	0.178	-0.164	-0.933
Varieties	55	-6.994	0.658	7.336
Error	110	0.034	0.011	0.369

Source	df	MSP of Hands per bunch with	
		Fingers per hand	Peduncle length
Replications	2	-0.328	-1.979
Varieties	55	2.371	52.083
Error	110	-0.515	1.100

Source	df	MSP of Fingers per hand with
		Peduncle length
Replications	2	1.052
Varieties	55	10.723
Error	11 0	0.243

A STUDY OF GENETIC DIVERSITY IN DESSERT AND CULINARY TYPES OF BANANA VARIETIES

BY

MERCEY K. A.

ABSTRACT OF A THESIS

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ABSTRACT

The data taken from the Bana Research Station, Kannara for 30 culinary varieties for 13 morphological characters and 56 dessert varieties for 12 morphological characters were the base material for this study. Genetic divergence in the varieties were studied using D^2-statistic and canonical analysis. The varieties were grouped into clusters by using Tocher's minimum generalised distance concept. The same clustering pattern was obtained through canonical analysis.

In the case of culinary varieties 12 clusters were formed consisting 11 varieties in the first cluster 5 each in second and third and the others were single variety clusters. Whereas the dessert varieties were grouped into 7 clusters 13 varieties in the first cluster 17 in the second cluster, 20 in the third, 2 each in the fourth and fifth and the last two were single variety clusters.

The intra and inter cluster distance were diagrammatically represented in a two dimensional space. The scatter diagram showing the mean values

of the canonical varieties in order to have an idea of the appropriateness of the clustering pattern were also formed in both the type of varieties.

In the case of culinary varieties the character bunch weight and in the case of dessert varieties the character finger length was contributing maximum towards divergence. The character girth was contributing minimum towards divergence in both the cases.