A COMPARATIVE STUDY OF GENOTYPE-ENVIRONMENT INTERACTIONS IN SESAME

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "A COMPARATIVE STUDY OF GENOTYPE-ENVIRONMENT INTERACTIONS IN SESAME" is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled "A COMPARATIVE STUDY OF GENOTYPE-ENVIRONMENT INTERACTIONS IN SESAME" is a record of research work done independently by Smt. MINI.C.J. 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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CONTENTS

GLOSSARY OF SYMBOLS AND ABBREVIATIONS

CF	:	Correction Factor
df	:	degrees of freedom
EMS	:	Error mean square
ER	:	Eberhart and Russell
FP	:	Freeman and Perkins
GE	:	Genotype-Environment
PJ	:	Perkins and Jinks
SS	:	Sum of squares
S_e^2	:	Error mean square pooled over environments
Y_{ijk}	:	Performance of i^{th} genotype (variety) in the k^{th} replicate of the j^{th} environment.
Y_{ij}	:	Mean performance of the i^{th} genotype in the j^{th} environment.
e_{ij}	:	error associated with the i^{th} genotype in the j^{th} environment.
		$i = 1,2.........t$
		$j = 1,2..........s.$
		$k = 1,2.........r.$
t	:	number of genotypes
s	:	number of environments
r	:	number of replications
$Y_{i..}$	:	sum of Y_{ijk} over the suffix omitted
$Y_{i.}$	:	Sum of Y_{ij} over the suffix omitted. Similar notations are followed for $Y_{.j..}$ $Y_{....}$ $Y_{.j}$ and $Y_{..}$
b_i	:	regression coefficient under ER model
β_i	:	regression coefficient under PJ model
b'_i	:	regression coefficient under FP model

I_j	:	Environmental index under ER and PJ models
Z_j	:	Environmental index under FP model
S_d^2	:	Second parameter for stability under ER and PJ models.
$S_d'^2$	:	Second parameter of stability under FP model.
$\sum_{j=1}^{s} \frac{\delta_{ij}^2}{s-2}$	:	Deviation mean square for the i^{th} genotype under ER and PJ models
$\sum_{j=1}^{s} \frac{\delta_{ij}'^2}{s-2}$	:	Deviation mean square for the i^{th} genotype under FP model.
W_i	:	Ecovalence ratio ofthe i^{th} genotype
σ_i^2	:	Stability variance for the i^{th} genotype

Introduction

INTRODUCTION

The phenotype of an individual is the result of an interplay between its genotype and the environment in which it develops. Furthermore, the effects of genotype and environment may not be independent. A specific difference of environment may have a greater effect on some genotypes than on others, or there may be a change in the ranking of genotypes when measured in diverse environments, etc. This interplay of genetic and non-genetic effects on the phenotype expression is called genotype-environment (GE) interaction. The failure of a genotype to give the same response in different environments is a definite indication of GE interaction.

The environment of an individual is made up of all the factors other than genotypes of the individual that affect its development. That is to say environment is the sum total of all non-genetic factors external to the organism. There can be two kinds of environments - micro and macro. Micro environment is the environment of a single organism as opposed to that of another growing at the same time and almost at the same place. Especially, micro environmental differences are those environmental fluctuations which occur even when individuals are apparently treated alike. On the other hand, environments that are potential or realized within a given area and period of time are referred to collectively as macro environment. A macro environment can thus be considered as a collection of micro environments - that are potential therein. Different locations and climates and even different management practices are examples of macro environmental differences. It is to be noted that, the effect of micro environment of an organism as well as its interaction with different genotypes is usually very small. It is macro-environmental deviation and interactions with genotype that can be isolated and tested for its significance.

Stability in performance is one of the most desirable properties of a genotype. Though the concept of stability has not yet been standardized and in fact, it means different things to different scientists and figures in different contexts, Plant Breeders were always concerned with the stability of the cultivars bred by them and were naturally interested in measuring the same in a statistically valid manner. Pioneering work was done in this regard by Eberhart and Russell (1966). Broadly, the concept of stability of crop yields was looked from three angles (Mead et al. 1986) viz., (i) variation over time and space, (ii) the interaction with environment and (iii) as the converse of risk associated with a particular crop/variety/

practice. As far as the plant breeders are concerned, they made three subtle differences in the concept of stability of a genotype (Lin et al. 1986) as follows:

(i) A genotype is considered to be stable, if its among environment variance is small.

(ii) A genotype is considered to be stable, if its response to environments is parallel to the mean response of all genotypes in the trial.

(iii) A genotype is considered to be stable, if the residual mean square from the regression model on environmental index is small.

Measures of stability in plant breeding can be obtained from estimates of the genotype-environment interactions. Various methods have been proposed for statistical analysis of interaction in general and genotype-environment (GE) interaction in particular. Much work has been done on this subject both by the statisticians interested in non-additivity in general and by those including agronomists, breeders and geneticists who are particularly concerned with genotype-environment (GE) interaction.

Different methods of studying the stability through genotype-environment interaction are (i) Eberhart and Russells (1966) regression coefficient b_i and deviation from regression S_d^2 (ii) Wricke's (1966) ecovalence W_i

(iii) Perkins and Jink's (1968) deviation parameter δ_{ij} (iv) Freeman and Perkin's (1971) regression coefficient b_i' and deviation from regression $S_{di}'^2$ and (v) Shukla's (1972) stability variance σ_i^2.

Sesame (<u>Sesamum indicum</u> L.) is an important and ancient oil yielding species cultivated extensively in India, Burma, Indo China, China, Japan, the hotter and drier parts of Africa and the Mediteranean region. In the recent years, its cultivation has been receiving much attention in USA, Mexico and parts of Latin America. Sesame is grown for its seed and the oil it contains. The seed is high in oil content (50 to 60%) but low in protein (25%). It is rich in calcium, phosphorous and vitamin E and is highly nutritious.

In India, sesame is grown in an area of 2.4 million hectares producing only 0.5 million tonnes of seed every year. India stands next to China in sesame seed production with 24.6 per cent of the world's total production. It is grown in the central states both as kharif and rabi crop. Sesame is the most valued annual oil seed crop of Kerala grown in an area of 14153 hectares with an annual seed production of 3648 tonnes per year (Sverup 1985). It is cultivated in wetlands during summer (January to April) and in uplands, during rabi (August-December).

Lack of high yielding varieties suited to the different soil types and seasons is the main factor limiting the production of sesame in this state. Kayamkulam I and Kayamkulam II are the two improved varieties already released for cultivation.

Genotype-environment (GE) interaction will be always having a definite influence on the seed production of any crop especially in the case of sesame. Even though the varieties Kayamkulam-I and Kayamkulam-II were released, it may or may not suit all localities and all seasons. Hence it is highly essential to find out varieties suitable to all regions by taking into consideration the GE interaction.

The present study has been conducted to choose a consistent variety for all the regions and all seasons in the light of genotype-environment interaction with the following objectives.

(i) to evaluate the existing techniques available for studying GE interaction in sesame.

(ii) to develop new concepts and methods to solve some problems peculiar to crop sesame like non-linearity of interactions, non-orthogonality of data and different patterns of genotype-environment (GE) interactions that are encountered while studying the stability of varieties simultaneously for several traits.

The techniques of genotype-environment interaction can be studied through different methods. With this in view, the stability performance of twenty varieties of sesame were assessed based on six useful characters - seed yield/plot, number of days for flowering, 1000 seed weight, oil content percentage, seed yield/plant and number of days to maturity individually and combinedly were investigated. Over and above the already available five techniques - Eberhart and Russell, Perkins and Jinks, Freeman and Perkins, Wricke's ecovalence method and Shukla's stability variance method for the individual characters, the multivariate procedures - selection index method and principal component method were also used to have complete idea of GE interactions by taking into considerations all the characters simultaneously.

Out of the existing five techniques, Wricke's ecovalence method and Shukla's method relate to non-linearity of interaction. Selection index method and principal component method are based on multivariate technique considering simultaneously several traits.

Review of literature

REVIEW OF LITERATURE

The genotype-environment (GE) interaction has been widely observed to play an important role in the expression of phenotype. In the last one and a half decades a considerable amount of work has been done to analyse and interpret GE interaction. Complications arising from differential response of genotypes due to different environments have been considered in detail by many workers.

Fisher and Mackenzie (1923) considering the manurial responses of different potato varieties, concluded that the yields of different varieties under different manurial treatment are better fitted by a product formula than by a sum formula.

Yates and Cochran (1938) has given a method of partitioning the interaction sum of squares. They regressed the genotype means on the environmental means, calculated by taking the average of all genotypes in that environment and partitioned GE interactions into two components. In their works, the degree of association between varietal differences and general fertility were ~~can be~~ further investigated by calculating the regression of yields of the separate varieties on the mean yields of all varieties.

Sprague and Federer (1951) used variance components approach to show how variance components could be used to separate the effects of genotype, environments and their interactions by equating the observed mean squares in the analysis of variance to their expectations in the random model. The estimates of error, year x variety, location x variety and variety variance components were obtained from a series of top cross, single cross and double crosses of varietial yield comparisons grown in Iowa during the period 1940-1947. The result obtained, suggested that the optimum distribution of a given number of plots, disregarding costs would be one replicate per location with an increase in number of locations and years.

Williams (1952) considered an equivalent model of the linear regression approach. He showed that least squares estimation of the regression coefficients was equivalent to extracting the first principal component of the genotypic performances. The validity of the model can then be assessed by extracting further principal components, or by inspection of the residual correlation matrix after extracting the first component.

Plaisted and Peterson (1959) computed an analysis of variance for every pair of genotypes so as to estimate the interaction variance for every combination of two genotypes. The mean of the interaction variances obtained for each genotype was used as an indicator of the contribution of that genotype to the total GE interaction. The variety with the smallest mean value was considered as the most stable. The major drawback of this procedure is that computation becomes tedious with increase in the number of varieties.

According to Miller et al. (1962), a substantial variety-location-year second order interaction, for lint yield in cotton was observed in their tests, indicating that the varieties showed differential responses when grown under different environments. The variety-year and variety-location first order interaction however were small and non-significant for yield. Apparently neither location nor years had any consistent effect on these differential varietal responses. Furthermore, the lack of a sizeable variety-location interaction in the North Carolina area suggested that it would not be necessary to divide the state into sub areas for variety evaluation purposes. They found that most of the three interaction sources of variances were statistically significant for lint percentage, boll size, and fiber length. In all cases, the magnitudes of these interactions were very small as compared with the varietal sources of variations and are thus of less concern to the breeder.

Comstock and Moll (1963) have classified the environment into two categories - one is micro environment and the other macro environment. Micro environment is the environment of a single organism, as opposed to that of another growing at the same time and in almost the same place. Macro environment is the environment which is associated with a general location and period of time and is a collection of micro environments.

Finlay and Wilkinson (1963) developed a dynamic approach to the interpretation of varietal adaptation to varying environments. It led to the discovery that the components of a genotype and the environmental interactions were linearly related to environmental effects, when these effects were measured on the same scale as the genotypic effects. The technique involves the growing of a large number of genotypes in a number of environments. The mean yield of all the genotypes for each site and season gave a quantitative grading of the environments. Then the linear regression of the mean values for each genotype on the mean values for environments is estimated. From the analysis, the varieties specifically adapted to good or poor environments and those showing general adaptability could be identified. An ideal variety with general adaptability was defined as the one with the maximum yield potential under the most favourable environment and with the minimum phenotypic stability.

Allard and Bradshaw (1964) coined the terms predictable environment and unpredictable environment. The predictable environment includes the permanent features of the environment, such as general features of the climate, soil type, day length and controllable factors such as planting date, sowing density and other agronomic practices. The unpredictable or the uncontrollable environments include weather fluctuations, such as differences between seasons in terms of the amount and distribution of rainfall and the prevailing temperatures and other factors such as established density of the crop. For the uncontrollable variables, a low level of interation would be desirable so as to have the maximum uniformity of performance over a number of seasons. In contrast, for the controllable variables a high level of interaction will be desirable to produce the maximum increase in performance. But the distinction between these two categories is not always clear cut, and characteristics included will vary from crop to crop

Sucio Ananis (1966) developed a mathematical model to measure GE interaction when only two homozygous parents were grown under a large number of environments. Biometrical genetical analysis of genotype-environment interactions were presented, this exploited the empirical findings, that the interactions were a linear function of the additive environmental effects in the generations derived from an initial cross.

Eberhart and Russell (1966) improved the joint regression analysis suggested by Finlay and Wilkinson (1963) by adding one more stability parameter, namely the deviation from regression. They developed a regression model such that there exist a linear relationship between phenotype and environment when the latter is measured by its effect on the character under study. They defined a stable variety as one with the regression coefficient $\hat{b} = 1$ and the deviation from regression as small as possible ($S_{di}^2 = 0$). The estimates of the squared deviation from regression for many hybrids were near zero, whereas, extremely large estimates were obtained for other hybrids, thus indicating the utility of the parameter in characterizing varieties for their stability.

Wricke (1966) developed a method to estimate the ecological valence or ecovalence (W_i) of genotypes (g) grown under several environments (n) to measure the stability of performance. He suggested the ecovalence ratio as the percentage contribution of a genotype to the sum of squares due to GE interaction ie, ecovalence for i^{th} genotype is

$$W_i = \sum_{j=1}^{n} \left(Y_{ij} - \frac{Y_{i.}}{n} - \frac{Y_{.j}}{g} + \frac{Y_{..}}{gn}\right)^2$$

expressed as percentage of the total of all W_i's. The lower the ecovalence of a variety, the smaller its fluctuations from the experimental mean under different environments and thus a smaller share in the interaction sum of square. Accordingly, the variety with the least ecovalence can be considered as more stable and the varieties with a high ecovalence less stable.

Perkins and Jinks (1968 a) have proposed that where a number of genotypes have been tested in several environments, the yield of a genotype should be regressed on the mean yield of all genotypes in each environment. According to them two aspects of the phenotype must be considered jointly in deciding which is the best genotype namely the genetic component of performance d_i' and the sensitivity to the environmental variation measured by β_i'. A higher d_i' value is in general accompanied by a greater sensitivity to the environment. The magnitude of an individual regression coefficient can be interpreted as a measure of the stability of a genotype, a low value indicating stability and a high value instability.

Perkins and Jinks (1968 b) investigated the nature of the non-linear component of variation. In every set of data he examined, an overall reduction in the non-linear portion of variation due to GE interaction has resulted from placing the lines into groups such that members of the same group are positively correlated for their deviations (δ_{ij}) from their regressions. In general the linear and non-linear component of the GE interaction and the within-environmental variation not only differ among genotypes, but they do so independently. According to them the three characteristics of the phenotype are the additive genetic component d_i', the linear β_a' and non-linear portions of the interaction between the genotype and the environment.

Baker (1969) estimates the magnitudes of the various GE interaction of regression methods as applied to the study of the nature of GE interactions. Eberhart and

Russel (1966) proposed that the criteria for stability should be a regression coefficient of unity and a minimum deviation from the regression line. A cultivar with high mean yield and fulfilling these two criteria could perform well in all environments. He proposed that stability of a cultivar is inversely proportional to the sum of squares for genotype-environment interaction. The result of his paper show that the higher ratio most probably explained by the large component of variance for genotype-place interaction. It also suggests that cultivars should be developed for regional adaptability rather than general adaptability.

According to Breese (1969) the performances of individual genotypes are linear functions of the environmental values. The linear regression of individual genotypic values on the mean value of all genotypes for each of a number of environments provide measures of response which can be used to predict relative performance over a range of environmental conditions. The essence of the method is that appropriate biological material can be used to quantify environments and so provide a basis for measuring genotypic response to changing conditions. The measure of the environment has been provided by the mean values of the set of genotypes under test, and the response of each individual genotype then determined by the regression of its individual values on these means for a range of environments. The regression provided a means of accurately predicting relative performance over a wide range of environments and could also be used to simplify varying relationships between parents and offsprings under changing conditions.

Hanson (1970) has defined the stability of a genotype with reference to its position in a space of 1 environments (when tried in 1 variable environments) where a stable genotype would be located at the centre of the space ($Z_i = 0$) and unstable genotype would be located in the periphery of the space. The distance of a genotype from $Z_i = 0$ measures its stability. He has defined a stable genotype as one which has the minimum possible variability when grown in the 1 (variable) environments. This genotype must have minimum (most negative) B_i expected for the improved genotypes represented in the test and have no contribution to the GE interaction.

Perkins and Jinks (1970) defined the assumptions that must be satisfied for making predictions over environments and over generations when GE interactions are present. In their paper, predictions have been made for the character plant height, of the expected means of 21 generations derived from a cross between inbred varieties when grown in two environments from estimates of parameters obtained from the inbred varieties and their F_1 grown in 16 environments. The predictions were satisfactory for one of the environments which was of the same kind as the previous 16 environments but not for the other environments, which introduced new environmental factors.

Freeman and Perkins (1971) developed an approach in which the mean value of the phenotype is regressed to an independent measure of the environment. They critized the improper choice of sum of squares and degrees of freedom and also of measure of environment and the partitioning of the GE sum of squares into parts attributable to individual genotypes. They listed and discussed a number of ways in which independent environmental values might be obtained and describe a biometerical-genetical model and a regression analysis. They suggest the use of parental genotypes to assess the environments in studies involving either crosses between inbred lines derived from such crosses.

According to Fripp and Caten (1971), most of the deviations over environments can be accounted for, by its linear regression on the environmental values. GE interactions have been analysed using the regression approach of Freeman and Perkins. He found that a significant part of the GE variation is accounted by differences in linear sensitivity.

Mandel (1971) considered the principal components approach further, using a multiplicative model. This method indicated the number of dimensions necessary to contain the genotypic variation and gave estimates of the corresponding coefficients, without, any prior knowledge of which factors these dimensions represented. When the deviations from regression on the environmental mean are substantial but no environmental variables have been measured, Mandel's method is particularly valuable.

Perkins and Jinks (1971) gave a satisfactory and a simple method of quantifying the interaction and evidence of its genetical control to design an appropriate breeding programme to select for any desired level of interaction. They observed that GE interaction can also result due to environment specific genes, as distinct from general genes causing differential changes in all circumstances. The reactions of genotypes to environments were specific to the character under study and GE interaction would differ for different kinds of environmental variables. Most of the GE interaction between the environments within each set can be accounted for by linear regression on the additive environmental values. They also found that the relative sensitivity of the genotypes to environmental variation are consistent over the micro, macro and super macro environmental levels. The overall result suggests that different characters are independent in their reaction to the environment.

Tai (1971) employed structural analysis for studying GE interactions to overcome the limitations of joint regression analysis of regressing one set of variables into another, which is not independent of them. He presented a method of genotypic stability where a GE interaction of a particular variety is partitioned into two components, the linear response to environmental effects (α) and a deviation from the linear response (λ) when g genotypes are tested over an environments with r replications under each environment. A perfectly stable variety will be characterized by $\hat{\alpha} = -1$ and $\hat{\lambda} = 1$. The perfectly stable varieties may not exist and the breeders may be satisfied with varieties having $\hat{\alpha} = 0$ and $\hat{\lambda} = 1$.

Fripp (1972) considered different environmental measures for the regression approach and made an assessment of the environments with non-independent environment values and concluded that the amount of bias introduced by the use of non-independent values is very small. The linearity of regression reduces with increase in distance of the environmental measures from the genotypes under study. He found that a single assessment genotype could very satisfactorily be used as the environmental measure. The results show that the interpretation is largely independent of the method of assessing the environment and might at first seem to indicate that the choice of the assessment genotype is of minor importance in designing an experiment.

Hardwick and Wood (1972) showed that the bias in the estimate of regression coefficient of genotypes on environmental mean reduces with increase in the number of genotypes and the ratio of variation between environment to the error mean square. They considered an alternative method of analysis, using multiple regression of performance, on the levels of the environmental variables. They also showed that the slopes of the regression on the environmental mean can be expressed in terms of the coefficients of regression on environmental variables. The deviation from regression are not independent of the slopes, but can be expressed in terms of some coefficients. They recommended physical measures of the environmental assessment and formulated the regression model to understand the physiological causes of the observed regression.

Perkins (1972) used the principal component analysis of the environmental, and genotype environmental interaction components of variation. Perkins carried out the principal component analysis of the sum of squares and sum of products matrix of the genotypes over environments and found that the score of each genotype in the first principal component was directly related to the regression coefficient of the genotype on the non-independent environmental measure. He considered the problem of finding functions of the environmental variables which would best explain the interaction and calculated principal components of weather variables and then used functions of the first few components as predictors. He found that principal component analysis were more informative than the joint regression analysis in his study, where he observed more than one principal component for the interaction.

Shukla (1972) considered the usual regression approach of explaining genotype-environment interaction by using non-additive model and the statistical validity. He suggested a method of directly partitioning GE interaction into individual components, one for each of the genotype from which he drived the 'stability variance' of genotype. He calls a genotype stable, if its stability variance σ_i^2 is equal to within environmental variance (σ_o^2) which means that $\sigma_i^2 = 0$. Relatively large values of σ_i^2 will indicate more stability of genotypes, on the basis of the linear regression coefficients also, may not be very effective when only a small fraction of sum of squares of GE interaction is accounted for by regression. He also discussed the relationship of his method to the regression approach.

Freeman (1973) discussed the various methods of studying GE interaction and suggested the use of multivariate techniques, like the principal component analysis, the cluster analysis and the factor analysis, which may yield answer to complex situations which cannot adequately be explained on the basis of the simple regression analysis. According to him, a high proportion of the sum of squares of the GE interaction should be explained by the linear regression. He also suggested that when the inferences are drawn only about the sample of the genotypes and environments used, the procedure of using means of genotypes to assess the environments is perfectly valid.

Freeman and Dowker (1973) observed non-linear relationship between the performance of the genotype and environment. They used joint regression analysis to data recorded in a series of yield trials in carrots and found that the difference between two major groups was non-significant. They observed that principal component analysis could identify the genotypes as well as the environments which gave significant contribution to the interaction, after the joint regression analysis had been only partially successful in explaining GE interactions. As a result, they were able to demonstrate the importance of site x year and density effects upon the yield differences between the varietal groups.

Freeman (1975) suggested the use of 'fitting constants' to estimate the parameters $\hat{\mu}$ and θ_j of varieties and environments and used these estimate to fill up the gaps in the incomplete table and conducted regression analysis on the completed table.

According to Hill (1975), by the use of multivariate techniques, sometime biological relevance is sacrificed for statistical pedantry. In his paper, it is made clear that before using the regression technique to predict performance, careful consideration must be given to the choice of environments used for the assessment phase. The linear regression technique can be used to predict the performance, either of genotypes in the environments other than those sampled experimentally or of segregating generations from the non-segregating generations from which they were derived.

According to Fernando Orozco (1976) the degree of adaptation to adverse environments was mainly determined by the magnitude of the genetic correlation between performances in the adverse and the optimum environments. The evolution of such correlations through selection has been investigated. Considering the genetic correlations between performances in optimum and in adverse environments in the base population, he concluded that, the smaller these correlations, larger would be the interaction effects. He expressed these GE interaction effects in a simple and logical way and they are even predictable as a function of the magnitude of the genetic correlation. According to his view point, the possibility of a high adaptation or even a true specialisation of the line to the new environment depends not only on a very low genetic correlation but also on a high heritability in that environment and on the number of generations of selection allowed to express that adaptation.

Wood (1976) extended the method proposed by Hardwick and Wood (1972) for relating GE interaction to measure of environmental variables where more than one function is necessary to explain the interaction. In his analysis, the problem is to find functions of the environmental variables which can be used to explain the variance in performance of the genotypes from environment to environment. His analysis is much more economical in terms of the number of parameters used. He made a comparison between his present paper and the principal component analysis by Perkins (1972).

Varma et al. (1978) proposed a modification of the conventional regression technique in the form of fitting two straight lines for the poor and favourable environments to account for the non-linearity around single best fitting regression line in all environments. The availability of genotypes with different levels of mean performance and environmental sensitivity suggests that sensitivity has not only a separate genetic control but that in fact there may be two distinct sets of gene-systems controlling sensitivity in contracting environments in addition to some common genes. According to him, the theoretically ideal genotype has been defined as one with relatively low sensitivity in the poor environments and a high sensitivity in the favourable environments. The computation of separate regression coefficients on the two regions of the response curve has been suggested to detect such genotypes.

Digby (1979) developed a modified regression analysis where in he improved the technique, by introducing the sensitivity parameter β_i ($=1-b_i$) for the i^{th} variety. He presents an iterative analysis of incomplete variety-environment tables. The analysis estimates potential differences in the sensitivity of varieties to the environment effect. His technique allows unequal weighing of data and discussed the complete table as a special case. When the data are incomplete, the technique is to first fit the additive model using fitting constants and obtain estimates for β_i's.

Freeman and Crisp (1979) proposed that when genotypes are grown in a range of environments several variables are often recorded on the same genotype. Regressing one character on another may, not only give useful information about the relation between them but also help to explain GE interaction observed in the character of primary interest. The conclusion drawn from this technique may be of practical plant breeding importance and also illustrates how the method may be used to assist the interpretation of GE interaction.

Nor and Cady (1979) developed a quantitative measure of wide adaptability, the beta response model from a multivariate regression approach for providing an alternate environmental index based on linear function of three weather variables (rain fall, temperature, growing degree days). The functional relationship assumed in the beta response concept between the i^{th} cultivar and j^{th} environment is a linear relationship. Any cultivar within the population whose beta response coefficient β_i is equal to the average beta response coefficient β is considered widely adaptable.

Finney (1980) obtained the estimates of varietal and site effects by minimising the weighted sum of squares of deviations of observations from the expectation with weights proportional to the number of observations on which the means of these effects are based. His paper presents illustrations of circumstances in which either least squares or some analogous process is essential to the fair interpretation of data. He is intended to illustrate the need for least square procedure in the analysis of unbalanced sets of data.

Timothy <u>et al.</u> (1980) observed non-linearity of response for some fruit characters like fruit weight and soluble solids through the response of yield for these cultivars was mostly linear.

According to Suresh Babu (1981), a breeding programme aimed at developing phenotypically stable varieties, requires information on the extent of GE interaction for yield and more particularly the interactions between component characters of yield and environment. He gave two approaches to analyse the data in his work. One approach is to identify developmental sequences which can counteract the fluctuations in environmental conditions. The other approach is genetical, where bufferin capacity is created through genetic mixtures or through gene pools from contrasting environments as a mean to reduce GE interaction. He showed that the second approach is more tenable in bhindi. He found that the effects of the environments and genotypes were not linear for the characters under study. He tried to classify genotypes under study for their adaptability to low, medium and high yielding environments.

Miriani <u>et al.</u> (1983) employed a three-line regression model by subdividing the many available environments into three subsets on the basis of the confidence limits of the general mean to analyse the response of grain yield of Durum wheat varieties. When the regression change gradually a quadratic curve may be more appropriate to explain the varietal response over environments.

Shukla (1983) showed that emprical regression based mean of genotypes as environmental effects holds only if the varieties differ in one dimension. He proved theoritically that the regression coefficient is estimated as a relative measure - relative to the other genotypes in trial. He suggested that the bias in the estimates of regression coefficients would be reduced with large number of genotypes and environments. He also considered multiple regression on a number of environmental variables.

According to Geetha (1984) the primary components of seed yield in sesame are number of capsules per plant, number of seeds per capsule and weight of 1000 seeds. It was found from her studies that the character seed yield, is highly influenced by its components and that have to be considered in selection programmes for improving yield.

Laly (1984) proposed a method of forming groups of genotypes such that interaction of genotypes with environments is insignificant within any group, but significant between any two groups. The genotypes so included in a group will have same sensitivity to differing environments and thus can be said to be relatively stable. She discussed the ranking of genotypes by different stability parameters. According to her view point, Wricke's ecovalence ratios W_is and Shukla's stability variances σ_i^2's can be used as a measure of stability in almost all situations. The regression coefficient can be used as a measure of relative sensitivity of a genotype to the environment, only if it accounts for all or most of the GE interactions. She found that the grouping technique can be used effectively to verify the comparative efficiency of the various stability parameters as well as to identify genotypes of same stability.

Narain and Bhatia (1984) discussed various methods proposed for the statistical analysis of interaction in general and GE interaction in particular. The simple methods including the use of variance components as well as regression and other similar methods have been considered. The usual regression approach of explaining GE interaction is studied by using a non-additive model. The statistical validity of this analysis has also been discussed. The use of external variables to assess the environment as well as the basic concepts of stability are further mentioned.

John Sverup (1985) estimate the stability parameters of selected sesame genotypes in different agro-climatic conditions of Kerala. Considering the stability parameters, he concluded that the varieties IS.284 and C.8 had high mean and average responsiveness and stability for yield of seeds. According to him, number of branches number of seeds per capsule and weight of 1000 seeds were found to be stable over different environments.

Lin *et al*. (1985) defined the following three types of concepts of stability.

Type I : A genotype is considered to be stable, if its environmental variance is small.

Type II : A genotype is considered to be stable, if its response to environments is parallel to the mean response of all genotypes.

Type III : A genotype is considered to be stable, if its residual mean square from the regression model on the environmental index is small.

Type I stability has four possibilities. They are varieties with (i) high yield, small variation (ii) high yield, large variation (iii) low yield, small variation and (iv) low yield, large variation. According to him, the first category of hybrids are more desirable which gives high and consistant performance among genotypes.

Balakrishnan (1986) made a critical appraisal of the existing methods for the analysis of GE interactions and in addition, gave different approaches for studying the stability and adaptability of genotypes. According to him, the existing approaches for the analysis of non-linear GE interactions like two-phase and multi-phase regressions were found inadequate to describe the response pattern of different varieties in vegetable crops. He fitted four new regression models, viz. linear, quadratic, exponential linear and exponential quadratic to study their suitability in explaining non-linear GE interactions observed in the vegetable crops. He compared the two phase least squares and FITCON analysis for the estimation of varietal means for non-orthogonal (unbalanced) data with the modified joint regression analysis and found that, FITCON analysis can be used with equal advantage in comparison with the more difficult procedure of modified regression analysis unless the sensitivities of varieties differ significantly or the non-orthogonality, as measured by the number of missing values, is large.

Brain Westcott (1986) attempts an examination of some of new techniques of analysing GE interaction. He offers a criticism of some established methods, while pointing out others which have been neglected. Firstly he discussed the methods of linear regression and related stability parameters. According to him, the linear regression approach to analysing GE interaction cannot be regarded as trustworthy. He discussed the method of cluster analysis and principal component analysis. In principal component analysis he found that, the chief difficulty is in the interpretation of the resulting principal components, which may not bear any obvious relationship to environmental conditions. He also considered geometerical methods and stochastic dominance methods to analyse the GE interaction.

According to Bhatia and Narain (1988) there are situations where the usual measures of stability cannot be as such applied because of various reasons like size, physical conduct of the experiment, large number of varieties under test etc. In these cases the stability aspects has to be looked into through different angles and they attempted to study these aspects of varietal adaptation in the presence of GE interaction. They discussed the methods of reducing the effective number of varieties to be tested, grouping the similar lines and methods of stability analysis for the case of missing observation and unequal weightage of data. They suggested a modified joint regression analysis for the incomplete GE tables, which will be suitable to both situations for missing observations and data sets with unequal experimental error.

Goswami *et al.* (1988) made an attempt to detect the presence of long term cycle in the production and prices of commercial crops (cotton and sugarcane) by method of harmonic analysis. They employed harmonic analysis using trignometric functions to uncover inherent periodicity of a series. They used ordinary least squares procedure to estimate the unknown parameters.

Rai and Shanti Sarup (1988) discussed the case of binary responses in pre-post treatment situations and a simple measure of stability. They worked out the sampling distribution of the measure of stability s and presented a test for testing whether the treatment is stable. They observed the range of stability coefficient s is from -1 to +1 and concluded that s= -1 indicates perfect instability and s = 1 implies perfect stability. They presented a procedure for testing the significance of change in binary responses.

Ramanatha Chetty (1988) looked into the concept of stability of crop yields from three angles.

(i) variation over time and space

(ii) the interaction with environment and

(iii) as the converse of risk associated with a particular crop/variety/practice.

He made three subtle differences in the concept of stability of a genotype as, a genotype is considered to be stable if

(i) its variability among environment variance is small

(ii) its response to environments is parallel to the mean

(iii) the residual MS from the regression model on environmental index is small.

According to him, variation in yields due to crop/variety/practice can be measured by standard deviation or logarithm of standard deviation and he proposed coefficient of variation as a measure of stability.

According to Rao and Shukla (1988), one of the criteria to assess the phenotypic superiority of a crop variety is through its stability in performance. The methods generally followed to measure it are mostly based on variance concept or regression against environmental indices. They considered the alternate risk based on decision, which may alter the relative ranking of a variety at a given or different risks. Since risk analysis mainly rests on the existence of variability of both temporal and spatial, they found that the yield variability of a variety is appropriate to estimate through a response function by incorporating the independent variables influenced by the above type of variation.

Subrahmanyam (1988) re-examined all the nine statistics employed by Lin et al. (1985). These nine stability statistics are derived from the components of a two-way classification of data and grouped them into three major types. He grouped the stability statistics as A, B, C, D. He concluded that the concept of stability and the kind of environments chosen for the experiment must be clear before taking the experiment, otherwise it will be misleading. He found that if the regression model fits the data, Group C stability statistics is the best and when data do not fit or the residual mean square from regression are heterogeneous, Wricke's ecovalence ratio W_i^2 and Shukla's stability variance σ_i^2 are to be used.

Materials and Methods

MATERIALS AND METHODS

3.1. Materials

A secondary data on the following characters

1. Height
2. Number of branches
3. Number of capsule per plant
4. Length of capsule
5. Circumference of capsule
6. Number of seeds per capsule
7. Number of days for flowering
8. Number of days to maturity
9. 1000 seed weight
10. Oil content percentage
11. Seed yield per plant (gm)
12. Seed yield per plot (gm)

of a multilocational trial on twenty sesame varieties conducted by department of Plant Breeding, College of Agriculture, Vellayani at three different locations at Vellayani, Kayamkulam and Pattambi during 1982-83 has been utilized for this study. The experiment was laid in RBD with three replications at each location. The twenty varieties were K.1, K.2, IS.284, C.47, S.1, S.8, 42.1, 38-1, Pt.58-35-1, Rt.(1)37, Si.1, Si.902, Si.914, Si.953, Si.1036, Si.1275, T-12, Tc.25, Vayalathur and Vinayak. The data is as given in Appendix ..

3.2. Methods

3.2.1. Analysis of variance was performed in each of the location for each character separately.

Table 3.2.1.1. Analysis of variance for individual RBD

Source	df	SS	MS	F
Varieties	(t-1)	$\sum \frac{T_i^2}{s} - C.F.$	s_t^2	s_t^2/s^2
Locations	s-1	$\sum \frac{R_j^2}{t} - C.F.$		
Error	(t-1)(s-1)		s^2	
Total	ts-1			

Homogeneity of error variances in different environments was tested using Bartlett's test.

Let there be n mean squares, s_1^2, s_2^2 ... s_n^2 based respectively on k_1, k_2, ... k_n degrees of freedom. From these values a pooled estimate of variance $\bar{s}^2$ is calculated by the formula

$$\bar{s}^2 = \frac{1}{\sum_1^n k_r} \left(\sum_1^n k_r s_r^2 \right)$$

$$\chi^2 = \left(\sum_1^n k_r\right) \log_e \bar{s}^2 - \sum_1^n k_r \log_e s_r^2$$

$$c = 1 + \frac{1}{3(n-1)} \left[\sum_1^n \frac{1}{k_r} - \frac{1}{\sum_1^n k_r} \right]$$

$\chi^2 = \frac{\chi'^2}{c}$ with (n-1) degrees of freedom. If the value is significant, the variances are significantly heterogeneous. With the heterogeneous error variance, the procedure to be followed for the test of treatment differences depends on the presence or absence of the treatment x location interaction. The next step to be followed therefore consists of making a test of significance for the interaction. This is made by the method of the weighted analysis of variance. If the interaction is present, we carry out a simple analysis of variance and compare the treatment mean square with the interaction mean square for the significance of treatment differences. This procedure is known as unweighted analysis of variance. When the interaction is absent, the method of weighted analysis of variance itself is available for testing the treatment differences.

When heterogeneity of interaction is suspected, the significance of any component of the interaction which is of interest, can be tested by considering only that part of the table which is concerned with the particular component. If such interaction comes out to be significant, the significance of the relevant treatment differences can be tested by comparing the treatment and interaction mean squares obtained from an unweighted analysis.

Table 3.2.1.2. Unweighted analysis of variance of pooled data.

Source	df	SS	MS
Total	st-1	$\sum_{i=1}^{t} \sum_{j=1}^{s} Y_{ij}^2 - C.F.$	
Genotypes (G)	t-1	$\sum_{i=1}^{t} \frac{Y_{i.}^2}{s} - C.F.$	
Environments (E)	s-1	$\sum_{j=1}^{s} \frac{Y_{.j}^2}{t} - C.F.$	
GE interaction	(t-1)(s-1)	by subtraction	MS_1
Pooled error	s(t-1)(r-1)		se^2/r

where,

$$C.F. = \frac{\left(\sum_{i=1}^{t} \sum_{j=1}^{s} Y_{ij}\right)^2}{st}$$

Significance of GE interaction was tested using the F ratio

$$F = rMs_1/s_e^2$$

Table 3.2.1.3. Weighted analysis of variance of the pooled data.

Source	SS
Total	$\sum_{j=1}^{s} W_j S_j - C$
Environments	$\frac{1}{t} \sum_{j=1}^{s} W_j P_j^2 - C$
Genotypes	$\sum_{j=1}^{t} \frac{\left(\sum_{j=1}^{s} W_j \, Y_{ij}\right)^2}{\sum_{j=1}^{s} W_j}$
GE interaction	Total ss - Env.ss - Geno.ss

The terms in the analysis of variance were obtained as follows:

$W_j = \frac{r}{s_j^2}$, where s_j^2 is the error mean square in the j^{th} environment and r is the number of replications in each environment

S_j = crude ss for the j^{th} environment

P_j = total for the j^{th} environment

$$C = \frac{G^2}{t \sum_{j=1}^{s} W_j}$$

$$G = \sum W_j P_j$$

$$= \sum_{i=1}^{t} \left(\sum_{j=1}^{s} W_j Y_{ij} \right)$$

significance of GE interaction was tested using the test

$$\chi^2 = \frac{(n-1)\ (n-2)}{n(n+t-3)}\ I \text{ with}$$

$$d.f. = \frac{(s-1)(t-1)(n-4)}{(n+t-3)}$$

where,

n = the number of d.f. on which the error mean square is based in each environment.

I = Interaction sum of squares.

Once the GE interaction was found to be significant, stability of each genotype was assessed from the mean performance over the different environments by the different methods as follows:

3.2.2. Eberhart and Russell's model (ER model)

Eberhart and Russell (1966) considered a model by assuming that there are t varieties whose performance had been tested in as environments (locations). Considering Y_{ij} as the mean observation of i^{th} variety in j^{th} environment. Eberhart and Russell used the following model to study the stability of varieties under different environments.

$$Y_{ij} = \mu_i + b_i I_j + \delta_{ij}$$

$(i = 1, 2 \ldots t$ and $j = 1, 2 \ldots s)$

where,

Y_{ij} = Mean of i^{th} variety in j^{th} environment

μ = Mean of i^{th} variety over all environments

b_i = regression coefficient of the i^{th} variety on the environmental index which measures the response of this variety to varying environments.

I_j = The environmental index which is defined as the deviation of the mean of all varieties at a given location from the overall mean.

$$I_j = \frac{\sum_i Y_{ij}}{t} - \frac{\sum_i \sum_j Y_{ij}}{st}$$

with $\sum_j I_j = 0$

and δ_{ij} = The deviation from regression of the i^{th} variety at j^{th} environment.

Two parameters of stability are calculated.

a) The regression coefficient which is the regression of the performance of each variety under different environments on the environmental means over all genotypes. This is estimated as follows:

$$b_i = \frac{\sum_j Y_{ij} I_j}{\sum_{j=1}^{s} I_j^2}$$

where,

$_j Y_{ij} I_j$ is the sum of products I_j^2 is the sum of squares.

b) Mean square deviations (S_{di}^2) from linear regression.

$$S_{di}^2 = \sum_{j=1}^{s} \frac{\hat{\delta}_{ij}^2}{s-2} - \frac{s_e^2}{r}$$

where,

$$\sum_j \hat{\delta}_{ij}^2 = \left(\sum_j Y_{ij}^2 - \frac{Y_{i.}^2}{t}\right) - \frac{\left(\sum_j Y_{ij} I_j\right)^2}{\sum_j I_j^2}$$

$\frac{se^2}{r}$ = the estimate of pooled error.

The detailed analysis of variance under E_R model is given as below.

Table 3.2.2.1. Analysis of variance under ER model

Source	df	SS	MS
Total	st-1	$\sum_{i=1}^{t} \sum_{j=1}^{s} Y_{ij}^2 - C.F.$	
Varieties	t-1	$\frac{1}{s} \sum_{i=1}^{t} Y_{i.}^2 - C.F.$	MS_1
Environments+ Varieties x Environments	(s-1) (s-1)+(t-1)= t(s-1)	$\sum_{i=1}^{t} \sum_{j=1}^{s} Y_{ij}^2 - \sum_{i=1}^{t} \frac{Y_{i.}^2}{s}$	
Environment (linear)	1	$\frac{1}{t} \frac{\left(\sum_{j=1}^{s} Y_{.j} I_j\right)^2}{\sum_{j=1}^{s} I_j^2}$	
Variety x Environment (linear)	(t-1)	$\sum_{i=1}^{t} \frac{\left(\sum_{j=1}^{s} Y_{ij} I_j\right)^2}{\sum_{j=1}^{s} I_j^2}$ - SS due to environments (linear)	MS_2

Source	df	SS	MS
Pooled deviation	t(s-2)	$\sum_{i=1}^{t} \sum_{j=1}^{s} \delta_{ij}^2$	MS_3
Variety 1	(s-2)	$\sum_{j=1}^{s} \delta_{1j}^2$	
.	.	.	
.	.	.	
.	.	.	
.	.	.	
Variety t	(s-2)	$\sum_{j=1}^{s} \delta_{tj}^2$	
Pooled error	s(t-1)(r-1)		$\frac{S_e^2}{r}$

The following F tests were made use of

1. $F = \frac{MS_1}{MS_3}$, test total the significant difference mean among variety

2. $F = \frac{MS_2}{MS_3}$, to test the qequality of regression coefficients.

3. $F = \frac{\sum_{j=1}^{s} \hat{\delta}_{ij}^2 / (s-2)}{S_e^2/r}$, to test the individual deviation from regression.

A variety with unit regression coefficient (bi = 1) and S_{di}^2 not significantly different from zero ($S_{di}^2 = 0$) could be considered as stable.

To test whether the regression coefficients of individual varieties differed significantly from unity, the following t test was applied,

$$t = \frac{|b_{i-1}|}{SE(b)}$$

where,

$$SE(b) = \left(\frac{\text{MS due to pooled deviation}}{\sum_{j=1}^{s} I_j^2} \right)^{\frac{1}{2}}$$

3.2.3. Perkins and Jinks model (PJ model)

From stability point of view, the variance due to GE interaction being the most important, Perkins and Jinks (1968) proposed that a regression of GE interaction on environmental index should be obtained rather than regression of mean performance (Y_{ij}) on the latter as done in the Eberhart and Russell's model. For describing Y_{ij} the mean performance of the i^{th} variety in j^{th} location, they proposed following model:

$$Y_{ij} = \mu + d_i + \varepsilon_j + g_{ij} + e_{ij}$$

to analyse GE interaction

where,

μ = grand mean of all genotypes overall environments.

d_i = additive genetic effect of the i^{th} genotype

ε_j = additive environmental effect of j^{th} environment

g_{ij} = GE interaction effect of the i^{th} genotype at the j^{th} environment.

e_{ij} = error associated with i^{th} genotype in the j^{th} environment.

The effects are estimated as follows:

$$\mu = \frac{Y_{..}}{st}$$

$$d_i = \frac{Y_{i.}}{s} - \mu$$

$$\varepsilon_j = \frac{Y_{.j}}{t} - \mu$$

$$g_{ij} = Y_{ij} - d_i - \varepsilon_j - \mu$$

g_{ij} was further defined as

$g_{ij} = \beta_i \varepsilon_j + \delta_{ij}$ so that the model becomes

$$Y_{ij} = \mu + d_i + (1+ \beta_i)\varepsilon_j + \delta_{ij} + e_{ij}$$

where,

β_i = linear regression coefficient for the i^{th} genotype.

δ_{ij} = deviation from the regression line for the i^{th} genotype on j^{th} environment.

In this approach also the same two parameters, regression coefficient and the deviation from regression, are used as the parameters of stability. In comparison to Eberhart and Russell's model, the regression coefficient in this model is different in the sense that Perkins and Jinks proposed to calculate the regression of GE interaction value on the environmental index. In terms of this model, the earlier model of Eberhart and Russell is thus regression of $(\varepsilon_j + g_{ij})$ on ε_j. The regression of ε_j on

ε_j being one, and regression of g_{ij} on ε_j being β_i, the b_i value of Eberhart and Russell model is thus:

$$b_i = 1 + \beta_i$$

$$\text{or } \beta_i = b_i - 1$$

The regression coefficient under this model is nothing but that in ER model reduced by unity. S^2_{di} remains exactly same as that of ER model.

The analysis of variance under this model, adopting earlier notations is given as below:

Table 3.2.3.1. Analysis of variance under PJ model.

Source	df	SS	MS
Genotypes	(t-1)	$\sum_{i=1}^{t} \frac{Y_{i.}^2}{s} - \frac{Y_{..}^2}{st}$	
Environments (Joint regression)	(s-1)	$\sum_{j=1}^{s} \frac{Y_{.j}^2}{t} - \frac{Y_{..}^2}{st}$	
Genotype x Environment interaction (GxE)	(t-1)(s-1)	$\sum_{i=1}^{s} \sum_{j=1}^{s} Y_{ij}^2 - \sum_{i=1}^{t} \frac{Y_{i.}^2}{s} - \sum_{j=1}^{t} \frac{Y_{.j}^2}{t} + \frac{Y_{..}^2}{st}$	
Heterogeneity among regression	(t-1)	$\sum_{i=1}^{t} \frac{\left[\sum_{j=1}^{s} Y_{ij} \left(\frac{Y_{.j}}{t} - \frac{Y_{..}}{st}\right)\right]^2}{\sum_{j=1}^{s} I_j^2}$ - SS due to environments	

Source	df	SS	MS
Remainder	(t-1)(s-2)	(GxE) SS-SS due to heterogenity	
Error	s(t-1)(r-1)		$\frac{S_e^2}{r}$

the GE interaction SS is partitioned into two components, viz. heterogeneity among regression with (s-1) df and remainder SS with (t-1) (s-2) d.f. The environments (Joint regression) SS with (s-1) df in this case is the same as the environments (linear) ss of Eberhart and Russell, with d.f=1. Similarly, ss due to heterogeneity among regression in this case is equal to the variety x environment (linear) ss of ER model, both with d.f = (t-1). The pooled deviation ss with t(s-2) df in the former case is equal to the reminder ss with (t-1) (s-2) df in this case.

A variety with linear regression coefficient $\beta_i = 0$ (ie. $b_i = 1$) and the deviation not significantly different from zero ($S_{di}^2 = 0$) could be considered as stable.

3.2.4. Freeman and Perkins model (FP model)

In the previous two models, the mean performance of a variety in a given environment (Y_{ij}) is regressed over the environmental index defined as $(\sum_i Y_{ij}/t) - \sum_{ij} Y_{ij}/st)$. Obviously, the estimation of these two variables is not independent. This being an objectional point, Freeman and Perkins (1971) proposed independent estimate of environmental index in the following two ways: (i) Divide the replications into groups, so that the one group may be used for measuring the average performance of varieties in various environments and the other group, averaging over the varieties is used for estimating the environmental index. (ii) Use one or more varieties as check and assess the environmental index on the basis of their performance.

Another objection of Freeman and Perkins to other two models was about the partitioning of the degrees of freedom. Though S.S. due to environment (linear) of Eberhart and Russell's model being the same as S.S. due to environment (joint regression) of Perkins and Jink's model, yet the degree of freedom is one in the former and s-1 in the latter.

For describing Y_{ij}, ie. performance of i^{th} genotype in the j^{th} environment, Freeman and Perkins proposed the following model.

$$Y_{ij} = \mu + d_i + \bar{\beta} z_j + \bar{\delta}_j + \beta d_i z_j + \delta d_{ij}$$

where,

μ = mean of all genotypes over all environments

d_i = effect of i^{th} genotype

$\bar{\beta}$ = combined regression coefficient

Z_j = environmental index

βd_i = difference between the regression coefficient of i^{th} genotype and the combined regression coefficient

$\overline{\delta_j}$ = deviation of mean of all genotypes in the j^{th} environment from the combined regression line.

δd_{ij} = deviation of the i^{th} genotype from its linear regression of Z_j in the j^{th} environment minues $\overline{\delta_j}$.

The two parameters of stability were computed as

$$b_i' = \sum_{j=1}^{s} Y_{ij} Z_j \Big/ \sum_{j=1}^{s} Z_j^2$$

$$S_{di}'^{2} = \sum_{j=1}^{s} \frac{\delta_{ij}^2}{s-2} - \frac{s_e^2}{r}$$

where,

$$Z_j = Y_{.j} - \overline{Y_{..}}$$

$$\sum_{j=1}^{s} \delta_{ij}^2 = \sum_{j=1}^{s} Y_{ij}^2 - \frac{Y_{i.}^2}{s} - b_i \sum_{j=1}^{s} Y_{ij} Z_j$$

$\frac{s_e^2}{r}$ is the estimate of pooled error.

Table 3.2.4.1. Analysis of variance under FP model

Source	df	SS	MS
Genotypes (G)	(t-1)	$\sum_{i=1}^{t} \frac{Y_{i..}^2}{rs} - \frac{Y_{...}^2}{rst}$	

Source	df	SS	MS
Environments (E)	(s-1)	$\sum_{j=1}^{s} \frac{Y_{.j.}^2}{rt} - \frac{Y_{...}^2}{rst}$	
Combined regression	1	$\frac{(\sum_{j=1}^{s} Y_{.j.} Z_j)^2}{rt \sum_{j=1}^{s} Z_j^2}$	
Environmental residual	(s-2)	By subtraction from E	
Genotype x environment interaction (GxE)	(t-1)(s-1)	$\sum_{i=1}^{t} \sum_{j=1}^{s} \frac{Y_{ij.}^2}{r} - \sum_{i=1}^{t} \frac{Y_{i..}^2}{rs} - \sum_{j=1}^{s} \frac{Y_{.j.}^2}{rt} + \frac{Y_{...}^2}{rst}$	
Heterogenity among regressions	(t-1)	$\sum_{i=1}^{t} \frac{(\sum_{j=1}^{s} Y_{ij.} Z_j)^2}{r \sum_{j=1}^{s} Z_j^2} - \frac{(\sum_{j=1}^{s} Y_{.j.} Z_j)^2}{rt \sum_{j=1}^{s} Z_j^2}$	
(GxE) residual	(t-1)(s-2)	By subtraction from (GxE)	
Pooled error	s(t-1)(r-1)	$\sum_{i} \sum_{j} \sum_{k} Y_{ijk}^2 - \sum_{i} \sum_{k} Y_{ij.}^2/r$	S_e^2/r

The significance of each item was tested by using variance ratio against the pooled error mean square.

A variety with unit regression coefficient ($b_i' = 1$) and the deviation not significantly different from zero ($S_{di}'^2 = 0$) could be considered as stable variety.

The above three methods used the theory of regression and two stability parameters. The characterisation of genotypes on the basis of regression coefficient may not be very effective when only a small fraction of the SS due to GE interaction can be attributed to heterogeneity among regression. For such situations, single stability parameter approaches suggested by Wricke (1966) and Shukla (1972) can be used. In the following methods, SS due to GE interaction was split up into components attributable to different genotypes.

3.2.5. Wricke's Method

Wricke (1966) suggested ecovalence ratio as the percentage contribution of a genotype to ss due to GE interaction Ecovalence for i^{th} genotype is

$$W_i = \sum_{j=1}^{s} \left(Y_{ij} - \frac{Y_{i.}}{s} - \frac{Y_{.j}}{t} + \frac{Y_{..}}{st}\right)^2,$$

where,

Y_{ij} is the mean performance of i^{th} genotype in the j^{th} environment (location) expressed as percentage of the total of all W_is.

A variety having least ecovalence was considered most stable and a variety with large ecovalence value, least stable.

3.2.6. Shukla's Method:

Stability variance σ_i^2 of i^{th} genotype as per Shukla (1972) is

$$\sigma_i^2 = \frac{1}{(s-1)(t-1)(t-2)} \quad t(t-1) \sum_{j=1}^{s} \left(Y_{ij} - \frac{Y_{.j}}{t} + \frac{Y_{..}}{st}\right)^2$$

$$- \sum_{i=1}^{t} \sum_{j=1}^{s} \left(Y_{ij} - \frac{Y_{i.}}{s} - \frac{Y_{.j}}{t} + \frac{Y_{..}}{st}\right)^2$$

A variety having σ_i^2 values less than the within environmental variance σ_o^2 (σ_o^2 is estimated as the pooled error mean square) or having negative σ_i^2 value was defined as stable. F test given by $F = \frac{\sigma_i^2}{\sigma_o^2}$ with d.f. ((s-1), s(t-1) (r-1)) was used to test the significance of σ_i^2.

3.3. Simultaneous stability analysis for several traits

3.3.1. Phenotypic index method

Smith (1936) proposed a selection model for making selection on several characters simultaneously using discriminant function of Fisher (1936). Fisher (1936) mentioned a function I to discriminate the individuals belonging to two different population showing some degree of overlapping. The function I is defined as

$$I = b_1 x_1 + b_2 x_2 + \ldots\ldots\ldots + b_n x_n$$

where,

$x_1, x_2, \ldots\ldots x_n$ are the variables measured, and

$b_1, b_2 \ldots\ldots b_n$ are the weighing coefficients. The b_i values are estimated based on I values, such that the ratio of variance between populations to that of within the populations would be maximised. The maximisation of this ratio leads to a set of simultaneous equations which after solution provide the desired b_i values. The simultaneous equations take the following form:

$$\left.\begin{array}{l} b_1' + b_2' r_{12} + b_3' r_{13} + \ldots\ldots\ldots b_n' r_{1n} = d_1' \\ b_1' r_{12} + b_2' + b_3' r_{23} + \ldots\ldots\ldots b_n' r_{2n} = d_2' \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ b_1' r_{1n} + b_2' r_{2n} + \ldots\ldots\ldots \ldots + b_n' = d_n' \end{array}\right\} - \text{I}$$

A solution of these equations in terms of matrix notation is

$$\underline{b} = \underset{\sim}{R}^{-1} \underline{d}$$

$\underline{b}$ is the column vector of coefficients R^{-1} is the inverse of the correlation matrix. $\underline{d}$ is the column vector for d_i values. Various components of equation I can be estimated as

$$r_{ij} = \frac{\Sigma(x_i\, x_j)}{\sqrt{\Sigma(x_i)^2 \quad \Sigma(x_j)^2}}$$

$$d_i = x_i^1 - x_i^2$$

$$d_i' = \frac{d_i}{\sqrt{\Sigma(x_i)^2}}$$

$$b_i' = \frac{b_i}{\sqrt{\Sigma(x_i)^2}}$$

b_i values have to be estimated and x_i^1 and x_i^2 indicate mean of i^{th} character in population 1 and 2 respectively.

Application of Discriminant function as a basis for making selection on several characters simultaneously is aimed at discriminating the desirable genotypes from undesirable ones on the basis of their phenotypic performance. Smith (1936) defined the genetic worth H of an individual as

$$H = a_1 G_1 + a_2 G_2 + \cdots\cdots a_n G_n$$

where

G_1, G_2 .... G_n are the genotypic values of individual characters and a_1, a_2, ... a_n signify their relative economic importance. Another function I based on the phenotypic performance of various characters is defined as

$$I = b_1 P_1 + b_2 P_2 + \cdots\cdots\cdots b_n P_n$$

where

b_1, b_2 .... b_n are to be estimated.such that the correlation between H and I ie, r (H, I) becomes maximum. Once such function is obtained, discrimination of good genotypes from the undesirable ones will be possible on the basis of phenotypic performance, ie. P_1, P_2 ..... P_n directly. The maximisation of r (H, I) leads to a set of simultaneous equations which upon solving give the desired estimate of b_i values. Simultaneous equations are as follows:

$$b_1 x_{11} + b_2 x_{12} + \cdots + b_n x_{1n} = a_1 G_{11} + a_2 G_{12} + \cdots + a_n G_{1n}$$
$$b_1 x_{21} + b_2 x_{22} + \cdots + b_n x_{2n} = a_1 G_{21} + a_2 G_{22} + \cdots + a_n G_{2n}$$
$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$
$$b_1 x_{n1} + b_2 x_{n2} + \cdots + b_n x_{nn} = a_1 G_{n1} + a_2 G_{n2} + \cdots + a_n G_{nn}$$

which in matrix form becomes

$$\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nn} \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ \cdot \\ b_n \end{bmatrix} = \begin{bmatrix} G_{11} & G_{12} & \cdots & G_{1n} \\ G_{21} & G_{22} & \cdots & G_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ G_{n1} & G_{n2} & \cdots & G_{nn} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ \cdot \\ a_n \end{bmatrix}$$

The solution of these equation give the estimates of b_i values in the following manner

$$\underline{b} = \underset{\sim}{x}^{-1} \underset{\sim}{G}\underline{a}$$

where,

$\underline{b}$ is the column vector

$\underset{\sim}{x}^{-1}$ is the inverse of phenotypic variance and covariance matrix

$\underset{\sim}{G}$ is the genotypic variance and covariance matrix

$\underline{a}$ is the column vector for economic weights.

Assuming that all the characters are economically equally important.

ie. $a_1 = a_2 = \cdots\cdots = a_n = 1$

b values can be estimated as

$$\begin{bmatrix} \hat{b}_1 \\ \hat{b}_2 \\ \\ \hat{b}_n \end{bmatrix} = \begin{bmatrix} x^{11} & x^{12} & \cdots & x^{1n} \\ x^{21} & x^{22} & \cdots & x^{2n} \\ \cdot & \cdot & \cdot & \cdot \\ x^{n1} & x^{n2} & \cdots & x^{nn} \end{bmatrix} \begin{bmatrix} G_{11} & G_{12} & \cdots & G_{1n} \\ G_{21} & G_{22} & \cdots & G_{2n} \\ \cdot & \cdot & \cdot & \cdot \\ G_{n1} & G_{n2} & \cdots & G_{nn} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ \cdot \\ 1 \end{bmatrix}$$

where

$$\begin{bmatrix} x^{11} & x^{12} & \ldots & x^{1n} \\ x^{21} & x^{22} & \ldots & x^{2n} \\ - & - & - & - \\ - & - & - & - \\ x^{n1} & x^{n2} & \ldots & x^{nn} \end{bmatrix} = \underset{\sim}{x}^{-1}$$

The mathematical description of the function I is known as phenotypic index or selection index.

$$I = \hat{b}_1 x_1 + \hat{b}_2 x_2 + \ldots + \hat{b}_n x_n$$

From the above function I, we get the phenotypic index or selection index for each of the 20 varieties at three different locations with three replications. GE interaction will be studied for the varieties based on the index values. Once the GE interaction was found to be significant, stability of each genotype will be assessed from the mean phenotypic index over the different environments by the following methods.

(i) Eberhart and Russell's method

(ii) Perkins and Jinks model

(iii) Freeman and Perkins model

(iv) Wricke's method

(v) Shukla's method

3.3.2. <u>Principal component analysis method:</u>

In many of the experimental situations of multivariate data analysis, the characters may be intercorrelated. In order to examine the relationship among a set of p correlated variables, it may be useful to transform the original set of variables to a new set of uncorrelated variables called principal components. These new variables are linear combinations of the original variable and one derived in the decreasing order of importance so that, for eg: the first principal component accounts for the maximum possible of the variation in the original data.

Principal component analysis (PCA) consists in transforming the original set of variables $\underline{x}$ to a new set of derived variables $\underline{y}$ by the orthogonal transformation (Morrison, 1978). $\underline{y} = \underline{A}\,\underline{x}$ where $\underline{A}$ is the p x p matrix of weighting coefficients. The usual objectives of the analysis is to see if the first few components account for most of the variation in the original data. PCA will simply find components which are close to the original variables but arranged in decreasing order of variance.

Let $x' = (x_1, x_2 \ldots x_p)$ be a p variate vector of observations from a multiviate population with mean vector μ and variance covariance matrix $\underset{\sim}{\Sigma}$. The estimate of $\underset{\sim}{\Sigma}$ will be the usual sample variance covariance matrix s.

If $a_{11}, a_{21}, \ldots a_{p1}$ are weights given to the variables according to their relative importance, the first principal component y_1 is defined as

$$y_1 = a_{11}x_1 + a_{21}x_2 + \ldots \ldots + a_{p1}x_p$$

$$y_1 = \underline{a}_1' \underline{x}$$

where

$a_1' = (a_{11}, a_{21}, \ldots \ldots a_{p1})$ is a vector of constants.

Sample variance $s_{y1}^2 = a_1' \underset{\sim}{s} a_1$

The first principal component is the vector of weighting coefficients $\underline{a}_1$ which maximises the variation subject to the restriction that sum of squares of $\underset{\sim}{a}_1'$ is a constant.

$$\Sigma a_{ij}^2 = 1 \qquad \text{ie, } a_1' a_1 = 1$$

Introducing Lagrange's multiplier λ_1, the function becomes

$$L = s_{y1}^2 + \lambda_1 (1 - a_1' a_1)$$

$$= \underline{a}_1' \underset{\sim}{s} a_1 + \lambda_1 (1 - a_1' a_1)$$

Maximise L with respect to a_1

$$\frac{\partial L}{\partial a_1} = 2 \underset{\sim}{s} a_1 - 2 \lambda_1 \underline{a}_1$$

$$= 2 (\underset{\sim}{s} - \lambda_1 I) a_1$$

$\frac{\partial L}{\partial a_1} = 0$ If and only If

$$\left| \underset{\sim}{s} - \lambda_1 I \right| a_1 = 0$$

The above will have a solution other than $a_1 = 0$

Iff $\left| \underset{\sim}{s} - \lambda_1 I \right| = 0$

λ_1 is the characteristic root of the covariance matrix s and a_1' is its associated characteristic vector. The coefficient vector a_1 must be chosen in such a way that λ_1 is the greatest characteristic root of s.

The second principal component may be y_2 is found by choosing a_2 so that y_2 having the next largest possible variation. With 'n' characters, a maximum of n principal component vectors are possible. The principal components partition the total variance of the original variables into p additive components. From the general properties of characteristic roots,

$$\sum_j \lambda_j = \text{Trace } s$$

The relative contribution of j^{th} component in the system (j) is measured by

$$E_j = \frac{\lambda_j}{\text{Trace } s}$$

The first principal component of sample observations $x_1, x_2 \ldots x_p$ is the linear combination

$y_1 = a_{11} x_1 + a_{21} x_2 + \ldots + a_{p1} x_p$ whose coefficients a_{i1} are the elements of the characteristic vector associated with the greatest characteristic root λ_1 of the sample covariance matrix of the observations.

In the present investigation the characteristic roots for the observations correspond to each variety will be studied. If the first characteristic root is found to have explained a reasonable percentage of the total variation, the principal component corresponding to the first characteristic root will be taken for studying that variety. The first principal components of all the varieties will be used for studying the GE interaction, if the first principal component explains the maximum variation. The method of using first principal component for the study of GE interaction is more reasonable in comparison to the phenotypic index method, as we are assuming equal weights to the economic characters while calculating the phenotypic index. GE interactions will be studied for the varieties based on the first principal components through following five methods.

(i) Eberhart and Russell's method

(ii) Perkins and Jinks method

(iii) Freeman and Perkins method

(iv) Wricke's method

(v) Shukla's method.

Results

RESULTS

The data collected from a multilocational trial on twenty sesame varieties from three different locations - Kayamkulam, Pattambi and Vellayani during the year 1982-83 by the Plant Breeding department of College of Agriculture, Vellayani on twelve characters based on twenty varieties were statistically analysed on the basis of the methodology described in the previous chapter. The results were as given below:

Out of the twelve characters of twenty varieties analysed the pooled analysis were done individually for all the characters pooling all the locations. GE interaction based on all the characters were examined and it was found that the characters - length of capsule, height, number of capsule/plant have no GE interaction. The pooled analysis of these characters were shown in the Table 4.10.1, 4.11.1. Hence these three characters were not further investigated. The remaining nine characters, which were showing genotype-environment interaction were further investigated and the results were as follows:

4.1. Seed yield per plot

The error mean square of the three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (χ^2 = 15.056) was found to be significant.

Hence weighted analysis has been done. The pooled ANOVA is given in Table 4.1.1. The variety x location interactions was found to be significant.

The treatment means of the 20 varieties in the three locations averaged over the replications were worked out as shown in the Table 4.1.2.

The analysis of variance under Eberhart and Russel model was worked out as given in Table 4.1.3.

The variety x location (linear) component (which is same as the difference between regression) was non-significant. Pooled deviation from regression was significant at 5% level. This was because of the significance of deviation for the varieties 8, 9, 12, 16. The deviation from regressions was significant for none of the other varieties.

The analysis of variance of Perkins and Jinks model for the same data was as given in Table 4.1.4. Heterogeneity among regression was not significant and the remainder part of the variety x location interaction was significant.

One of the replications (Ist replication) in each locations was used for the measure of environment under Freeman and Perkins model, the remaining two replications (2nd and 3rd) were used for the analysis of variance and the same is given in Table 4.1.5. From the table it could be inferred that heterogeneity among the regressions was not significant and the remainder part of the variety x location interaction was significant in this model also.

The environmental indices I_j and Z_j were worked out as given in the Table 4.1.6. It was found from Table 4.1.6 that they were in close agreement to each other.

Stability parameters for the twenty varieties under the three models are provided in Table 4.1.7. S_{di}^2 values are the same for ER and RJ models.

The values of Wricke's ecovalence ratio W_i and Shukla's stability variance σ_i^2 and F values for testing the significance of σ_i^2 are given in Table 4.1.8. All the varieties had non-significant σ_i^2 values except the variety 14. The W_i's were also high for these varieties.

Correlation coefficients between the various pairs of stability parameters were worked out as given in Table 4.1.9.

A correlation coefficient of unity was obtained between W_i and σ_i^2. Hence σ_i^2 had the same correlation coefficient with other parameters as W_i had with them. The regression coefficient showed positive correlation with W_i. S_{di}^2 and W_i were highly correlated.

But inspite of these limitations, from the examination of Table 4.1.7, it could be reasonably concluded that varieties 2, 3, 6, 11, 19 and 20 are stable varieties. This fact has been almost corroborated from the Table 4.1.8 of W_i and σ_i^2.

4.2. Oil content percentage

The error mean square of the three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (= 175.093) was found to be significant. Hence the weighted analysis has been done.

The pooled ANOVA was given in Table 4.2.1. The variety x locations interactions was found to be significant.

The treatment means of the 20 varieties in the three locations averaged over the replications were worked as shown in the Table 4.2.2.

The analysis of variance under Eberhart and Russel model was worked out as given in Table 4.2.3. The variety x location (linear) component which is some as the difference between regression was non-significant. Pooled deviation from regression was significant at 5% level. This was because of the significance of deviation for all the varieties except the variety 3, ie, the deviation from regression was significant for all varieties except the variety 3.

The analysis of variance of Perkins and Jinks model for the same data was as given in Table 4.2.4. Heterogeneity among regression and the remainder part of the variety x location interaction were significant.

One of the replications (Ist replication) on each locations was used for the measure of the environment under Freeman and Perkins model, the remaining two replications (2nd and 3rd) were used for the analysis of variance and the same is given in Table 4.2.5. From the table it could be inferred that heterogeneity among the regressions and the remainder part of the variety x location interaction were significant in this model also.

The environmental indices I_j and Z_j were worked out as given in the Table 4.2.6. It was found from Table 4.2.6 that they were in close agreement to each other.

Stability parameters for the twenty varieties under three models were provided in Table 4.2.7. S_{di}^2 values are the same for ER and PJ models.

The values of Wricke's ecovalence ratio W_i and Shukla's stability variance σ_i^2 and F values for testing the significance of σ_i^2 are given in Table 4.2.8.

All the varieties had non significant σ_i^2 values except the variety 18. The W_i was also high for the variety.

Correlation coefficients between the various pairs of stability parameters were worked out as given in Table 4.2.9.

A correlation coefficient of unity was obtained between Wi and σ_i^2. Hence σ_i^2 had the same correlation coefficient with other parameters as W_i had with them.

From the examination of Table 4.2.7 it could be reasonably concluded that varieties 1, 2, 12, 13, 16 and 20 are stable varieties. This fact has been almost corroborated from the Table 4.2.8 of W_i and σ_i^2.

4.3. Seed yield per plant

The error mean square of the three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (= 6.921) was found to be significant. Hence the weighted analysis has been done. The pooled ANOVA is given in Table 4.3.1. The variety x locations interactions was found to be significant.

Treatment means of the 20 varieties in the three locations averaged over the replications were worked out as shown in the Table 4.3.2.

The analysis of variance under Eberhart and Russel model was worked out as given in Table 4.3.3.

The variety x location (linear) component (which is some as the difference between regression) was non significant. Pooled deviation from regression was significant at 5% level. This was because of the significance of the deviation for the varieties 6, 7, 8, 12 and 17. The deviation from regression was significant for none of the other varieties.

The analysis of variance of Perkins and Jinks model for the same data was given in Table 4.3.4. Heterogeneity among regression was not significant and the remainder part of the variety x location interaction was significant.

One of the replications (Ist replication in each location) was used for the measure of environment under Freeman and Perkins model, the remaining two replications (2nd and 3rd) were used for the analysis of variance and the same is given in Table 4.3.5. From the table it could be inferred that heterogeneity among the regressions and the remainder part of the variety x location interaction were not significant.

The environmental indices I_j and Z_j were worked out as given in the Table 4.3.6. It was found from Table that they were in close agreement to each other.

Stability parameters for the twenty varieties under the three models are provided in Table 4.3.7. S_{di}^2 values are the same for ER and PJ models.

The values of Wricke's ecovalence ratio W_i and Shukla's stability variance σ_i^2 and F value for testing the significance of σ_i^2 are given in Table 4.3.8. All the varieties had non significant σ_i^2 values except the varieties 6, 7, and 12. The W_i were also high for those varieties.

Correlation coefficient between the various pairs of stability parameters were worked out as given in Table 4.3.9.

A correlation coefficient of unity was obtained between W_i and σ_i^2. Hence σ_i^2 had the same correlation coefficient with other parameters as W_i had with them.

From the examination of Table 4.3.7 it could be reasonably concluded that varieties 2, 13, 15, 18, 19 and 20 are stable varieties. This fact has been almost corroborated from the Table 4.3.8 of W_i and σ_i^2.

4.4. Number of seeds per capsule

The error mean square of three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (= 1.696) was found to be significant. Hence weighted analysis has been done. The pooled ANOVA is given in Table 4.4.1. The variety x locations interactions was found to be significant.

The treatment means of 20 varieties in the three locations averaged over the replications were worked out as shown in the Table 4.4.2.

The analysis of variance under Eberhart and Russel model was worked out as given in Table 4.4.3. The variety x location (linear) component (which is same as the difference between regression) was non significant. Pooled deviation from regression was significant at 5% level. This was because of the significance of deviation for the varieties 10, 11, 13, 15, 16. The deviation from regression was significant for none of the other varieties.

The analysis of variance of Perkins and Jinks model for the same date was as given in Table 4.4.4. Heterogeneity among regression was significant and the remainder part of the variety x location interaction was also significant.

One of the replications (Ist replication) in each location was used for the measure of environment under Freeman and Perkins model, the remaining two replications (2nd and 3rd) were used for the analysis of varianco and the same is given in Table 4.4.5. From the table it could be inferred that heterogeneity among the regressions and the remainder part of the variety x location interaction were significant in this model also.

The environmental indices I_j and Z_j were worked out as given in the Table 4.4.6.

Stability parameters for the twenty varieties under the three models are provided in Table 4.4.7. S_{di}^2 values are the same ER and PJ models.

The values of Wricke's ecovalence ratio W_i and Shukla's stability variance σ_i^2 and F values for testing the significance of σ_i^2 are given in Table 4.4.8.

All the varieties had non-significant σ_i^2 values except the varieties 10, 11 and 16. The W_i's were also high for these varieties.

Correlation coefficients between the various pairs of stability parameters were worked out as given in Table 4.4.9.

A correlation coefficient of unity of was obtained between W_i and σ_i^2. Hence σ_i^2 had the same correlation coefficient with other parameters as W_i had with them.

From the examination of Table 4.4.7 it could be reasonably concluded that varieties 4, 6, 8, 12, 17 and 20 are stable varieties. This fact has been almost corroborated from the Table 4.4.8 of W_i and σ_i^2.

4.5. Circumference of capsule

The error mean square of the three locations were tested for its homogeneity using Bartlett's test. The

Bartlett's χ^2 (= 69.485) was found to be significant. Hence the weighted analysis has been done. The pooled ANOVA was given in Table 4.5.1. The variety x locations interactions was found to be non-significant.

The treatment means of 20 varieties in the three locations averaged over the replications were worked out as shown in Table 4.5.2.

The analysis of variance under Eberhart and Russel model was worked out as given in Table 4.5.3.

The variety x location (linear) component (which is same as the difference between regression) was non-significant. Pooled deviation from regression was non-significant at 5% level. The deviation from regression was significant for none of the varieties.

The analysis of variance of Perkins and Jinks model for the same data was as given in Table 4.5.4. Heterogeneity among regression was not significant and the remainder part of the variety x location interaction was not significant.

One of the replications (Ist replication) in each locations was used for the measure of environment under Freeman and Perkins model, the remaining two replications (2nd and 3rd) was used for the analysis of variance and the same is given in Table 4.5.5. From the table it could be inferred that heterogeneity among regression was significant and the remainder part of the variety x location interaction was significant.

The environmental indices I_j and Z_j were worked out as given in Table 4.5.6. It was found from Table 4.5.6. that they were in close agreement to each other.

Stability parameters for the twenty varieties under the three models are provided in Table 4.5.7. S_{di}^2 values are the same for ER and PJ models.

The values of Wricke's ecovalence ratio W_i and Shukla's stability variance σ_i^2 and F values for testing the significance of σ_i^2 are given in Table 4.5.8. All the varieties had non significant σ_i^2 values except the varieties 2 and 7. The W_i's were also high for these varieties.

Correlation coefficients between the various pairs of stability parameters were worked out as given in Table 4.5.9.

A correlation coefficient of unity was obtained between W_i and σ_i^2. Hence σ_i^2 had the same correlation coefficient with other parameters as W_i had with them.

From the examination of Table 4.5.7 it could be reasonably concluded that varieties 13, 15, 19, 16, 20 and 18 are stable varieties. This fact has been almost corroborated from the Table 4.5.8 of W_i and σ_i^2.

4.6. Number of branches

The error mean of the three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (= 10.005) was found to be significant. Hence the weighted analysis has been done. The pooled ANOVA is given in Table 4.6.1.

The variety x location was found to be significant. The treatment means of the 20 varieties in three locations averaged over the replications were worked out as shown in the Table 4.6.2.

The analysis of variance under Eberhart and Russel model was worked out as given in Table 4.6.3.

The variety x location (linear) component (which is same as the difference between regression) was significant. Pooled deviation from regression was significant at 5% level. This was because of the significance of deviation for the variety 3. The deviation from regression was significant for none of the other varieties.

The analysis of variance of Perkins and Jinks model for the same data was as given in Table 4.6.4. Heterogeneity among regression was significant and the remainder part of the variety x location interaction was not significant.

One of the replications (Ist replication) in each locations was used for the measure of environment under

Freeman and Perkins model, the remaining two replications (2nd and 3rd) were used for the analysis of variance and the same is given in Table 4.6.5. From the table it could be inferred that heterogeneity among the regression was not significant and the remainder part of the variety x location interaction was significant.

The environmental indices I_j and Z_j were worked out as given in the Table 4.6.6. that they were in close agreement to each other.

Stability parameters for the twenty varieties under the three models are provided in Table 4.6.7. S_{di}^2 values are the same for ER and FJ models.

The values of Wricke's ecovalence ratio W_i and Shukla's stability variance σ_i^2 and F values for testing the significance are given in Table 4.6.8. All the varieties had non significant σ_i^2 values except the variety 14. The W_i was also high for this variety.

Correlation coefficients between the various pairs of stability parameters were worked out as given in Table 4.6.7.

A correlation coefficient of unity was obtained between W_i and σ_i^2. Hence σ_i^2 had the same correlation coefficient with other parameters as W_i had with them.

From the examination of Table 4.6.7 it could be reasonably concluded that varieties 1, 10, 2, 4, 17 and 20 are stable varieties. This fact has been almost corroborated from the Table 4.6.8 of W_i and σ_i^2.

4.7. <u>1000 seed weight</u>

The error mean square of the three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (= 34.652) was found to be significant. Hence the weighted analysis has been done. The pooled ANOVA is given in Table 4.7.1. The variety x locations interactions was found to be significant.

The treatment means of the 20 varieties in the three locations averaged over the replications were worked out as shown in the Table 4.7.2.

The analysis of variance under Eberhart and Russel model was worked out as given in Table 4.7.3. The variety x location (linear) component (which is same as the difference between regression) was non-significant. Pooled deviation from regression was significant at 5% level. This was because of the significance of deviation for the varieties 3, 10, 11, 12, 18, 19. The deviation from regression was significant for none of the other varieties.

The analysis of Perkins and Jinks model for the same data was given in Table 4.7.4. Heterogeneity among regression and the remainder part of the variety x location interaction were significant.

One of the replications (Ist replication) in each location was used for the measure of environment under Freeman and Perkins model, the remaining two replications (2nd and 3rd) were used for the analysis of variance and the same is given in Table 4.7.5. From the table it could be inferred that heterogeneity among the regressions and the remainder part of the variety x location interaction were non significant.

The environmental indices I_j and Z_j were worked out as given in the Table 4.7.6. It was found from Table 4.7.6 that they were in close agreement to each other.

Stability parameters for the twenty varieties under the three models are provided in Table 4.7.7. S_{di}^2 values are the same for ER and PJ models.

The values for Wricke's ecovalence ratio W_i and Shukla's stability variance σ_i^2 and F values for testing the significance of σ_i^2 are given in Table 4.7.8.

All the varieties had non significant σ_i^2 values except the variety 12. The W_i was also high for this variety.

Correlation coefficients between the various pairs of stability parameters were worked out as given in Table 4.7.9.

A correlation coefficient of unity was obtained between W_i and σ_i^2. Hence σ_i^2 had the same correlation coefficient with other parameter as W_i had with them.

From the examination of Table 4.7.7 it could be reasonably concluded that varieties 1, 4, 7, 8, 16 and 19 are stable varieties. This fact has been almost corroborated from the Table 4.7.8 of W_i and σ_i^2.

4.8. Number of days for flowering

The error mean square of the three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (= 7.818) was found to be significant. Hence the weighted analysis has been done. The pooled ANOVA is given in Table 4.8.1. The variety x locations interactions was found to be significant.

The treatment means of the 20 varieties in the three locations averaged over the replications were worked out as shown in the Table 4.8.2.

The analysis of variance under Eberhart and Russel model was worked out as given in Table 4.8.3. The variety x location (linear) component (which is same as the difference between regression) was non-significant. Pooled deviation from regression was significant at 5% level. This was because of the significance of the deviation for the varieties 1, 2, 3, 4, 7. The deviation from regression was significant for none of the other varieties.

The analysis of variance of Perkins and Jinks model for the same data was given in Table 4.8.4. Heterogeneity among regression and the remainder part of the variety x location interaction were significant.

One of the replications (Ist replication) in each locations was used for the measure of environment under Freeman and Perkins model, the remaining two replications (2nd and 3rd) were used for the analysis of variance and the same is given in Table 4.8.5. From the table it could be inferred that heterogeneity among the regressions and the remainder part of the variety x location interaction were significant in this model also.

The environmental indices I_j and Z_j were worked out as given in the Table 4.8.6. It was found from Table 4.8.6 that they were in close agreement to each other.

Stability parameters for the twenty varieties under the three models are provided in Table 4.8.7. S_{di}^2 values are the same for ER and PJ models.

The values of Wricke's ecovalence ratio W_i and Shukla's stability variance σ_i^2 and F values for testing the significance of σ_i^2 values are given in Table 4.8.8. All the varieties had non significant σ_i^2 values.

Correlation coefficients between the various pairs of stability parameters were worked out as given in Table 4.8.9.

A correlation coefficient of unity was obtained between W_i and σ_i^2. Hence σ_i^2 had the same correlation coefficient with other parameters as W_i had with them.

From the examination of Table 4.8.7, it could be reasonably concluded that varieties 3, 5, 8, 9, 12 and 20 are stable varieties. This fact has been almost corroborated from the Table 4.8.8 of W_i and σ_i^2.

4.9. Number of days to maturity

The error mean square of the three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (= 2.588) was found to be significant. Hence weighted analysis has been done. The pooled ANOVA is given in Table 4.9.1.

The variety x locations interactions was found to be significant.

The treatment means of 20 varieties in the three locations averaged over the replications were worked out as shown in Table 4.9.2.

The analysis of variance under Eberhart and Russel model was worked out as given in Table 4.9.3. The variety x location (linear) component (which is same as the difference between regression) was non-significant. Pooled deviation from regression was significant at 5% level. This was because of the significance of deviation of all the varieties except 1, 2, 3, 9, 17 and 19. The deviation from regression was non-significant for the varieties 1, 2, 3, 9, 17 and 19.

The analysis of variance of Perkins and Jinks model for the same data was as given in Table 4.9.4. Heterogeneity among regression and the remainder part of the variety x location interaction were significant.

One of the replications (Ist replication) in each location was used for the measure of the environment under Freeman and Perkins model, the remaining two replications (2nd and 3rd) were used for the analysis of variance and the same is as given in Table 4.9.5. From the table it could be inferred that heterogeneity among the regression and the remainder part of the variety x location interactions were significant in this model also.

The environmental indices I_j and Z_j were worked out as given in the Table 4.9.6. It was found from Table 4.9.6 that they were in close agreement to each other.

Stability parameters for the 20 varieties under the three models are provided in Table 4.9.7. S_{di}^2 values are the same for ER and PJ models.

The values of Wricke's ecovalence ratio W_i and Shukla's stability variance σ_i^2 and F values for testing the significance of σ_i^2 are given in Table 4.9.8. All the varieties had non significant values except the variety 10. The W_i's was also high for these varieties.

Correlation coefficients between the various pairs of stability parameters were worked out as given in Table 4.9.9.

A correlation coefficient of unity was obtained between W_i and σ_i^2. Hence σ_i^2 had the same correlation coefficient with other parameters as W_i had with them.

From the examination of Table 4.9.7, it could be reasonably concluded that varieties 1, 3, 8, 14, 16 and 19 are stable varieties. This fact has been almost corroborated from the Table 4.9.8 of W_i and σ_i^2.

4.10. <u>Length of capsule</u>

The error mean square of the three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (= 1.02) was found to be non-significant. Hence the pooled analysis has been done.

The pooled ANOVA was given in the Table 4.10.1.

The variety x locations interactions was not significant.

4.11. Height

The error mean square of the three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (= 4.549) was found to be non-significant. Hence the pooled analysis has been done.

The pooled ANOVA was given in the Table 4.11.1.

The variety x locations interactions was not significant.

4.12. Number of capsule/plant

The error mean square of three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (= 11.336) was found to be significant. Hence weighted analysis has been done. From the weighted analysis, it is found that interaction is absent.

4.13. Selection Index

The scores of selection index of twenty varieties of multilocation trials of the crop sesame conducted at three location with 3 replications at each locations were analysed as per the methods suggested.

The error mean square of the three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (= 205.310) was found to be significant. Hence the weighted analysis has been done.

The pooled ANOVA is given in Table 4.13.1.

The scores of selection index of the 20 varieties in the three locations averaged over the replications were worked out as shown in Table 4.13.2.

The analysis of variance under Eberhart and Russel model was worked out as given in Table 4.13.3. The variety x location (linear) component (which is same as the difference between regression) was significant. Pooled deviation from regression was non significant.

In the analysis of variance of Perkins and Jinks model for the same data was as given in Table 4.13.4. Heterogeneity among regression was significant and the remainder part of the variety x location interaction was not significant.

One of the replications (Ist replication) in each location was used for the measure of environment under Freeman and Perkins model, the remaining two replications (2nd and 3rd) were used for the analysis of variance and the same is given in Table 4.13.5. From the table it could be inferred that heterogeneity among the regression was significant and the remainder part of the variety x location interaction was not significant in this model also.

The environmental indices I_j and Z_j were worked out as given in the Table 4.13.6. It was found from Table 4.13.6 that they were in close agreement to each other.

Stability parameters for the twenty varieties under three models are provided in Table 4.13.7. S_{di}^2 values are the same for ER and PJ models.

The values of Wricke's ecovalence ratio W_i and Shukla's stability variance σ_i^2 and F values for testing the significance of σ_i^2 are given in Table 4.13.8. All the varieties had non significant σ_i^2 values except the variety 6. The W_i was also high for this variety.

Correlation coefficients between the various pairs of stability parameters were worked out as given in Table 4.13.9.

A correlation coefficient of unity was obtained between W_i and σ_i^2. Hence σ_i^2 had the same correlation coefficient with other parameters as W_i had with them.

From the examination of Table 4.13.7, it could be reasonably concluded that varieties 2, 3, 4, 5, 7 and 11 are stable varieties. This fact has been almost corroborated from the Table 4.13.8 of W_i and σ_i^2.

4.14. Principal components

In the present investigation the characteristic roots for the observations corresponding to each variety by taking into consideration of all the characters were studied. In all the case, the first characteristic root was found to have explained a reasonable percentage of the total variation (more than 78%). The principal components corresponding to the first characteristic root were taken for the study stability parameter analysis. The method of using first principal component for the study of genotype environment interaction is more reasonable in comparison to the phenotypic index method, as we are assuming equal weights to the economic characters while calculating the phenotypic index. Genotype environment interaction were studied for the varieties based on the first principal components through following five methods.

i. Eberhart and Russell's method
ii. Perkins and Jinks method
iii. Freeman and Perkins method
iv. Wricke's method
v. Shukla's method.

The scores of principal components of twenty varieties of multilocation trials of the crop sesame conducted at three locations with three replications at each locations were analysed as per the methods suggested above. The data were shown in the Table 4.14.2.

The error mean square of the three locations were tested for its homogeneity using Bartlett's test. The Bartlett's χ^2 (= 15.207) was found to be significant. Hence the weighted analysis has been done. The pooled ANOVA is given in Table 4.14.1.

The variety x locations interactions was found to be significant.

The analysis of variance under Eberhart and Russel model was worked out as given in Table 4.14.3.

The variety x location (linear) treatment (which is same as the difference between regression) was non significant. Pooled deviation from regression was significant at 5% level. This was because of the significance of deviation for the varieties 8, 9, 12, 13, 16 and 17. The deviation from regression was significant for none of the other varieties.

The analysis of variance of Perkins and Jinks model for the same data was as given in Table 4.14.4.

Heterogeneity among regression and the remainder part of the variety x location interaction were significant.

One of the replications (Ist replication) in each locations was used for the measure of environment under Freeman and Perkins model, the remaining two replications (2nd and 3rd) were used for the analysis of variance and the same is given in Table 4.14.5. From the table it could be inferred that heterogeneity among regressions and the remainder part of the variety x location interaction were significant in this model also.

The environmental indices I_j and Z_j were worked out as in the Table 4.14.6. It was found from Table 4.14.6 that they were in close agreement to each other.

Stability parameters for the twenty varieties under the three models are provided in Table 4.14.7. S_{di}^2 values are the same for ER and PJ models.

The value of Wricke's ecovalence ratio W_i and Shukla's stability variance σ_i^2 and F values for testing the significance of σ_i^2 values are given in Table 4.14.8.

All the varieties had non significant σ_i^2 values except the variety 14. The W_i's was also high for the variety.

Correlation coefficients between the various pairs of stability parameters were worked out as given in Table 4.14.9.

A correlation coefficient of unity was obtained between W_i and σ_i^2. Hence σ_i^2 had the same correlation coefficient with other parameters as W_i had with them.

From the examination of Table 4.14.7, it could be reasonably concluded that varieties 2, 3, 7, 12, 19 and 20 are stable varieties. This fact has been almost corroborated from the Table 4.14.8 of W_i and σ_i^2.

Table 4.1.1. Pooled Analysis of Variance

Source	df	SS	MS	F
Varieties	19	57196.49	3010.34	
Locations	2	88121.51	44060.73	
Var x Loc	38	84859.00	2233.13	2.41*
Average Error	114		926.55	

* Significant at 5% level.

Table 4.1.2. Treatment means of 20 varieties of sesame in 3 locations averaged over 3 replications.

Varieties	L1	L2	L3	Total	Mean
T1	220.067	254.100	315.833	790.000	263.333
T2	263.900	277.733	349.000	890.633	296.878
T3	244.367	296.833	379.500	920.700	306.900
T4	299.333	309.300	344.333	952.967	317.656
T5	283.067	313.200	318.333	914.600	304.867
T6	315.833	437.900	415.000	1168.733	389.578
T7	213.000	349.767	342.500	905.267	301.756
T8	283.833	363.767	278.767	926.367	308.789
T9	261.167	252.467	381.467	895.100	298.367
T10	277.633	249.467	330.667	857.767	285.922
T11	209.733	265.533	347.667	822.933	274.311
T12	203.700	376.833	299.333	879.867	293.289
T13	180.333	262.200	369.100	811.633	270.544
T14	153.133	384.167	356.500	893.800	297.933
T15	227.033	328.567	351.833	907.433	302.478
T16	204.933	376.133	306.500	887.567	295.856
T17	225.800	281.933	204.667	712.400	237.467
T18	274.400	218.267	296.167	788.833	262.944
T19	232.567	299.000	266.333	797.900	265.967
T20	269.467	391.233	350.333	1011.034	337.011
Total	4843.300	6288.401	6603.835		
Mean	242.165	314.420	330.192		295.592

Table 4.1.3. Analysis of variance under ER model

Source	df	SS	MS	F
Total	59	230177.998		
Varieties	19	57197.499	3010.395	
Environment + Variety x Env.	40	172980.499		
Environment	1	88122.615		
Environment x Variety (linear)	19	37686.140	1983.481	0.84 N.S
Pooled Dev.	20	47171.144	2358.557	2.54*
Variety - 1	1	1164.689		
Variety - 2	1	1839.576		
Variety - 3	1	2002.988		
Variety - 4	1	426.365		
Variety - 5	1	.797		
Variety - 6	1	966.409		
Variety - 7	1	544.124		
Variety - 8	1	4145.553*		
Variety - 9	1	6767.553*		
Variety - 10	1	3013.450		
Variety - 11	1	1932.705		
Variety - 12	1	5249.876*		
Variety - 13	1	3130.590		
Variety - 14	1	2408.779		
Variety - 15	1	.374		
Variety - 16	1	4522.108*		
Variety - 17	1	3165.161		
Variety - 18	1	3210.126		
Variety - 19	.1	878.687		
Variety - 20	1	1798.380		
Average Error	114	105626.257	926.546	

* Significant at 5% level

Table 4.1.4. Analysis of variance under FP Model

Source	df	SS	MS	F
Genotypes	19	140645.00331		
Environments	2	155207.01408		
Combined regression	1	154768.81504		
Residual (E)	1	438.18750		
Interaction	38	210243.98803		
Heterogeneity of regression	19	84079.03671	4425.2124	1.7252
Residual (GxE)	19	126164.94894	6040.2600	2.5888*
Pooled Error	57	146205.99746	2565.0177	

* Significant at 5% level.

Table 4.1.5. Analysis of variance under PJ model

Source	df	SS	MS	F
Genotypes	19	57197.499	3010.395	
Environment (Joint Regression)	2	88122.501	44061.250	
Genotype x Environment (Interaction - GxE)	38	84857.997	2233.105	
Heterogeneity	19	37686.264	1983.488	2.14*
Remainder	19	47171.735	2482.723	2.68*
Average Error	114		926.546	

* Significant at 5% level

Table 4.1.6. Environmental indices under ER model (I_j) and under FP model (Z_j).

Environments	I_j	Z_j
1	-53.427	-59.6866
2	18.8278	19.2583
3	34.5995	40.4283

Table 4.1.7. Stability parameters for 20 varieties under three models (viz. ER, PJ and FP models)

Variety	b_i	S_{di}^2	β_i	b'_i	S'^2_{di}
1	0.90	-1614.95	-0.10	0.44	-2422.45
2	0.73	-940.06	-0.27	1.00	-2302.97
3	1.29	-776.65	0.29	1.02	-1566.69
4	0.40	-2353.27	-0.60	0.26	-1971.17
5	0.41	-2778.84	-0.59	0.35	-2543.92
6	1.30	-1810.23	0.30	0.90	-2314.30
7	1.60	-2235.51	0.60	1.58	-2564.70
8	0.30	1365.77	-0.70	0.33	3435.99
9	0.91	3987.91	-0.09	0.57	6307.72
10	0.29	233.81	-0.70	0.19	-877.01
11	1.32	-846.93	0.32	1.20	-1221.00
12	1.49	2470.24	0.49	1.02	-1817.02
13	1.83	350.95	0.83	1.48	9970.34
14	2.58	-370.86	1.58	2.25	5338.44
15	1.41	-2779.26	0.41	1.48	-2559.53
16	1.53	1742.47	0.53	1.21	5078.32
17	0.07	385.52	-0.93	-0.12	870.67
18	-0.07	430.49	-0.93	-0.29	-285.67
19	0.55	-1900.95	-0.45	0.62	215.88
20	1.16	-981.26	0.16	1.17	3229.53

Table 4.1.8. Wricke (1966) Ecovalence ratio (W_i) and Shukla (1972) stability variance (σ_i^2) and F values to test σ_i^2 with (s-1), s(t-1)(r-1) d.f.

Variety	W_i	σ_i^2	F
1	1211.0933	548.7673	.2457
2	2167.1183	1079.8922	.4836
3	2361.8514	1188.0778	.5320
4	2034.0495	1005.9653	.4505
5	1557.0113	740.9440	.3318
6	1366.9328	635.3449	.2845
7	2137.5184	1063.4479	.4762
8	6293.4236	3372.2839	1.5101
9	6805.3121	3656.6669	1.6375
10	5196.6395	2762.9592	1.2373
11	2388.4348	1202.8460	.5386
12	6311.3012	3382.2162	1.5146
13	6181.7669	3310.2531	1.4823
14	13466.9137	7357.5582	3.2947
15	755.2239	295.5066	.1323
16	5755.8155	3073.6131	1.3764
17	6943.9878	3733.7088	1.6720
18	8244.6308	4456.2883	1.9955
19	1774.7707	861.9215	.3860
20	1904.7836	934.1509	.4183

Table 4.1.9. Correlation tables of the variables W_i, σ_i^2, S_{di}^2, b_i, b_i', $S_{di}'^2$.

VAR	W_i	σ_i^2	S_{di}^2	b_i	b_i'	$S_{di}'^2$
W_i	1.0000	1.0000	.6276	.2124	.1018	.6069
σ_i^2		1.0000	.6276	.2124	.1018	.6069
S_{di}^2			1.0000	.0087	-.1255	.5849
b_i				1.0000	.9536	.3310
b_i'					1.0000	.2662
$S_{di}'^2$						1.0000

Table 4.2.1. Pooled Analysis of variance

Source	df	SS	MS	F
Varieties	19	137.8672	7.2562	
Locations	2	55.1719	27.5859	
Var x Loc	38	116.4141	3.0635	70.9144*
Average Error	114		0.0432	

* Significant at 5% level.

Table 4.2.2. Treatment means of 20 varieties of sesame in 3 locations averaged over 3 replications

Varieties	L1	L2	L3	Total	Mean
T1	48.767	45.233	48.633	142.633	47.544
T2	49.367	45.567	48.700	143.633	47.878
T3	51.333	48.767	50.133	150.233	50.078
T4	47.467	47.367	46.433	141.267	47.089
T5	45.400	43.300	47.533	136.233	45.411
T6	49.800	45.333	49.500	144.633	48.211
T7	49.500	46.633	50.033	146.167	48.722
T8	50.833	44.200	50.467	145.500	48.500
T9	49.200	44.833	48.733	142.767	47.589
T10	45.833	45.100	48.500	139.433	46.478
T11	49.300	45.333	45.300	139.933	46.644
T12	43.867	42.733	45.800	132.400	44.133
T13	46.233	43.067	44.167	133.467	44.489
T14	44.500	47.167	46.167	137.833	45.944
T15	50.233	44.733	44.167	139.133	46.378
T16	46.667	44.700	46.700	138.067	46.022
T17	46.667	46.500	45.367	138.533	46.178
T18	48.900	47.333	42.800	139.033	46.344
T19	47.133	46.800	43.767	137.700	45.900
T20	44.567	44.167	43.700	132.433	44.144
Total	955.567	908.867	936.600		
Mean	47.778	46.443	46.830		

Table 4.2.3. Analysis of variance under ER model

Source	df	SS	MS	F
Total	59	309.469		
Varieties	19	137.867	7.256	
Env + Var x Env	40	171.602		
Environment	1	55.163		
Env x Variety (linear)	19	48.223	2.538	0.74 NS
Pooled Dev.	20	68.238	3.412	78.92*
Variety 1	1	1.117*		
2	1	0.508*		
3	1	0.016		
4	1	0.650		
5	1	5.875*		
6	1	1.511		
7	1	1.899*		
8	1	3.569*		
9	1	1.126*		
10	1	5.791*		
11	1	3.761*		
12	1	3.775*		
13	1	0.401*		
14	1	0.224*		
15	1	9.681*		
16	1	0.457*		
17	1	1.000*		
18	1	19.670*		
19	1	6.881*		
20	1	0.327*		
Average Error	114	4.9247	0.0432	

* Significant at 5% level.

Table 4.2.4. Analysis of variance under FP model

Source	df	SS	MS	F
Genotypes	19	137.867	7.256	
Environment (Joint regression)	2	55.172	27.586	
Genotype x Env. Interaction (GxE)	38	116.430	3.064	
Heterogeneity (Among Regression)	19	48.214	2.538	58.75*
Remainder	19	68.216	3.590	83.10*
Average Error	114		0.0432	

* Significant at 5% level.

Table 4.2.5. Analysis of variance under PJ model

Source	df	SS	MS	F
Genotypes	19	276.89061		
Environments	2	109.73438		
Combined regression	1	108.19394		
Residual (E)	1	1.54044		
Interaction	38	244.10939		
Heterogeneity of Regression	19	99.48837	5.2362	616.0235*
Residual (G x E)	19	144.62101	7.6116	895.486*
Pooled Error	57	0.48438	0.0085	

* Significant at 5% level.

Table 4.2.6. Environmental indices under ER model (I_j) and under FP model (Z_j)

Environments	I_j	Z_j
1	1.0944	1.037
2	-1.2406	-1.293
3	0.1461	0.257

Table 4.2.7. Stability parameters for 20 varieties under three models (viz. ER, PJ and FP models).

Variety	b_i	S^2_{di}	b_i'	S'^2_{di}
1	1.58	0.987	1.60	0.7286
2	1.67	0.378	1.71	0.2132
3	1.09	-0.113	1.09	0.0601
4	-0.010	0.520	-0.05	0.6559
5	1.06	5.746	1.16	5.0444
6	1.99	1.381	2.02	0.9004
7	1.32	1.769	1.38	1.3823
8	2.96	3.440	2.99	2.0934
9	1.94	0.996	1.98	0.5988
10	0.47	5.662	0.57	5.5283
11	1.57	3.631	1.31	11.4882
12	1.61	3.645	0.68	3.4493
13	1.31	0.271		0.6283
14	-1.11	0.094	1.26	11.3853
15	2.15	9.551	-1.01	
16	0.89	0.327	1.98	0.2795
17	0.01	0.871	-0.05	0.9958
18	0.38	19.541	0.18	19.9085
19	-0.03	6.751	-1.13	6.8530
20	0.13	0.197	0.08	0.3371

Table 4.2.8. Wricke (1966) Ecovalence ratio (W_i) and Shukla (1972) stability variance (σ_i^2) and F values to test σ_i^2 with (s-1), s(t-1)(r-1) d.f.

Variety	W_i	σ_i^2	F
1	2.0512	0.9693	0.3163
2	1.7588	0.8068	0.2633
3	0.0391	-0.1485	-0.0485
4	3.4616	1.7529	0.5720
5	5.8851	3.0993*	1.0113
6	4.2309	2.1802	0.7114
7	2.1772	1.0393	0.3391
8	14.2095	7.7239*	2.5203
9	3.5588	1.8069	0.5896
10	6.5624	3.4755*	1.1340
11	4.6638	2.4207	0.7899
12	4.1901	2.1516	0.7040
13	0.6748	0.2046	0.0668
14	12.5170	6.7837*	2.2135
15	13.3433	7.2427*	2.3633
16	0.4918	0.1030	0.0336
17	3.7253	1.8993	0.6197
18	20.7255	11.3439*	3.7015*
19	9.7971	5.2726*	1.7204
20	2.3953	1.1604	0.3786

* Significant at 5% level.

Table 4.2.9. Correlation tables of the variables W_i, σ_i^2, S_{di}^2, b_i, b_i', $S_{di}'^2$.

Variables	W_i	σ_i^2	S_{di}	b_i	b_i'	$S_{di}'^2$
W_i	1.0000	1.0000	0.8005	-0.0659	-0.1045	0.7213
σ_i^2		1.0000	0.8005	-0.0660	-0.1045	0.7213
S_{di}^2			1.0000	-0.0151	-0.0657	0.9350
b_i				1.0000	0.9947	0.0041
b_i'					1.0000	-0.0680
$S_{di}'^2$						1.0000

Table 4.3.1. Pooled Analysis of Variance

Source	df	SS	MS	F
Varieties	19	19.1537	1.0081	
Locations	2	11.4685	5.7343	
Var x Loc	38	27.5860	0.7259	2.21*
Average Error	113		0.3292	

*Significant at 5% level.

Table 4.3.2. Treatment means of 20 varieties of sesame in 3 locations averaged over 3 replications.

Varieties	L1	L2	L3	Total	Mean
1	2.757	2.807	3.050	8.613	2.871
2	3.140	3.960	3.600	10.700	3.567
3	4.687	4.370	5.700	14.757	4.919
4	3.900	4.450	4.600	12.950	4.317
5	3.657	3.547	3.933	11.137	3.712
6	3.643	7.090	3.300	14.033	4.678
7	3.140	4.217	6.567	13.923	4.641
8	2.850	4.157	5.183	12.190	4.063
9	3.530	3.637	3.653	10.820	3.607
10	4.050	4.243	4.900	13.193	4.398
11	3.647	3.963	3.067	10.677	3.559
12	3.520	6.313	2.800	12.633	4.211
13	2.267	3.253	2.610	8.130	2.710
14	3.063	5.343	3.317	11.723	3.908
15	3.387	5.133	4.050	12.570	4.190
16	3.543	5.147	5.500	14.190	4.730
17	3.830	4.753	2.657	11.240	3.747
18	3.337	4.433	4.117	11.887	3.962
19	3.623	4.728	4.567	12.913	4.304
20	3.430	4.727	4.677	12.823	4.274
Total	69.000	90.267	81.837		
Mean	3.450	4.513	4.092		

Table 4.3.3. Analysis of variance under ER model

Source	df	SS	MS	F
Total	59	58.208		
Varieties	19	19.154	1.008	
Env+Variety x Env	40	39.055		
Environment	1	11.469		
Env x Variety (linear)	19	7.593	0.400	0.4 NS
Pooled Dev.	20	19.993	1.000	3.04*
Variety 1	1	0.046		
2	1	0.001		
3	1	0.954		
4	1	0.089		
5	1	0.077		
6	1	3.861*		
7	1	5.068*		
8	1	1.568*		
9	1	0.002		
10	1	0.353		
11	1	0.391		
12	1	3.805*		
13	1	0.042		
14	1	0.829		
15	1	0.100		
16	1	0.643		
17	1	1.969*		
18	1	0.009		
19	1	0.051		
20	1	0.135		
Pooled Error	114	37.5326	0.3292	

* Significant at 5% level

Table 4.3.4. Analysis of variance under FP model

Source	df	SS	MS	F
Genotypes	19	19.154	1.008	
Environment (Joint Regression)	2	11.469	5.734	
Genotype x Env Interaction (G x E)	38	27.586	0.726	2.20
Heterogeneity (among regression)	19	7.593	0.400	1.22 NS
Remainder	19	19.993	1.052	3.20*
Average Error	114		0.3292	

*Significant at 5% level.

Table 4.3.5. Analysis of variance under PJ model

Source	df	SS	MS	F
Genotypes	19	59.2784		
Environments	2	19.4418		
Combined regression	1	17.7788		
Residual (E)	1	1.6630		
Interaction	38	58.8090		
Heterogeneity of regression	19	24.1697	1.2721	1.10 NS
Residual (G x E)	19	34.6392	1.8231	1.58 NS
Pooled Error	57	65.6824	1.1523	

Table 4.3.6. Environmental indices under ER model (I_j) and under FP model (Z_j)

Environments	I_j	Z_j
1	-0.5084	-0.614
2	0.4949	0.659
3	0.400	-0.045

Table 4.3.7. Stability parameters for 20 varieties under three models (viz. ER, PJ and FP models)

Variety	b_i	S_{di}^2	b_i'	$S_{di}'^2$
1	0.08	-0.942	-0.24	-0.100
2	0.77	-0.987	-0.78	-1.12
3	-0.14	-0.034	-0.61	-0.92
4	0.56	-0.899	-0.21	-0.39
5	-0.06	-0.9100	-0.34	-1.14
6	2.93	2.873	3.09	1.21
7	1.37	4.080	0.66	4.06
8	1.43	0.580	1.15	0.79
9	0.11	-0.985	0.032	-1.15
10	0.28	-0.634	0.58	-1.62
11	0.20	-0.597	0.15	-1.14
12	2.32	2.817	-0.26	1.48
13	0.90	-0.946	1.26	-1.15
14	2.00	-0.159	0.97	-1.09
15	1.59	-0.887	1.60	-1.00
16	1.63	-0.345	0.83	0.92
17	0.65	0.981	1.13	0.36
18	1.05	-0.979	1.13	-0.96
19	1.07	-0.936	0.98	-0.69
20	1.28	-0.852	1.01	-0.94

Table 4.3.8. Wricke (1966) Ecovalence ratio (W_i) and Shukla (1972) stability variance (σ_i^2) and F values to test σ_i^2 with (s-1), s(t-1)(r-1) d.f.

Variety	W_i	σ_i^2	F
1	0.5301	0.2542	0.3501
2	0.0320	-0.02225	-0.0311
3	1.7034	0.9060	1.2480
4	0.1978	0.0696	0.0958
5	0.7211	0.3303	0.4963
6	5.9992	3.2926*	4.5355*
7	5.1456	2.8183	3.8823*
8	1.6725	0.8888	1.2244
9	0.4587	0.2145	0.2985
10	0.6542	0.3231	0.4451
11	0.7587	0.3812	0.5251
12	4.8023	2.6276	3.6196*
13	0.0481	-0.0136	-0.0188
14	1.4026	0.7369	1.0178
15	0.3018	0.1273	0.1754
16	0.8736	0.4450	0.6130
17	2.0402	1.0931	1.5058
18	0.0104	-0.0346	-0.0476
19	0.541	-0.0595	-0.0141
20	0.1797	0.0597	0.0819

* Significant at 5% level.

Table 4.3.9. Correlation tables of the variables W_i, σ_i^2, S_{di}^2, b_i, b_i', $S_{di}'^2$.

Varieties	1	2	3	4	5	6
W_i	1.0000	1.0000	0.9697	0.5993	0.5691	0.8117
σ_i^2		1.0000	0.9697	0.5993	0.5691	0.8117
S_{di}^2			1.0000	0.5743	0.5192	0.9058
b_i				1.0000	0.8972	0.5117
b_i'					1.0000	0.4437
$S_{di}'^2$						1.0000

Table 4.4.1. Pooled Analysis of Variance

Source	df	SS	MS	F
Varieties	19	64738.6264	3407.2959	
Locations	2	112.3125	56.1562	
Var x Loc	38	280081.5010	528.4605	18.92*
Average Error	114		27.9306	

* Significant at 5% level.

Table 4.4.2. Treatment means of 20 varieties of sesame in 3 locations averaged over 3 replications

Varieties	L1	L2	L3	Total	Mean
T1	61.333	49.333	58.667	169.333	56.444
T2	53.333	50.667	52.000	156.000	52.000
T3	104.000	114.667	117.333	336.000	112.000
T4	70.667	66.667	61.333	198.667	62.222
T5	91.333	68.000	68.000	227.333	75.778
T6	60.000	60.000	49.333	169.333	56.444
T7	90.667	117.333	112.000	320.000	106.667
T8	109.333	98.667	98.667	306.667	102.222
T9	56.000	48.000	49.333	153.333	51.111
T10	74.667	72.000	112.000	258.667	86.222
T11	50.667	56.000	98.667	205.333	68.443
T12	54.667	52.000	53.333	160.000	53.333
T13	57.333	45.333	72.000	174.667	58.222
T14	50.667	48.000	60.667	159.333	53.111
T15	57.333	65.333	48.000	170.667	56.889
T16	109.333	104.000	48.000	261.333	87.111
T17	61.333	61.333	49.333	172.000	57.333
T18	54.667	54.667	54.667	104.000	54.667
T19	60.000	64.000	50.667	174.667	58.222
T20	76.000	69.333	64.000	209.333	69.778
Total	1403.333	1365.333	1378.000		
Mean	70.167	68.267	68.900		89.111

Table 4.4.3. Analysis of variance under ER model

Source	df			
Total	59	28310.87		
Varieties	19	21579.594	1135.765	
Env + Var x Env.	40	6731.250		
Environment	1	37.501		
Env x Var (linear)	19	1313.543	69.139	0.2569
Pooled Dev.	20	5380.221	269.011	9.6316*
Variety 1	1	18.272		
2	1	0.124		
3	1	24.924		
4	1	28.562		
5	1	38.843		
6	1	73.140		
7	1	8.201		
8	1	8.100		
9	1	1.133		
10	1	983.373*		
11	1	1269.863*		
12	1	0.125		
13	1	330.276*		
14	1	89.173		
15	1	138.293*		
16	1	2145.992*		
17	1	92.568		
18	1	0.001		
19	1	92.574		
20	1	36.683		
Average Error	114	9552.277	27.93	

* Significant at 5% level.

Table 4.4.4. Analysis of variance under FP model

Source	df	SS	MS	F
Genotypes	19	21579.594	1135.765	
Environment (joint Regression)	2	37.500	18.750	
Genotype x Env. (Interaction GxE)	38	6693.750	176.151	
Heterogeneity (among regression)	19	1313.544	69.134	2.475*
Remainder	19	5380.206	283.169	
Average Error	114		27.930	

* Significant at 5% level.

Table 4.4.5. Analysis of variance under PJ model

Source	df	SS	MS	F
Genotype	19	49361.93943		
Environments	2	68.81250		
Combined regression	1	0.21851		
Residual (E)	1	68.59399		
Interaction	38	17783.18786		
Heterogeneity of regression	19	5747.70402	302.51073	4.2242*
Residual (G x E)	19	12035.48312	633.44648	8.8453*
Pooled Error	57	4081.99977	71.61404	

* Significant at 5% level

Table 4.4.6. Environmental indices under ER model (I_j) and under FP model (Z_j).

Environments	I_j	Z_j
1	1.0556	1.400
2	-0.8444	-2.700
3	-0.2111	1.300

Table 4.4.7. Stability parameters for 20 varieties under three models (viz. ER, PJ and FP models)

Variety	b_i	S_{di}^2	b'_i	S'^2_{di}
1	5.7150	-65.520	1.96	-62.8098
2	1.3540	-83.668	0.02	-63.6177
3	-6.3144	-58.868	-1.06	54.7560
4	2.8580	-55.229	0.79	-22.3753
5	13.1588	-44.949	4.86	632.3408
6	1.2037	-10.652	-1.43	2.1422
7	-14.4348	-75.590	-6.07	421.3839
8	6.0163	-75.692	1.06	54.7505
9	4.3615	-82.659	2.01	-41.1903
10	-3.0065	899.581	4.95	1203.8563
11	-7.8187	1186.071	3.25	-69.7609
12	1.3540	-83.667	0.75	-69.7609
13	3.7601	246.485	4.90	-35.5621
14	0.0758	5.381	1.48	-71.6042
15	-2.5557	54.501	-3.91	-36.3879
16	9.3244	2062.200	-10.21	1852.5825
17	1.3541	8.776	-1.68	-19.8925
18	0.0007	-83.791	0.49	-71.6129
19	-0.7512	8.782	-2.18	-19.3890
20	4.3618	-47.109	-0.44	0.9474

Table 4.4.8. Wricke (1962) ecovalence value (W_i) and Shukla (1972) stability variance (σ_i^2) and F values to test σ_i^2 with (s-1), s(t-1)(r-1) d.f.

Variety	W_i	σ_i^2	F with 2, 114 d.f.
1	59.8867	23.4841	0.1333
2	0.3607	-9.5859	-0.0544
3	125.0719	59.6981	0.3389
4	35.0274	9.6734	0.0549
5	315.5755	165.5335	0.9397
6	73.2200	30.8915	0.1754
7	454.1387	242.5130	1.3767
8	55.2052	20.8833	0.1186
9	22.2866	2.5952	0.0147
10	1013.4276	553.2290	3.1406
11	1415.4423	776.5707	4.4085
12	0.3607	-9.5859	-0.0544
13	344.5386	181.6241	1.0311
14	90.7756	40.6446	0.2307
15	161.9608	80.1919	0.4552
16	2275.7086	1254.4963	7.1216
17	92.8051	41.7721	0.2371
18	1.8719	-8.7464	-0.0497
19	98.3162	44.8338	0.2545
20	57.8422	22.3483	0.1269

Table 4.4.9. Correlation tables of the variables W_i, σ_i^2, S_{di}^2, b_i, b_i', $S_{di}'^2$.

VAR	1	2	3	4	5	6
W_i	1.0000	1.0000	0.9814	-0.0094	-0.3363	0.9504
σ_i^2		1.0000	0.9814	-0.0094	-0.3363	0.9504
S_{di}^2			1.0000	0.0531	-0.3016	0.9113
b_i				1.0000	0.1795	0.0542
b_i'					1.0000	-0.2622
$S_{di}'^2$						1.0000

Table 4.5.1. Pooled Analysis of Variance

Source	df	SS	MS	F
Varieties	19	7.2644	0.3823	
Locations	2	0.5424	0.2712	
Var x Loc	38	1.6643	0.0438	1.37
Average Error	114		0.03186	

Table 4.5.2. Treatment means of 20 varieties of sesame in 3 locations averaged over 3 replications.

Varieties	L1	L2	L3	Total	Mean
1	2.533	2.633	2.400	7.467	2.489
2	2.567	2.600	3.433	8.600	2.867
3	3.467	3.767	3.567	10.800	3.600
4	2.600	2.733	3.200	8.533	2.844
5	3.333	2.900	3.100	9.333	3.111
6	2.567	2.567	2.733	7.867	2.622
7	2.869	3.700	3.133	9.700	3.233
8	3.867	3.500	3.867	11.233	3.744
9	2.533	2.433	3.133	8.100	2.700
10	2.667	2.833	2.833	8.333	2.778
11	2.533	2.633	2.700	7.867	2.622
12	2.567	2.700	2.700	7.867	2.656
13	2.567	2.567	2.567	7.700	2.567
14	2.567	2.500	2.700	7.767	2.589
15	2.700	2.900	2.700	8.300	2.767
16	3.267	3.633	3.400	10.300	3.433
17	2.667	2.600	3.033	8.300	2.767
18	2.533	2.633	2.767	7.933	2.644
19	2.567	2.567	3.100	8.233	2.744
20	2.700	3.033	3.200	8.933	2.978
Total	55.667	57.333	60.267		
Mean	2.783	2.867	3.013		2.887

Table 4.5.3. Analysis of variance under ER model

Source	df	SS	MS	F
Total	59	9.471		
Varieties	19	7.265	0.382	
Env + Var x Env	40	2.207		
Environment	1	0.543		
Env x Var (linear)	19	0.795	0.042	0.977
Pooled Dev.	20	0.869	0.043	1.344
Variety 1	1	0.002		
2	1	0.051		
3	1	0.045		
4	1	0.005		
5	1	0.079		
6	1	0.002		
7	1	0.353		
8	1	0.087		
9	1	0.065		
10	1	0.007		
11	1	0.001		
12	1	0.005		
13	1	0.000		
14	1	0.009		
15	1	0.026		
16	1	0.066		
17	1	0.026		
18	1	0.000		
19	1	0.029		
20	1	0.015		
Average Error	114	10.898	0.032	

Table 4.5.4. Analysis of variance under FP model

Source	df	SS	MS	F
Genotypes	19	7.265	0.382	
Environment (Joint Regression)	2	0.543	0.271	
Genotype x Env. Interaction GxE)	38	1.663	0.044	
Heterogeneity (Among regression)	19	0.795	0.042	1.31
Remainder	19	0.869	0.046	1.44
Average Error	114		.032	

Table 4.5.5. Analysis of variance under PJ model

Source	df	SS	MS	F
Genotypes	19	17.96759		
Environments	2	0.88580		
Combined Regression	1	0.84323		
Residual (E)	1	0.04257		
Interaction	38	2.86761		
Heterogeneity of Regression	19	1.12504	0.0592	2.40*
Residual (G x E)	19	1.74257	0.0917	3.72*
Pooled Error	57	1.40479	0.02465	

* Significant at 5% level.

Table 4.5.6. Environmental indices under ER model (I_j) and under FP model (Z_j).

Environments	I_j	Z_j
1	-0.1044	-0.112
2	-0.0211	-0.047
3	0.1256	0.158

Table 4.5.7. Stability parameters for 20 varieties under three models (viz. ER, PJ and FP models)

Variety	b_i	S_{di}^2	b_i'	$S_{di}'^2$
1	-.62	-.094	.199	-0.0246
2	3.99	-0.044	0.20	-0.0246
3	0.23	-0.050	1.24	.0007
4	2.67	-0.091	1.54	-.0233
5	-.7428	-0.016	0.11	-.02313
6	.7718	-0.093	-0.46	.2920
7	.5861	0.257	1.93	.0723
8	.2856	-0.008	1.20	-.0035
9	2.86	-0.030	.77	-.0127
10	0.64	-0.008	.76	-.0222
11	0.69	-0.095	.48	.0033
12	0.51	-0.091	.30	-.0243
13	0.0001	-0.096	-.398	-.0223
14	0.67	-0.087	.26	.0674
15	-.16	-0.070	-.27	.0468
16	0.33	-0.030	1.27	
17	1.75	-0.070	-0.08	-0.199
18	1.00	-0.095	.74	-0.0246
19	2.47	-0.071	2.53	-0.0177
20	2.06	-0.081	2.24	-0.0121

Table 4.5.8. Wricke (1966) Ecovalence ratio (W_i) and Shukla (1972) stability variance (σ_i^2) and F values to test σ_i^2 with (s-1), s(t-1)(r-1) d.f.

Variety	W_i	σ_i^2	F 1 with 2,114 df
1	.0725	.0378	.8635
2	.2931	.1609	3.6626*
3	.0613	.0316	.7225
4	.0806	.0423	.9668
5	.1615	.0873	1.9929
6	.0038	-.0003	-.0075
7	.3576	.1962	4.4800*
8	.1013	.0536	1.2290
9	.1589	.0858	1.9600
10	.0108	.0036	.0817
11	.0036	-.0005	-.0104
12	.0111	.0037	.0855
13	.0271	.0126	.2884
14	.0116	.0040	.0911
15	.0622	.0321	.7338
16	.0780	.0909	.9339
17	.0788	.0204	.4660
18	.0002	-.0023	-.0536
19	.0828	.0436	.9950
20	.0453	0.227	.5186

* Significant at 5% level

Table 4.5.9. Correlation tables of the variables W_i, σ_i^2, S_{di}^2, b_i, b_i', $S_{di}'^2$.

Variables	1	2	3	4	5	6
1	1.0000	1.0000	0.8078	0.2978	0.2596	0.6710
2		1.0000	0.8078	0.2978	0.2596	0.6710
3			1.0000	-0.0613	0.3628	0.8943
4				1.0000	0.3344	-0.3493
5					1.0000	0.2104
6						1.0000

Table 4.6.1. Pooled Analysis of Variance

Source	df	SS	MS	F
Varieties	19	54.1386	2.8494	
Locations	2	2.0274	1.0137	
Var x Loc	38	10.5444	0.2775	2.696
Average Error			0.1029	

Table 4.6.2. Treatment means of 20 varieties of sesame in 3 locations averaged over 3 replications

Varieties	L1	L2	L3	Total	Mean
T1	2.267	2.833	2.200	7.300	2.433
T2	1.100	1.267	.833	3.200	1.067
T3	4.167	2.933	3.767	10.867	3.622
T4	2.533	2.400	2.633	7.567	2.522
T5	2.400	2.933	1.567	6.900	2.300
T6	3.933	3.433	2.433	9.800	3.267
T7	1.500	2.033	2.433	5.967	1.989
T8	1.467	2.333	2.600	6.400	2.133
T9	3.167	3.000	2.033	8.200	2.733
T10	.067	.167	.167	.400	.133
T11	5.233	4.300	3.533	13.067	4.356
T12	3.167	3.500	2.300	8.967	2.989
T13	2.233	1.633	.833	4.700	1.567
T14	4.233	3.700	1.933	9.867	3.289
T15	2.967	2.767	2.800	8.533	2.844
T16	2.100	2.067	2.433	6.600	2.200
T17	3.467	2.967	2.333	8.767	2.922
T18	3.267	3.633	3.333	10.233	3.411
T19	.800	1.167	1.667	3.633	1.211
T20	2.367	2.800	2.533	7.700	2.567
Total	52.433	51.867	44.367		
Mean	2.622	2.593	2.218		2.478

Source	df	SS	MS	F
Total	59	66.710		
Varieties	19	54.139	2.849	
Env + Var x Env	40	12.572		
Environment	1	2.027		
Env x Variety (linear)	19	7.860	.414	3.08*
Pooled Dev.	20	2.685	.134	1.30*
Variety 1	1	.175		
2	1	.018		
3	1	.777*		
4	1	.011		
5	1	.083		
6	1	.083		
7	1	.117		
8	1	.331		
9	1	.004		
10	1	.005		
11	1	.354		
12	1	.083		
13	1	.135		
14	1	.074		
15	1	.019		
16	1	.002		
17	1	.095		
18	1	.070		
19	1	.050		
20	1	.095		
Average Error	114	11.731	.103	

* Significant at 5% level

Table 4.6.4. Analysis of variance under FP model

Source	df	SS	MS	F
Genotypes	19	54.139	2.849	
Environment (Joint Regression)	2	2.027	1.014	
Genotype x Env. (Int G x E)	38	10.544	.277	
Heterogeneity (among Regression)	19	7.860	.414	4.019*
Remainder	19	2.685	.141	1.369
Average Error	114		.103	

* Significant at 5% level

Table 4.6.5. Analysis of variance under PJ model

Source	df	SS	MS	F
Genotypes	19	116.03473		
Environments	2	6.22070		
Combined Regression	1	1.60357		
Residual (E)	1	4.61713		
Interaction	38	27.71942		
Heterogeneity of Regression	19	10.10463	.5318	1.630 NS
Residual (G x E)	19	17.61479	.9270	2.840*
Pooled Error	57	18.59985	.32631	

* Significant at 5% level

Table 4.6.6. Environmental indices under ER model (I_j) and under FP model (Z_j).

Environments	I_j	Z_j
1	.1439	-0.045
2	.1156	0.210
3	-.2594	-0.165

Table 4.6.7. Stability parameters for 20 varieties under three models (viz. ER, PJ and FP models)

Variety	b_i	S_{di}^2	b'_i	S'^2_{di}
1	.82	-.134	1.67	-.258
2	.87	-.290	1.41	-.266
3	-.38	.468	-2.73	.579
4	-.41	-.298	-2.96	-.305
5	2.74	-.121	3.29	.234
6	3.27	-.225	2.24	1.2409
7	-1.78	-.192	.80	-.0580
8	-1.91	.023	-.18	.3179
9	2.71	-.305	2.66	-.1981
10	-.14	-.304		-.3220
11	3.29	.040	.44	.341
12	2.60	-.226	3.16	.003
13	2.90	-.174	1.43	1.735
14	5.28	-.235	3.08	2.074
15	.20	-.290	-.73	-.263
16	-.89	-.307	-2.29	-.226
17	2.33	-.214	1.54	.605
18	.25	-.239	1.69	-.313
19	-1.80	-.559	-1.14	.041
20	.70	-.214	1.08	-.326

Table 4.6.8. Wricke (1966) Ecovalence ratio (W_i) and Shukla (1972) stability variance (σ_i^2) and F values to test σ_i^2 with (s-1), s(t-1)(r-1) d.f.

Variety	W_i	σ_i^2	F
1	0.1780	0.0835	0.3009
2	0.0200	-0.0043	-0.0154
3	0.9707	0.5339	1.8879
4	0.2115	0.1021	0.3678
5	0.4946	0.2594	0.9347
6	0.6053	0.3208	1.1562
7	0.9009	0.4851	1.7482
8	1.1914	0.6465	2.3297
9	0.3007	0.1516	0.5465
10	0.1368	0.0606	0.2184
11	0.8846	0.4760	1.7155
12	0.4320	0.1746	0.6292
13	0.5003	0.2625	0.9460
14	1.9297	1.0566	3.8079*
15	0.0841	0.0313	0.1128
16	0.3643	0.1869	0.6737
17	0.2740	0.1368	0.4931
18	0.1275	0.0554	0.1997
19	0.8449	0.4539	1.6359
20	0.1833	0.0864	0.3113

* Significant at 5% level.

Table 4.6.9. Correlation tables of the variables W_i, σ_i^2, S_{di}^2, b_i, b_i', $S_{di}'^2$

Variables	1	2	3	4	5	6
1	1.0000	1.0000	0.4092	0.2032	0.0401	0.6741
2		1.0000	0.4093	0.2032	0.0401	0.6741
3			1.0000	-0.0800	-0.2812	0.2183
4				1.0000	0.6920	0.6275
5					1.0000	0.2987
6						1.0000

Table 4.7.1. Pooled Analysis of variance

Source	df	SS	MS	F
Varieties	19	1.5236	0.0802	
Locations	2	5.9151	2.9575	
Var x Loc	38	0.8132	0.0214	2.78
Average Error	114		0.0077	

Table 4.7.2. Treatment means of 20 varieties of sesame in 3 locations averaged over 3 replications

Varieties	L1	L2	L3	Total	Mean
T1	2.500	2.557	2.040	7.097	2.366
T2	2.500	2.600	2.130	7.230	2.410
T3	2.560	2.963	2.440	7.963	2.654
T4	2.567	2.660	2.050	7.287	2.429
T5	2.600	2.623	2.153	7.377	2.459
T6	2.420	2.793	1.943	7.157	2.386
T7	2.573	2.617	2.010	7.200	2.400
T8	2.707	2.757	2.120	7.583	2.528
T9	2.414	2.733	1.953	7.103	2.368
T10	2.813	3.387	2.277	8.477	2.826
T11	2.857	3.390	2.440	8.687	2.896
T12	2.520	3.297	2.033	7.850	2.617
T13	2.340	2.717	2.130	7.187	2.396
T14	2.763	2.903	2.160	7.827	2.609
T15	2.873	3.240	2.273	8.387	2.796
T16	2.513	2.760	2.090	7.363	2.454
T17	2.760	2.947	2.080	7.787	2.596
T18	2.787	2.757	2.030	7.573	2.524
T19	2.970	2.880	2.137	7.987	2.662
T20	2.913	3.080	2.137	8.130	2.710
Total	52.963	57.660	42.627		
Mean	2.648	2.883	2.131		2.554

Table 4.7.3. Analysis of variance under ER model

Source	df	SS	MS	F
Total	59	8.252		
Varieties	19	1.523	0.080	
Env + Var x Env	40	6.728		
Environment	1	5.915		
Env x Var (linear)	19	0.396	0.021	1.00
Pooled Dev.	20	0.418	0.021	2.73
Variety 1	1	0.007		
2	1	0.001		
3	1	0.037		
4	1	0.007		
5	1	0.010		
6	1	0.007		
7	1	0.014		
8	1	0.014		
9	1	0.003		
10	1	0.033		
11	1	0.036		
12	1	0.093		
13	1	0.024		
14	1	0.005		
15	1	0.003		
16	1	0.001		
17	1	0.005		
18	1	0.042		
19	1	0.066		
20	1	0.010		
Average Error	114	2.645	0.0077	

Table 4.7.4. Analysis of variance under FP model

Source	df	SS	MS	F
Genotypes	19	1.523	0.080	
Environments (Joint Regression)	2	5.915	2.957	
Geno x Env. (Interaction GxE)	38	0.813	0.021	
Heterogeneity (Among Regression)	19	0.395	0.021	2.73*
Remainder	19	0.418	0.22	2.86*
Average Error	114		0.0077	

* Significant at 5% level

Table 4.7.5. Analysis of variance under PJ model

Source	df	SS	MS	F
Genotypes	19	2.74768		
Environments	2	13.85321		
Combined regression	1	12.68947		
Residual (E)	1	1.16374		
Interaction	38	2.03424		
Heterogeneity of Regression	19	0.72799	0.0038	0.09 N.S
Residual (G x E)	19	1.30625	0.0688	1.64 N.S
Pooled Error	57	2.39349	0.04199	

Table 4.7.6. Environmental indices under ER model (I_j) and under FP model (Z_j)

Environments	I_j	Z_j
1	0.0940	0.157
2	0.3288	0.223
3	-0.4228	-0.381

Table 4.7.7. Stability parameters for 20 varieties under three models (viz. ER, PJ and FP models)

Variety	b_i	S_{di}^2	b_i'	$S_{di}'^2$
1	0.72	-0.016	0.83	-0.0414
2	0.64	-0.022	0.91	-0.0391
3	0.62	0.013	0.86	-0.0640
4	0.85	-0.016	1.08	-0.0396
5	0.66	-0.013	7.19	-0.0344
6	1.10	-0.016	1.20	0.0183
7	0.85	-0.010	1.06	-0.0353
8	0.89	-0.009	1.35	-0.0404
9	1.01	-0.020	1.13	-0.0077
10	1.40	0.010	1.56	0.1826
11	1.19	0.012	1.24	0.0860
12	1.56	0.070	1.73	0.2658
13	0.72	0.001	0.80	0.0828
14	1.02	-0.018	1.55	-0.0406
15	1.27	-0.021	1.64	0.1034
16	0.88	-0.022	1.01	-0.0133
17	1.18	-0.019	1.38	-0.0188
18	1.05	0.019	1.19	-0.0420
19	1.09	0.043	1.38	-0.0235
20	1.30	-0.013	1.39	-0.0316

Table 4.7.8. Wricke (1966) Ecovalence ratio (W_i) and Shukla (1972) stability variance (σ_i^2) and F values to test σ_i^2 with (s-1), s(t-1)(r-1) d.f.

Variety	W_i	σ_i^2	F with 2,114 d.f
1	0.0301	0.0155	0.7249
2	0.0397	0.0209	0.9748
3	0.0793	0.0429	2.0039
4	0.0144	0.0068	0.3176
5	0.0430	0.0227	1.0606
6	0.0102	0.0045	0.2081
7	0.0200	0.0099	0.4624
8	0.0174	0.0083	0.3967
9	0.0174	0.0083	0.3967
10	0.0811	0.0439	2.0504
11	0.0462	0.0245	1.1427
12	0.1854	0.1018	4.7582
13	0.0472	0.0250	1.1688
14	0.0055	0.0019	0.0876
15	0.0235	0.0119	0.5547
16	0.0052	0.0017	0.0790
17	0.0141	0.0066	0.3093
18	0.0428	0.0226	1.0545
19	0.0686	0.0369	1.7249
20	0.0363	0.0190	0.8867

Table 4.7.9. Correlation tables of the variables W_i, σ_i^2, S_{di}^2, b_i, b_i', $S_{di}'^2$

Varieties	1	2	3	4	5	6
1	1.0000	1.0000	0.8853	0.4127	0.3043	0.7733
2		1.0000	0.8851	0.4127	0.3046	0.7735
3			1.0000	0.4468	0.3620	0.6134
4				1.0000	0.8962	0.5940
5					1.0000	0.4648
6						1.0000

Table 4.8.1. Pooled Analysis of Variance

Source	df	SS	MS	F
Varieties	19	367.7266	19.3540	
Locations	2	298.6875	149.3438	
Var x Loc	38	112.3203	2.9558	3.242
Average Error	114		0.9117	

Table 4.8.2. Treatment means of 20 varieties of sesame in 3 locations averaged over 3 replications.

Varieties	L1	L2	L3	Total	Mean
1	39.900	35.867	30.433	106.200	35.400
2	39.900	37.867	32.300	110.067	36.689
3	42.900	39.600	34.967	117.467	39.156
4	38.133	36.000	31.333	105.467	35.156
5	41.533	37.167	38.667	117.367	39.122
6	42.467	38.800	34.800	116.067	38.689
7	39.367	30.767	34.700	104.833	34.944
8	38.900	34.667	36.267	109.833	36.611
9	40.433	36.300	33.633	110.367	36.789
10	38.300	34.800	33.233	106.333	35.444
11	41.433	39.700	40.033	121.167	40.389
12	44.767	40.300	40.467	125.533	41.844
13	44.967	37.900	35.467	118.333	39.444
14	43.667	40.033	40.533	124.233	41.444
15	40.767	38.200	38.433	117.400	39.133
16	44.933	38.967	37.933	121.833	40.611
17	42.000	39.200	41.167	122.367	40.789
18	40.200	37.400	37.400	115.000	38.333
19	37.300	30.567	29.433	97.300	32.433
20	38.633	35.267	35.300	109.200	36.400
Total	820.500	739.367	716.500		
Mean	41.025	36.968	35.825		

Table 4.8.3. Analysis of variance under ER model

Source	df	SS	MS	F
Total	59	778.727		
Varieties	19	367.711	19.353	
Env + Var x Env.	40	411.016		
Environment	1	298.669		
Env x Vareity (linear)	19	54.651	2.876	0.997
Pooled Dev.	20	57.698	2.885	3.16
Variety 1	1	6.783		
2	1	9.160		
3	1.	5.039		
4	1	6.071		
5	1	2.740		
6	1	3.234		
7	1	14.845		
8	1	2.866		
9	1	0.829		
10	1	0.125		
11	1	0.248		
12	1	0.748		
13	1	0.074		
14	1	0.854		
15	1	0.337		
16	1	0.156		
17	1	2.790		
18	1	0.229		
19	1	0.216		
20	1	0.355		
Average Error	114	311.801	0.912	

Table 4.8.4. Analysis of variance under FP model

Source				
Genotypes	19	367.711	19.353	
Environment (Joint Regression)	2	298.672	149.336	
Geno x Env. (Interaction GxE)	38	112.344	2.956	
Heterogeneity (Among Regression)	19	54.648	2.876	3.15*
Remainder	19	57.696	3.037	3.33*
Average Error	114		0.912	

* Significant at 5% level

Table 4.8.5. Analysis of variance under PJ model

Source	df	SS	MS	F
Genotypes	19	725.39062		
Environments	2	573.98438		
Combined Regression	1	573.70073		
Residual (E)	1	2.28406		
Interaction	38	233.23435		
Heterogeneity of Regression	19	137.14879	7.21835	2.89*
Residual (G x E)	19	96.08557	5.0571	2.025*
Pooled Error	57	142.32813	2.49698	

* Significant at 5% level

Table 4.8.6. Environmental indices under ER model (I_j) and under FP model (Z_j)

Environments	I_j	Z_j
1	3.0856	3.227
2	-0.9711	-1.133
3	-2.1144	-2.093

Table 4.8.7. Stability parameters for 20 varieties under three models (viz. ER, PJ and FP models

Variety	b_i	S_{di}^2	b_i'	$S_{di}'^2$
1	1.6025	4.047	1.5785	6.3024
2	1.2052	6.425	1.1438	4.1813
3	1.3377	2.304	1.0068	-0.7673
4	1.1014	3.336	1.1533	4.7147
5	0.6898	0.005	0.6902	-0.6142
6	1.3238.	0.499	1.1958	-0.2224
7	1.2199	12.110	1.4468	1.6519
8	0.6481	0.131	0.4970	5.0422
9	1.2315	-1.906	1.0149	-1.4504
10	0.9449	-2.610	0.6566	-2.4443
11	0.3109	-2.487	0.3339	-2.1838
12	0.8992	-1.987	0.7285	-2.3685
13	1.8045	-2.661	1.6273	-1.0303
14	0.6798	-1.882	0.5297	-2.4930
15	0.4972	-2.398	0.4741	-1.1046
16	1.3790	-2.579	1.5347	-1.5957
17	0.3000	0.054	0.4480	0.0634
18	0.5785	-2.506	0.5871	-1.9146
19	1.5516	-2.519	1.8439	-2.4821
20	0.6908	-2.380	0.4000	-2.0479

Table 4.8.8. Wricke (1966) Ecovalence ratio (W_i) and Shukla (1972) stability variance (σ_i^2) and F values to test σ_i^2 with (s-1), s(t-1)(r-1) d.f.

Variety	W_i	σ_i^2	F(i) with 2,114 d.f.
1	12.2030	6.6152	2.2379
2	9.8086	5.2839	1.7875
3	6.7413	3.5809	1.2114
4	6.2244	3.2938	1.1143
5	4.1759	2.1557	0.7293
6	4.7990	2.5019	0.8464
7	15.5663	8.4837	2.8700
8	4.7149	2.4552	0.8306
9	1.6288	0.7407	0.2506
10	0.1690	-0.0704	-0.0238
11	7.3395	3.9133	1.3238
12	0.8981	0.3347	0.1132
13	9.7380	5.2458	1.7746
14	2.3836	1.1600	0.3924
15	4.1110	2.1197	0.7171
16	2.3001	1.1136	0.3767
17	10.1064	5.4504	1.8438
18	2.8821	1.4370	0.4861
19	4.7586	2.4794	0.8388
20	1.7817	0.8256	0.2793

Table 4.8.9. Correlation tables of the variables W_i, σ_i^2, S_{di}^2, b_i, b_i' , $S_{di}'^2$.

Variables	1	2	3	4	5	6
1	1.0000	1.0000	0.7678	0.2692	0.4062	0.5749
2		1.0000	0.7678	0.2692	0.4062	0.5749
3			1.0000	0.2594	0.3420	0.6581
4				1.0000	0.9299	0.2155
5					1.0000	0.2486
6						1.0000

Table 4.9.1. Pooled Analysis of variance

Source	df	SS	MS	F
Varieties	2	654.1250	327.0625	
Locations	19	2034.4998	107.0790	
Var x Loc	38	606.5001	15.9605	30.7821*
Average Error	114		0.5187	

* Significant at 5% level

Table 4.9.2. Treatment means of 20 varieties of sesame in 3 locations averaged over 3 replications.

Varieties	L1	L2	L3	Total	Mean
T1	81.333	78.333	76.000	235.667	78.556
T2	81.000	77.667	78.333	237.000	79.000
T3	89.333	86.333	86.000	261.667	87.222
T4	81.667	82.333	77.667	241.667	80.556
T5	81.333	74.667	77.667	233.667	77.889
T6	81.000	82.667	77.333	241.000	80.333
T7	88.667	82.333	85.333	256.333	85.444
T8	80.667	76.000	77.667	234.333	78.111
T9	81.333	80.667	78.000	240.000	80.000
T10	83.000	93.000	86.333	252.333	84.111
T11	90.667	83.333	84.667	258.667	86.222
T12	93.667	90.333	79.000	263.000	87.667
T13	82.000	79.667	75.333	237.000	79.000
T14	86.333	83.333	82.000	249.667	83.222
T15	88.667	85.667	84.000	256.000	85.333
T16	89.667	84.000	86.667	262.000	87.333
T17	90.333	84.000	81.667	256.000	85.333
T18	82.000	80.667	76.333	239.000	79.667
T19	82.335	80.000	77.667	240.000	80.000
T20	81.667	83.000	77.333	242.000	80.667
Total	1696.667	1635.333	1605.000		
Mean	84.833	81.767	80.250		

Table 4.9.3. Analysis of variance underER model

Source	df	SS	MS	F
Total	59	1098.438		
Varieties	19	678.187	35.694	
Env + Var x Env	40	420.250		
Environment	1	218.078		
Env x Var (Linear)	19	88.983	4.683	0.82 N.S
Pooled Dev.	20	113.148	5.657	10.91*
Variety 1	1	0.206		
2	1	1.540NS		
3	1	0.380NS		
4	1	7.176*		
5	1	11.401*		
6	1	10.899*		
7	1	10.811*		
8	1	4.540*		
9	1	1.571		
10	1	3.193*		
11	1	7.076*		
12	1	26.966*		
13	1	2.904*		
14	1	2.835*		
15	1	3.139		
16	1	2.549*		
17	1	0.182		
18	1	3.880*		
19	1	0.398		
20	1	11.503*		
Average Error	114	39.1357	0.5187	

* Significant at 5% level

Table 4.9.4. Analysis of variance under FP model

Source	df	SS	MS	F
Genotypes	19	678.187	35.694	
Environment (Joint Regression)	2	218.062	109.031	
Genotype x Environ (Interaction G x E)	38	202.187	5.321	
Heterogeneity (Among Regression)	19	88.998	4.684	9.03*
Remainder	19	113.189	5.957	11.48*
Average Error	114		0.5187	

* Significant at 5% level

Table 4.9.5. Analysis of variance under PJ model

Source	df	SS	MS	F
Genotypes	19	1379.50003		
Environments	2	432.93752		
Combined Regression	1	406.90803		
Residual (E)	1	26.02948		
Interaction	38	433.06250		
Heterogeneity of Regression	19	177.15246	9.3238	4.27*
Residual (GxE)	19	255.91003	13.469	6.16*
Pooled Error	57	124.50001	2.18421	

* Significant at 5% level

Table 4.9.6. Environmental indices under ER model (I_j) and under FP model (Z_j)

Environments	I_j	Z_j
1	2.5500	2.733
2	-0.5167	-0.967
3	-0.0333	-1.767

Table 4.9.7. Stability parameters for 20 varieties under three models (viz. ER, PJ and FP models)

Variety	b_i	S_{di}^2	b'_i	S'^2_{di}
1	1.14	-1.35	1.09	-0.83
2	0.66	-0.02	0.63	-1.66
3	0.76	-1.18	0.75	-2.10
4	0.71	5.62	0.53	8.59
5	1.00	9.84	1.36	8.64
6	0.60	9.34	0.33	14.75
7	0.92	9.26	0.88	1.57
8	0.79	2.98	0.72	0.03
9	0.65	0.01	0.50	0.08
10	-0.62	1.64	-0.66	2.37
11	1.47	5.52	1.51	0.32
12	2.89	25.41	2.47	44.44
13	1.35	1.35	1.16	4.37
14	1.05	1.28	1.54	
15	1.12	1.58	1.30	-1.40
16	0.75	0.99	0.60	-2.07
17	1.92	-1.37	1.05	-0.17
18	1.12	2.32	0.86	4.72
19	0.98	-1.16	0.52	-0.49
20	0.74	9.95		16.84

Table 4.9.8. Wricke (1966) Ecovalence ratio (W_i) and Shukla (1972) stability variance (σ_i^2) and F values to test σ_i^2 with (s-1), s(t-1)(r-1) d.f.

Variety	W_i	σ_i^2	F
1	0.4113	-0.0670	-0.0126
2	2.8372	1.2807	0.2408
3	0.9891	0.2540	0.0477
4	8.6669	4.1861*	0.07869
5	11.4002	6.0379*	1.1350
6	12.6039	6.7066	1.2607
7	10.8779	5.7478	1.0805
8	5.0668	2.5194	0.4736
9	2.8817	1.3054	0.2454
10.	31.8669	17.4083	3.2725
11	9.4446	4.9515	0.9308
12	66.0372	36.3918	6.8411
13	4.2705	2.0770	0.3904
14	2.8557	1.2910	0.2427
15	3.3039	1.5399	0.2895
16	3.2372	1.5029	0.2825
17	9.3372	4.8918	0.9196
18	4.0372	1.9474	0.3661
19	0.4039	-0.0711	-0.0134
20	12.2150	6.4906*	1.2201

* Significant at 5% level

Table 4.9.9. Correlation tables of the variables W_i, σ_i^2, S_{di}^2, b_i, b_i', $S_{di}'^2$.

Variables	1	2	3	4	5	6
W_i	1.0000	1.0000	0.8179	0.3951	0.2785	0.8546
σ_i^2		1.0000	0.8179	0.3951	0.2785	0.8546
S_{di}^2			1.0000	0.4845	0.4022	0.9230
b_i				1.0000	0.9464	0.5192
b_i'					1.0000	0.5137
$S_{di}'^2$						1.0000

Table 4.10.1. Pooled Aanalysis of variance

Source	df	SS	MS	F
Locations	2	0.7163	0.3582	
Varieties	19	13.4005	0.7053	
Interaction	38	1.6393	0.0431	1.1216
Pooled error mean square of interaction pooled error	152			
Pooled error	114			
Total	179	0.0385		

Table 4.11.1. Pooled analysis of variance

Source	df			
Varieties	19	10628.2496	559.3816	
Locations	2	79330.7495	39665.3747	
Interaction	38	6101.7503	160.5724	1.4937
Pooled error mean square of interactions pooled error	152			
Pooled error	114			
Total	179		107.500	

Table 4.13.1. Pooled Analysis of variance

Source	df	MS	F
Varieties	19	8189870.8343	
Locations	2	3142588853.8360	
Var x Loc	38	7238507.7476	2.43*
Average Error	114	2969836.599	

* Significant at 5% level

Table 4.13.2. Treatment means of 20 varieties of sesame in 3 locations averaged over 3 replications.

Varieties	L1	L2	L3	Total	Mean
I1	5755.317	21210.539	2845.630	29811.487	9937.163
I2	6524.689	23076.851	2805.259	32406.802	10802.267
I3	6969.053	25889.849	4218.717	37077.624	12359.206
I4	7526.583	25621.476	2866.437	36014.494	12004.832
I5	7539.487	26015.117	3078.403	36633.009	12211.004
I6	7672.564	35243.523	3548.687	46464.776	15488.258
I7	6122.536	30048.141	3647.215	39817.893	13272.631
I8	7843.451	30502.543	3065.168	41411.161	13803.720
I9	6505.559	21005.783	3147.676	30659.017	10219.674
I10	7192.800	21494.154	3439.613	32126.567	10708.855
I11	5382.196	22200.772	3786.516	31372.485	10457.495
I12	5356.716	30565.891	2397.274	38319.881	12773.293
I13	4879.121	21746.175	3387.070	30012.369	10004.123
I14	4238.147	30996.079	3105.901	38340.129	12780.044
I15	5863.988	27209.312	2915.904	35989.117	11996.372
I16	6214.356	31619.820	2395.417	40229.606	13409.868
I17	5900.465	23691.959	1568.257	31160.678	10386.894
I18	6737.633	18657.236	2437.216	27832.086	9277.361
I19	6014.778	24982.173	1916.273	32913.222	10971.074
I20	7028.679	31923.577	3040.487	41922.745	13997.579
Total	127268.052	523701.095	59616.127		
Mean	6363.403	26185.054	2980.806		

Table 4.13.3. Analysis of variance under ER model

Source	df	SS	MS	F
Total	59	6715853691.1010		
Varieties	19	155611648.5595	8190086.3647	
Env + Var x Env	40	6560242652.8930		
Environment	1	6285182476.0437		
Env x Var (linear)	19	259617280.9600	13664066.7915	4.6*
Pooled Dev	20	15442240.2381	772112.0357	.260NS
Variety 1	1	30751.9984		
2	1	333520.0071		
3	1	95167.9992		
4	1	1029792.0703		
5	1	712928.0090		
6	1	140160.0027		
7	1	1076671.9579		
8	1	345856.0228		
9	1	325099.0002		
10	1	717855.9780		
11	1	679888.0100		
12	1	750944.0422		
13	1	800815.9637		
14	1	4914015.7699		
15	1	200735.9981		
16	1	110783.9941		
17	1	699936.0561		
18	1	2140336.0366		
19	1	309279.9901		
20	1	27711.9994		
Average Error	114	338561296.4630	2969835.933	

* Significant at 5% level

Table 4.13.4. Analysis of variance under FP model

Source	df	SS	MS	F
Genotypes	19	155611648.559	8190086.364	
Environment (Joint Regress)	2	6285182476.043	3142591238.021	
Genotype x Env. Interaction (GxE)	38	275060248.374	7238427.639	
Heterogeneity (among regression)	19	259617805.480	13664095.401	4.6*
Remainder	19	15442430.973	812759.590	.27
Pooled Error	114		8909506.797	

* Significant at 5% level

Table 4.13.5. Analysis of variance under PJ model

Source	df	SS	MS	F
Genotypes	19	354635787.01019		
Environments	2	12619143558.50219		
Combined Regress	1	12616370916.36657		
Residual (E)	1	1772543.90716		
Interaction	38	652068853.37829		
Heterogeneity of regression	19	619597816.46728		11.24*
Residual (GxE)	19	32471039.29519		0.58
Pooled Error	57	495960044.86083	8701053.61958	

* Significant at 5% level

Table 4.13.6. Environmental indices under ER model (I_j) and under FP model (Z_j)

Environments	I_j	Z_j
1	-5479.6805	-5683.7482
2	14341.9671	13584.9214
3	-8862.2770	-8593.1532

Table 4.13.7. Stability parameters for 20 varieties under three models (viz. ER, PJ and FP models)

Variety	b_i	S_{di}^2	β_i	b_i'	$S_{di}'^2$
1	.79	-8878755.57	-.21	.85	-8388030.05
2	.86	-8575986.88	-.14	1.01	-8645886.42
3	.94	-8814338.68	-.06	.95	-8690717.70
4	.95	-7879714.97	-.04	.98	-6683165.55
5	.97	-8196578.98	-.03	.96	-7369502.07
6	1.37	-8769346.24	.37	1.31	-8647677.42
7	1.16	-7832834-72	.16	1.15	-7508029.94
8	1.17	-8563651.08	.17	1.20	-8326878.55
9	.76	-8584419.25	-.24	.70	-7516989.71
10	.76	-8191651.34	.24	.82	-7935182.09
11	.81	-8229619.03	-.18	.84	-8261358.26
12	1.23	-8158563.61	.23	.98	-8637598.04
13	.81	-8108690.26	-.19	.63	-8870133.59
14	1.25	-3995491.03	.25	1.31	-4398429.87
15	1.06	-8708770.75	.06	1.13	-8439325.33
16	1.27	-8798723.22	.27	1.34	-8698366.17
17	.93	-8209570.88	-.07	.92	-7460318.09
18	.67	-6769171.24	-.33	.58	-5649909.97
19	.98	-8600227.36	-.02	1.12	-8444286.35
20	1.25	-8881794.93	.25	1.33	-8528382.30

Table 4.13.8. Wrick (1966) Ecovalence ratio (W_i) and Shukla (1972) stability variance (σ_i^2) and F values to test σ_i^2 with (s-1) s(t-1)(r-1) d.f.

Variety	W_i	σ_i^2	F(2,114) d.f
1	14236163.1993	7506837.3680	1.0371
2	6467820.6443	3191091.0606	0.4408
3	1187235.3553	257432.7707	.0356
4	1605201.7211	489636.2304	.0676
5	1015490.2935	162018.8140	.0224
6	44230451.5838	24170329.5707	3.3391*
7	9294809.3414	4761641.6255	.6578
8	9306138.0386	4767934.3223	.6587
9	18966448.7838	10134774.4464	1.4001
10	19043473.2437	10177564.6209	1.4060
11	11731654.4055	6115443.2296	.8448
12	17949832.9162	9569986.3433	1.3221
13	11926383.9721	6223626.1367	.8598
14	25044689.1784	13511574.2683	1.8666
15	1232339.5013	282490.6349	.0390
16	22537236.2136	12118543.3864	1.6742
17	2063618.1831	744312.1910	.1028
18	37354702.9495	20350470.5429	2.8114
19	420471.2867	-168547.3108	-.0233
20	19451306.3430	10404138.5650	1.4373

* Significant at 5% level

Table 4.13.9. Correlation tables of the variables W_i, σ_i^2, S_{di}^2, b_i, b_i', $S_{di}'^2$.

Variables	1	2	3	4	5	6
W_i	1.0000	1.0000	0.2791	0.2210	0.0662	0.2377
σ_i^2		1.0000	0.2791	0.2210	0.0662	0.2377
S_{di}^2			1.0000	0.8758	0.0347	0.8991
b_i				1.0000	0.9014	-0.0962
b_i'					1.0000	-0.0925
$S_{di}'^2$						1.0000

Table 4.14.1. Pooled Analysis of variance

Source	df	SS	MS	F
Varieties	2	117892.0030	58946.0039	
Locations	19	57508.9931	3026.7894	
Interaction (Variety+location)	38	86805.0003	2284.3420	2.44*
Average Error	114		936.1996	

* Significant at 5% level

Table 4.14.2. Treatment means of 20 varieties of sesame in 3 locations averaged over 3 replications.

Varieties	L1	L2	L3	Total	Mean
T1	219.437	269.505	322.918	811.59	270.620
T2	262.514	293.946	356.723	913.183	304.394
T3	244.982	315.586	390.704	951.272	317.091
T4	298.186	324.082	352.469	974.736	324.912
T5	282.093	328.928	325.275	936.297	312.099
T6	314.607	455.132	421.546	1191.285	397.095
T7	213.476	370.902	353.957	938.335	312.778
T8	285.214	381.329	289.385	956.028	318.676
T9	259.951	267.143	387.953	915.048	305.016
T10	276.811	267.842	342.778	887.432	295.811
T11	207.813	281.718	357.716	847.247	282.416
T12	201.900	394.579	307.189	903.667	301.222
T13	179.025	278.018	377.974	835.017	278.339
T14	150.181	401.193	364.027	915.401	305.134
T15	224.996	346.018	358.724	929.737	309.912
T16	206.452	396.274	314.182	916.908	305.636
T17	224.107	300.088	211.558	735.753	245.251
T18	272.721	234.052	303.231	810.004	270.001
T19	231.314	316.722	274.204	822.240	274.080
T20	268.569	407.885	358.553	1035.007	342.002
Total	4824.349	6630.941	6771.165		
Mean	241.217	331.547	338.558		

Table 4.14.3. Analysis of variance under ER model

Source	df	SS	MS	F
Total	59	262207.007	3026.842	
Varieties	19	57509.999		
Environment + Variety x Environ	140	204696.989		
Environment	1	117892.396		
Environ x Variety (linear)	19	40090.432	2110.023	0.90 NS
Pooled Dev	20	46714.258	2335.713	7.48*
Variety 1	1	1131.781		
2	1	1679.816NS		
3	1	2237.603NS		
4	1	320.972		
5	1	24.487		
6	1	913.390		
7	1	392.410 NS		
8	1	4550.074*		
9	1	6672.142*		
10	1	2639.355		
11	1	2277.788		
12	1	4833.036*		
13	1	3928.417*		
14	1	1480.680*		
15	1	5.036		
16	1	4325.671*		
17	1	4114.140*		
18	1	2403.910		
19	1	1114.456NS		
20	1	1669.086NS		
Average Error	114	106726.777	936.200	

* Significant at 5% level

Table 4.14.4. Analysis of variance under FP model

Source	df	SS	MS	F
Genotypes	19	57509.999	3026.842	
Environment (Joint regression)	2	117893.004	58946.495	
Genotype x Environment (Interaction GxE)	38	86803.998	2284.316	
Heterogeneity (Among Regression)	19	40089.826	2109.991	2.25*
Remainder	19	46714.167	2458.641	2.63*
Pooled Error	114		936.200	

* Significant at 5% level

Table 4.14.5. Analysis of variance under PJ model

Source	df	SS	MS	F
Genotypes	19	142243.00384		
Environments	2	222284.00707		
Combined Regression	1	222128.27205		
Residual (E)	1	155.71874		
Interaction	38	215141.01028		
Heterogeneity of regression	19	90388.85116		34.66*
Residual (G x E)	19	124752.15196		47.83*
Pooled Error	57	148658.01334	2608.03532	

* Significant at 5% level

Table 4.14.6. Environmental indices under ER model (I_j) and under FP model (Z_j)

Environment	I_j	Z_j
1	-62.5568	-66.125
2	27.7728	28.376
3	34.7840	37.748

Table 4.14.7. Stability parameters for 20 varieties under three models (viz. ER, PJ and FP models)

Variety	b_i	S_{di}^2	b_i'	$S_{di}'^2$
1	.8465	-1676.8178	.5185	-2504.0850
2	.7040	-1128.7825	1.0285	-2228.4750
3	1.1926	-570.9966	1.0626	-1511.7256
4	.4423	-2487.7275	.3448	-2119.5871
5	.4755	-2784.1122	.4437	-2606.6274
6	1.2931	-1895.2095	.9836	-2402.5077
7	1.5707	-2416.1889	1.6333	-2569.2400
8	.4781	1741.4752	.5665	3671.5000
9	.7892	3863.5433	.5115	6034.2936
10	.3470	-169.2439	.3020	-1114.8203
11	1.2328	-530.8110	1.2027	-746.3057
12	1.5291	2024.4369	1.1191	-2007.4422
13	1.6404	1119.8179	1.3231	11860.5208
14	2.4446	-1327.9194	2.3391	2830.4608
15	1.3593	-2803.5629	1.5056	-2590.8741
16	1.5301	1571.0718	1.3874	4855.3171
17	.2839	1305.5405	.1266	1854.8257
18	-.0022	-404.6889	-.1904	-1103.9452
19	.6555	-1694.1432	1.3346	2457.2265
20	1.1874	-1139.5133		

Table 4.14.8. Wricke (1966) Ecovalence ratio (W_i) and Shukla (1972) stability variance (σ_i^2) and F values to test σ_i^2 with (s-1), s(t-1)(r-1) d.f.

Variety	W_i	σ_i^2	F (2,114) d.f.
1	1270.6190	578.9913	.2535
2	2196.2108	1093.2091	.4786
3	2456.1696	1237.6304	.5418
4	2154.1938	1069.8662	.4683
5	1646.2351	787.6669	.3448
6	1419.9202	661.9364	.2898
7	2312.2534	1157.6772	.5068
8	6155.9629	3293.0715	1.4416
9	6934.0338	3725.3322	1.6308
10	5152.7371	2735.7232	1.1976
11	2597.2235	1315.9940	.5761
12	6483.4313	3474.9979	1.5212
13	6345.9129	3398.5991	1.4878
14	13781.3520	7529.3989	3.2961
15	766.1609	298.7368	.1308
16	5981.9602	3196.4030	1.3993
17	7136.5494	3837.8413	1.6801
18	8324.0375	4497.5566	1.9689
19	1814.1134	880.9327	.3856
20	1876.1173	915.3792	.4007

Table 4.14.9. Correlation tables of the variables W_i, σ_i^2, S_{di}^2, b_i, b_i', $S_{di}'^2$.

Variables	1	2	3	4	5	6
W_i	1.0000	1.0000	0.5343	0.2405	0.1304	0.5007
σ_i^2		1.0000	0.5343	0.2405	0.1304	0.5007
S_{di}^2			1.0000	-0.0394	-0.1758	0.6395
b_i				1.0000	0.9476	0.2515
b_i'					1.0000	0.1758
$S_{di}'^2$						1.0000

Discussion

DISCUSSION

The data on the yield and other eleven characters of twenty varieties of sesame obtained from three different locations - Kayamkulam, Pattambi and Vellayani for the year 1982-83 by the Plant Breeding Department of K.A.U. were analysed for its stability by the various techniques, and presented in the previous chapter. From the results it was found that, out of the twelve characters studied only nine characters show GE interaction. The characters - length of capsule, height, number of capsule/plant were found to have no GE interaction, hence they were excluded from the present study. Remaining nine characters seed yield/plot, number of branches, circumference of capsule, number of seeds/capsule, number of days for flowering, 1000 seed weight, oil content percentage, seed yield/plant, number of days to maturity - which were showing significantGE interaction, were taken into consideration for the present investigation.

While investigating the characters - number of seeds/capsule, number of branches, circumference of capusle it was found that the b_i and b_i' values from Eberhart and Russell and Freeman and Perkins model were varying to a very large extent one σ_b range $(1 \pm \sigma_b)$ of these parameters taking very exorbitant values. Hence a study based on these parameters for the stability of the twenty varieties may not be much meaningful. Moreover from the table of inter-correlations of twelve characters (give in Appendix) it was seen that the character height was showing a significant positive correlation (0.6524) with yield. Similarly the character number of seeds/capsule is also having a significant negative correlation (-0.4479) with oil content percentage. Again the character, length of capsule is having a significant negative correlation with seed yield/plant (-0.4564). As the characters, yield and seed yield/plant have been already taken into consideration, there is no further need to include the characters height, length of capsule, number of seeds/capsule which were showing irregular values for the stability parameters in the case of ER and FP models and also showing significant correlation with other characters which were included in the study. Hence the present investigations were mainly based on six characters viz. seed yield/plot, number of days for flowering, 1000 seed weight, oil content percentage, seed yield/plant, number of days to maturity and the study through selection index method and principal component method. The analysis of these six characters and two different methods were presented in the previous chapter.

In order to find the stable varieties based on the GE interaction studies, varieties were ranked on the basis of each character, selection index method and principal component analysis method based on five different types of analysis - Eberhart and Russell's method, Perkins and Jinks method, Freeman and Perkins method, Wricke's eco-valence method and Shukla's stability variance method. The stability parameters of the twenty varieties were calculated under these five cases and were already given in the results. Considering all these stability parameters analysis, the stable varieties were located in two ways - (i) The varieties which are satisfying b_i and b_i' nearer to one, S_{di}^2 and S_{di}^2 nearly zero or negative (non significant) and similarly W_i minimum and σ_i^2 non significant taken as stable varieties. (ii) Based on the graph of the parameters b_i and mean value of the character (the graph of b_i' and mean value of the character are almost identical to b_i and mean value of the character, hence only the first type of graph were drawn and presented in figures (2, 3 and 4) the varieties which were lying in the range $b \pm \sigma_{bi}$ and $\bar{x} \pm \sigma_{\bar{x}}$ were considered, it was found that the varieties, 2, 3, 7, 12 and 19 were stable. Again through the 2nd method (graphical method) 2, 3, 4, 5, 7, 11, 12, 16 and 19 were found to be stable. Hence one can reasonably conclude that the varieties 2, 3, 7, 12 and 19 were stable. The stability parametric values for these five varieties for the six characters, selection index and principal component analysis are as given in Table 4.1. Similarly the mean values of the characters of these five varieties based on the six characters selection index and principal component analysis are given in Table 4.2.

From the table of stability parameters under the plot yield, it was found that the varieties 2, 3 and 19 can be considered as more stable. It could be seen that S_{di}^2 in all these varieties were non-significant.

From the table of stability parameters under the seed yield/plant, it was found that the varieties 2, 7 and 19 were found to be more stable varieties. But only the variety 7 was showing a non-significant S_{di}^2 values.

From the table of stability parameter under the character oil content percentage, it could be observed that varieties 3, 7 and 12 were found to be stable. Out of these, the variety 3 was having non-significant S_{di}^2 values.

From the table of stability parameters under the character 1000 seed weight, the varieties 2, 3, 7 and 19 were found to be stable. Out of these, varieties 2 and 7 were having non-significant S_{di}^2 values.

From the table of stability parameters under the character number of days for flowering, varieties 2, 3, 7 and 12 were found to be stable varieties. Out of these only the variety 12 was showing non-significant S_{di}^2 value.

From the table of stability parameters under the character, number of days to maturity it was found that the varieties 3, 7 and 19 were stable. But the varieties 3 and 19 were showing non-significant S_{di}^2 values.

From the table of stability parameters under selection index, it was found that the varieties 2, 3 and 19 were more stable. All these varieties were showing non-significant S_{di}^2 values.

From the dtable of stability parameters under principal component, it was found that the varieties 2, 3 and 19 were more stable. All these were showing non-significant S_{di}^2 values.

Considering all these characters together it could be concluded that the varieties 2, 3 and 19 were more stable. But S_{di}^2 were non-significant for the variety 2 in the case of following characters - plot yield, 1000 seed weight, selection index and principal components. The variety 3 was showing non significant S_{di}^2 in the following characters - plot yield, oil content percentage, number of days to maturity, selection index and principal components. The variety 19 was showing non-significant S_{di}^2 only in the following cases - plot yield, number of days to maturity, selection index and principal component. Other varieties - 7 and 12 were having significant S_{di}^2 in the majority of the characters including plot yield, selection index and principal component.

In order to have further analysis about the acceptability of these varieties 2, 3, and 19 (k.2, IS 284 and Vayalathur), the mean values of the six characters and selection index score and principal component score of the top ranking five varieties 2, 3, 7, 12 and 19 were examined. The mean values of the character of these varieties were as given in Table 4.2. From this table, it could be observed that the variety 3 (IS 284) was ranking 1st in the case of plot yield, seed yield per plant, number of days to maturity, oil content percentage and principal component analysis. Among the characters 1000 seed weight and number of days for flowering the variety 3 was ranking 2nd and in the case of selection index, the rank of the variety 3 (IS 284) was third. Similarly the variety 2 (k.2) ranked third in almost all the characters except in the case of seed yield per plant, 1000 seed weight and selection index score. Whereas the variety 19 (Vayalathur) ranked first in 1000 seed weight, second in number of days to maturity, third in seed yield per plot, fourth and fifth in the selection index score and principal components respectively. Hence it could be reasonably concluded that the variety 3 (IS 284) is the most stable variety from among the twenty varieties under consideration, ie. the variety IS 284 can be considered as the stable variety from among the twenty varieties under trial and can be recommended for further investigation.

4.1. Stability parameters

Seed yield per plot

Treatment No.	Variety	b_i	S^2_{di}	b_i	S^2_{di}	W_i	
2	K.2	0.73	-940.06	1.08	-2302.97	2167.1183	Non significant
3	IS 284	1.29	-776.65	1.02	-1566.69	2361.8514	,,
7	42-1	1.60	-2235.51	1.58	-2564.70	2137.5184	,,
12	Si.902	1.49	2470.24	1.02	-1817.02	6311.3012	,,
19	Vayalathur	0.55	-1900.25	0.62	215.88	1774.7707	,,
20	Vinayak	1.16	-981.26	1.17	3229.53	1904.7836	,,

Seed yield per plant

2	K.2	0.77	-0.987	-0.78	-1.12	0.0320	Non significant
3	IS 284	-0.14	-0.034	-0.61	-0.92	1.7034	,,
7	42-1	1.37	4.080	0.66	4.06	5.1456	Significant
12	Si.902	2.32	2.817	-1.92	1.48	4.8023	,,
19	Vayalathur	1.07	-0.936	0.98	-0.69	0.541	Non significant
20	Vinayak	1.28	-0.852	1.07	-0.94	6.1797	,,

1000 seed weight

Treatment No.	Variety	b_i	S_{di}^2	b_i	S_{di}^2	W_i	
2	K.2	0.64	-0.022	0.91	-0.0391	0.0397	Non significant
3	IS 284	0.62	0.013	0.86	0.0640	0.0793	,,
7	42-1	0.85	-0.010	1.06	-0.0353	0.0200	,,
12	Si.902	1.56	-0.070	1.73	0.2658	0.1854	,,
19	Vayalathur	1.09	0.043	1.38	-0.0235	0.0686	,,
20	Vinayak	1.30	-0.013	1.39	-0.0316	0.0363	,,
Oil content percentage							
2	K.2	1.67	0.378	1.71	0.2132	1.7588	Non significant
3	IS 284	1.09	-0.113	1.09	0.0601	0.0391	,,
7	42-1	1.32	1.769	1.38	1.3823	2.1772	,,
12	Si.902	0.61	3.645	0.68	3.4493	4.1901	,,
19	Vayalathur	-0.13	6.197	-1.13	6.8530	9.7971	,,
20	Vinayak	0.13	0.197	0.08	0.3371	2.3953	,,

Number of days for flowering

Treatment number	Variety	b_i	S_{di}^2	b_i	S_{di}^2	W_i	
2	K.2	1.2082	6.425	1.1438	4.1813	9.8066	Non significant
3	IS284	1.3377	2.304	1.0068	-0.7673	6.7413	,,
7	42-1	1.2199	12.110	1.4468	1.6519	15.5663	,,
12	Si.902	0.8992	-1.987	0.7285	-2.3685	0.8981	,,
19	Vayalathur	1.5516	-2.519	1.8439	-2.4821	4.7586	,,
20	Vinayak	0.6908	-2.380	0.400	-2.0479	1.7817	,,

Number of days to maturity

2	K.2	0.66	-0.02	0.63	-1.66	2.8372	Non significant
3	IS 284	0.76	-1.18	0.75	-2.10	0.9891	,,
7	42-1	0.92	9.26	0.88	1.57	10.8779	,,
12	Si.902	2.89	25.41	1.51	44.44	66.0372	,,
19	Vayalathur	0.98	1.16	0.86	-0.49	0.4039	,,
20	Vinayak	0.74	9.95	0.52	16.84	12.2150	,,

Selection index

Treatment No.	Variety	b_i	s_{di}^2	b_i	s_{di}^2	W_i	
2	k.2	0.86	-8575986.86	1.01	-8645886.42	6467820.6443	Non significant
3	IS 284	0.94	-8814338.86	0.95	-8690717.70	1187235.3553	,,
7	42-1	1.16	-7832834.24	1.15	-7508029.94	9294809.3414	,,
12	Si.902	1.23	-815863.61	0.98	-8637598.04	17949832.9162	,,
19	Vayalathur	0.98	-8600227.36	1.12	-8444286.35	420471.2867	,,
20	Vinayak	1.25	-8881794.93	1.33	-8528382.30	19451306.343	,,

Principal components

2	k.2	0.70	-1128.7825	-1.03	-2228.4750	2196.2108	Non significant
3	IS 284	1.19	-570.9966	1.06	-1571.7756	2456.1196	,,
7	42-1	1.57	-2416.1889	1.63	-2569.24	2312.2534	,,
12	Si.902	1.53	2024.4369	1.32	11860.5208	6483.4313	,,
19	Vayalathur	0.66	-1694.1432	0.80	234.3262	1814.1134	,,
20	Vinayak	1.19	-1139.5133	1.33	2457.2265	1876.1173	,,

Table 4.2. Mean yield

Treat-ment No.	Variety	Plot yield (g)	Seed yield/ plant (g)	Oil content percentage	1000 seed weight (g)	No.of days flowering	No.of daysto maturity	Selection index	Principal components
2	k.2	296.88	3.57	46.88	2.46	36.69	79	10802.27	304.39
3	IS 284	306.900	4.92	50.08	2.65	39.16	87.22	12359.21	317.09
7	42-1	301.76	4.64	48.72	2.40	34.94	78.11	13272.63	312.78
12	Si.902	293.29	4.21	44.13	2.62	41.84	79.00	12773.29	301.22
19	Vayalathur	265.97	4.30	45.90	2.66	32.43	80.00	10971.07	274.08

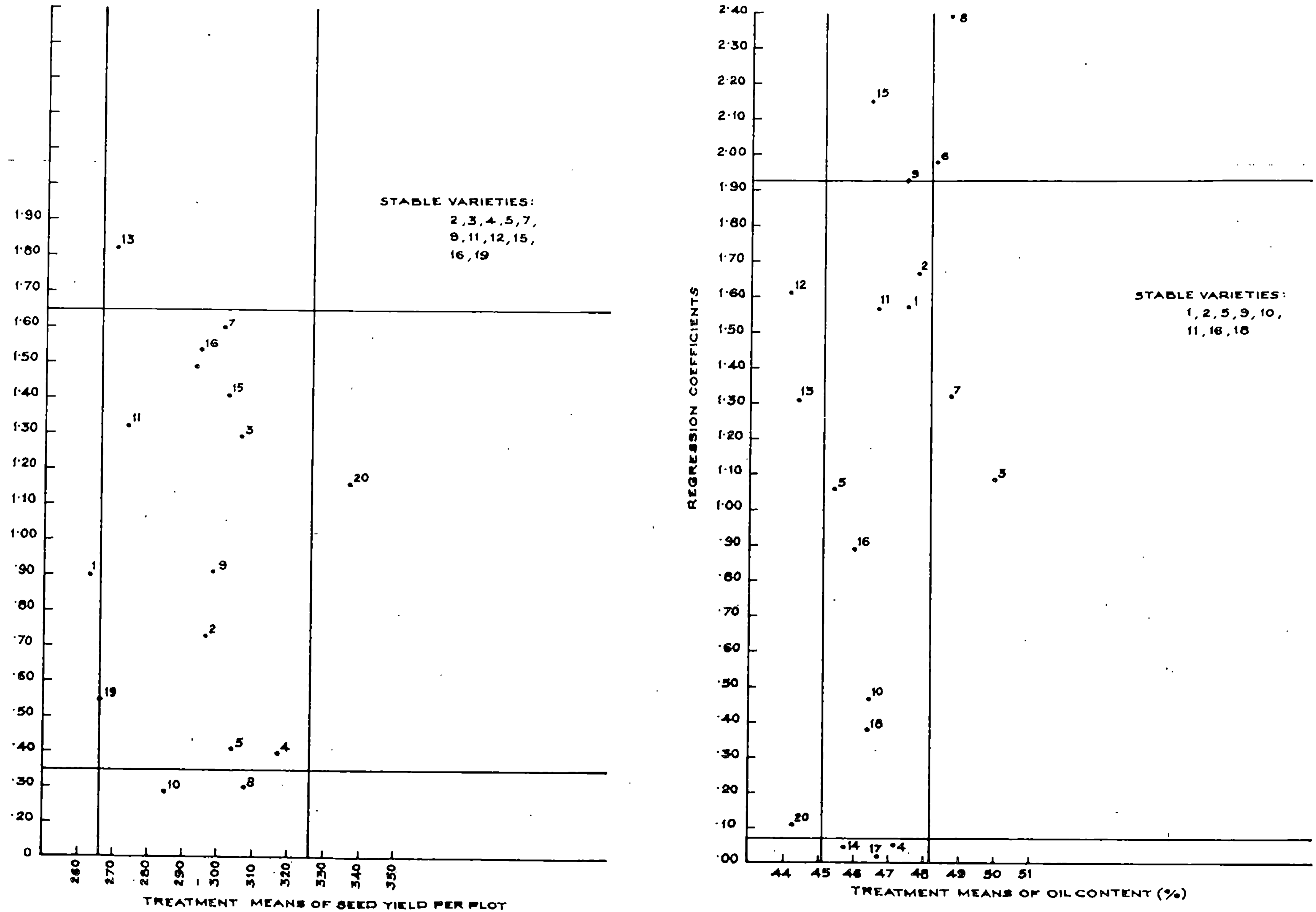

FIG. 1. THE RELATION OF TREATMENT MEANS AND STABILITY OF TWENY SESAME VARIETIES.

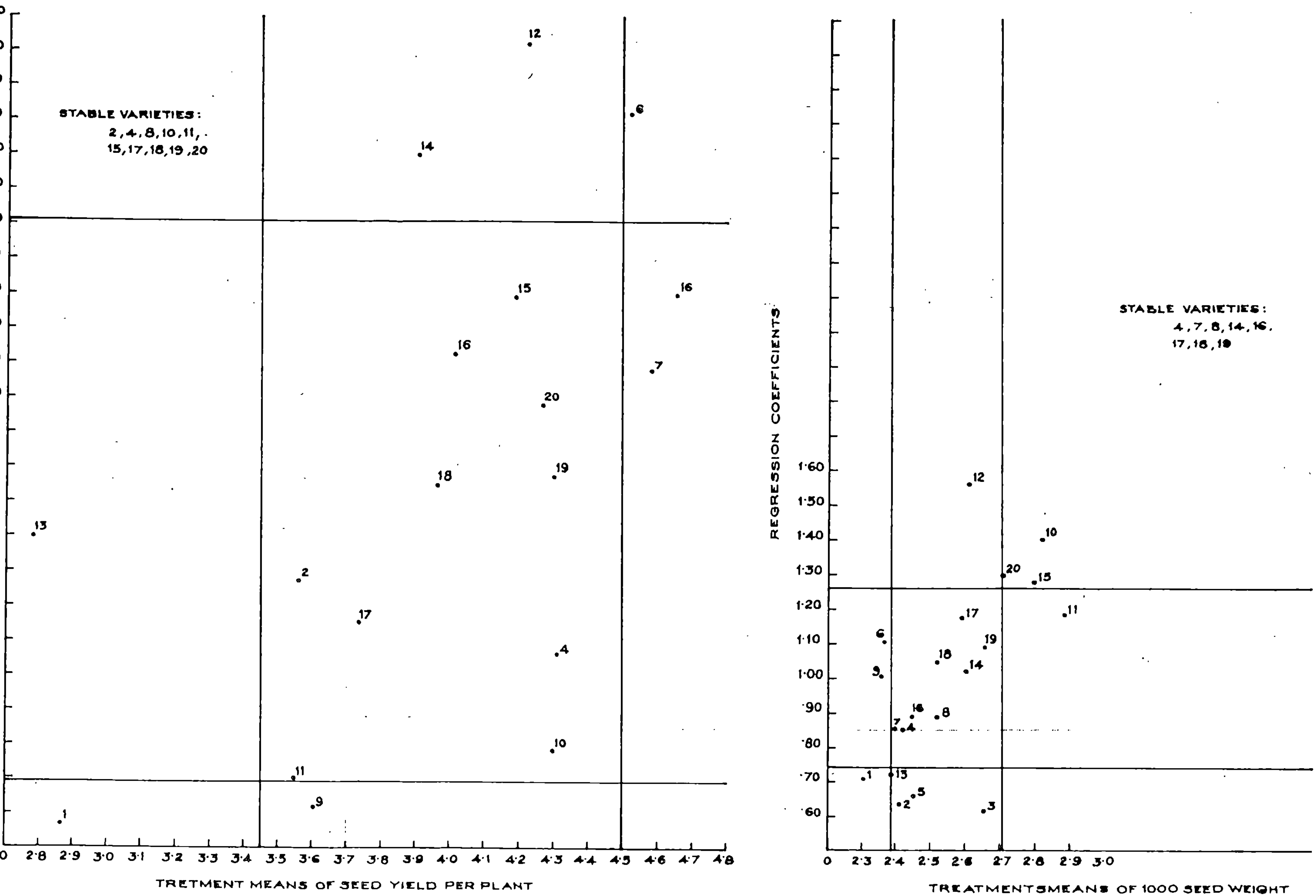

FIG. 2. RELATION OF TREATMENT MEANS AND STABILITY OF TWENTY SESAME VARIETIES.

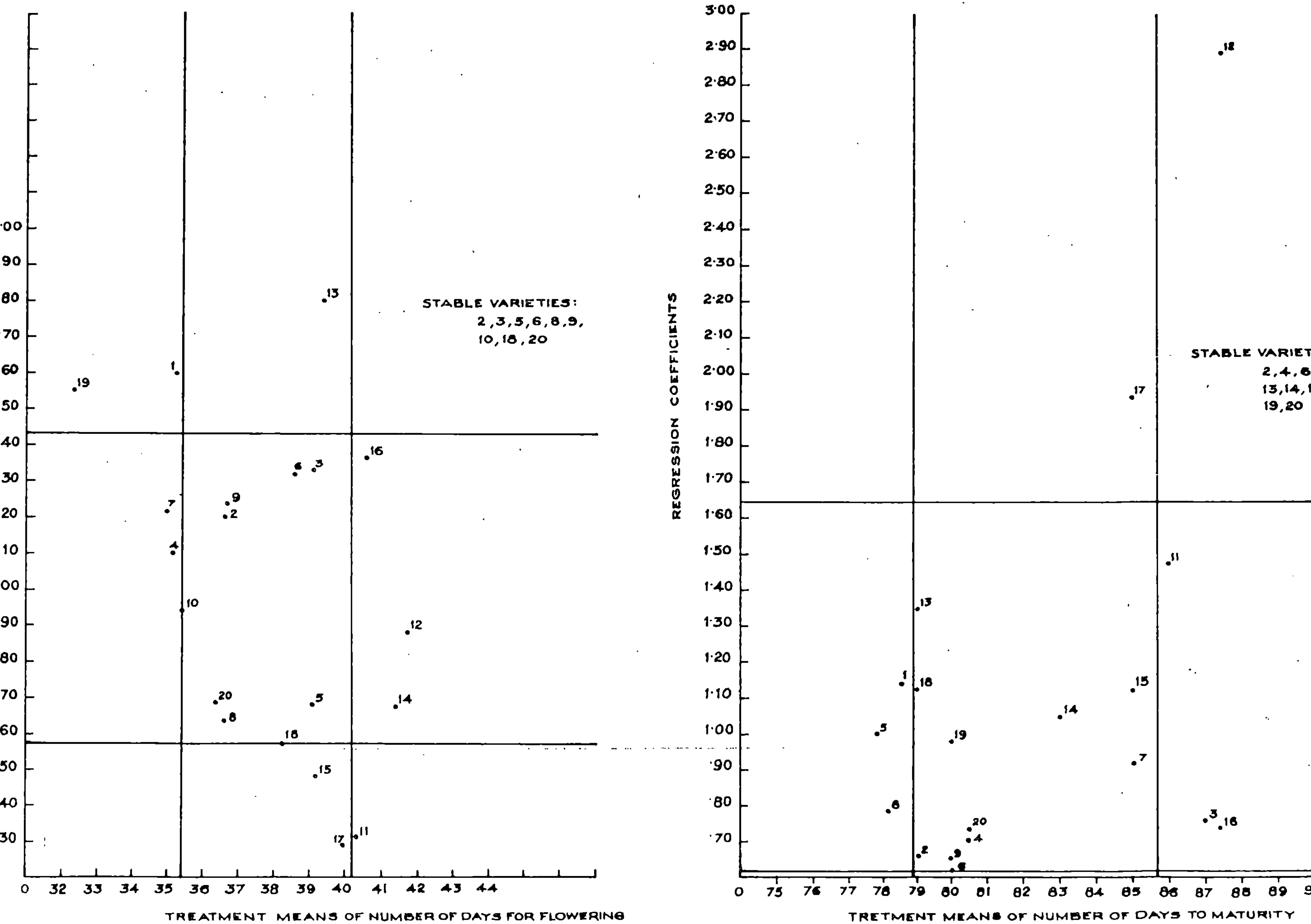

FIG. 3. THE RELATION OF TREATMENT MEANS AND STABILITY OF TWENTY SESAME VARIETIES.

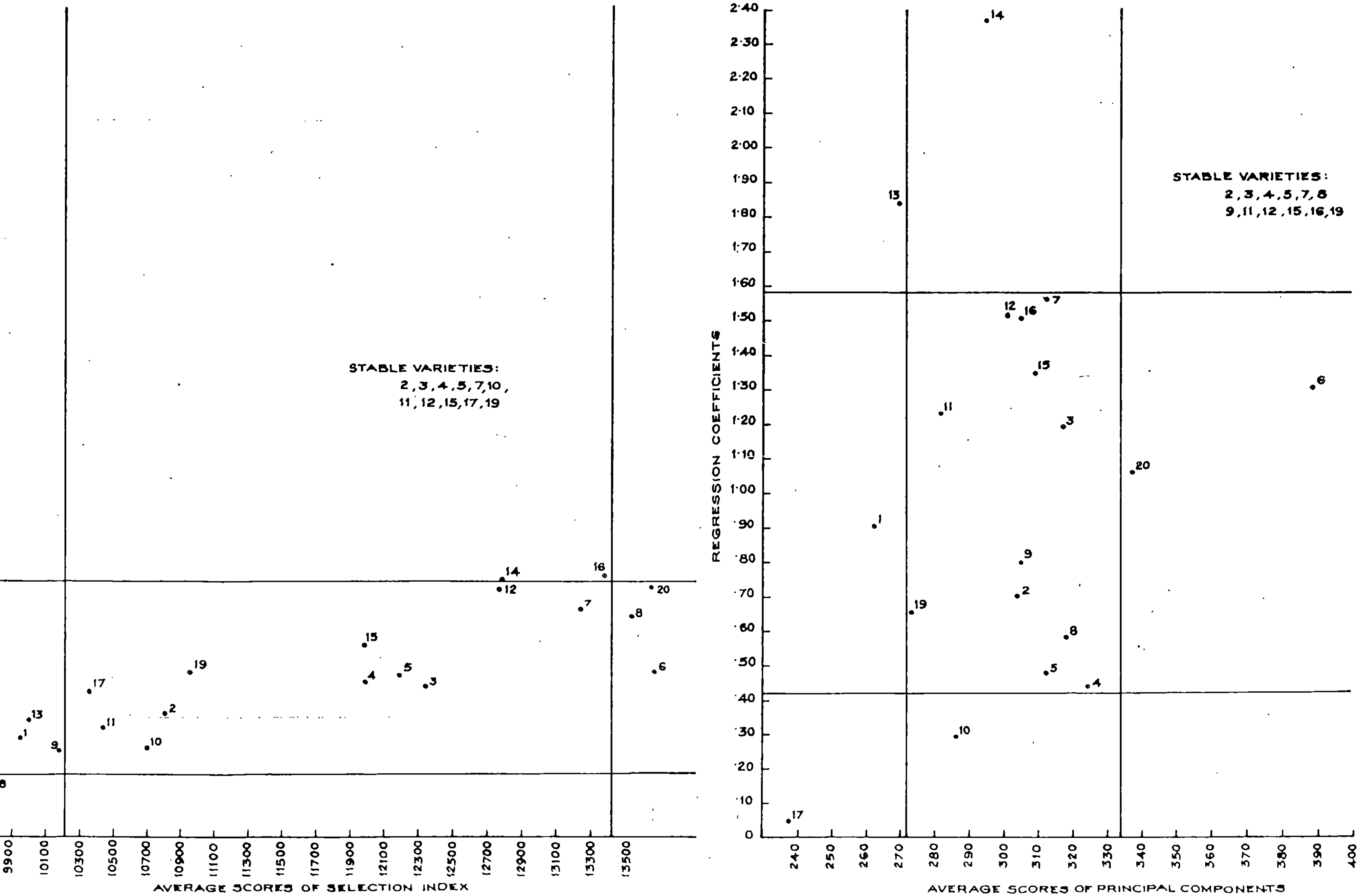

FIG. 4. THE RELATION OF AVERAGE SCORES AND STABILITY OF TWENTY SESAME VARIETIES.

Summary

SUMMARY

A comparative study of genotype-environment interaction in sesame of twelve characters of twenty varieties was undertaken in this present investigation. The data used for this study was from the experiment conducted by the Plant Breeding Department of K.A.U., Vellayani at three different locations - Kayamkulam, Pattambi and Vellayani for the year 1982-83. The stability of the performance of the varieties were studied through the three regression methods explained by Eberhart and Russel, Perkins and Jinks and Freeman and Perkins and also through Wricke's ecovalence ratio and Shukla's stability variance method.

Objectives of the study were (i) to evaluate the existing techniques available for studying GE interaction in sesame (ii) to develop new concepts and methods to solve some problems peculiar to crop sesame like, non-linearity of interactions, non-orthogonality of data and different patterns of genotype-environment interactions that are encountered while studying the stability of varieties simultaneously for several traits.

Out of the twelve characters studied, only nine characters were showing GE interaction. The characters - length of capsule, height, number of capsule per plant were found have no GE interaction hence they were rejected from the present study. While investigating the remaining nine characters, the characters - number of seeds per capsule, number of branches, circumference of capsule - it was found that the b_i and b_i' values from Eberhart and Russell and Freeman and Perkins model were varying to a very large extent so that the one σ_b range of these parameters ($1 \pm \sigma_b$) was taking very exorbitant values. Hence the present investigation is based on six characters - seed yield per plot, seed yield per plant, number of days for flowering, number of days to maturity, 1000 seed weight, oil content percentage and the study through selection index method and principal component method.

Stable varieties were located in two ways (i) from the examination of stability parameters, Wricke's ecovalence ratio W_i and stability variance σ_i^2 (ii) by graphical method. Based on these methods, it was concluded that the varieties 2, 3, 7, 12 and 19 were stable. Considering all the characters together it was concluded that the varieties 2, 3, 19 (K.2, IS 284 and Vayalathur) were more stable. The variety IS 284 was found to be more stable in the case of majority of characters - plot yield, seed yield per plant, oil content percentage, number of days to maturity and principal component analysis. Hence the variety IS 284 can be considered as the stable variety from among the twenty varieties under trial and was recommended for further investigation.

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* Original not seen.

Appendices

APPENDIX I: Data on twelve characters of twenty sesame varieties for the location at Pattambi.

	1	2	3	4	5	6	7	8	9	10	11	12
1.	095.9	1.8	22.0	2.9	2.5	072	38.8	81	2.45	48.8	1.74	158.9
	096.5	2.4	32.3	2.5	2.6	060	41.0	82	2.50	48.7	2.79	240.4
	118.0	2.6	44.5	2.0	2.5	052	39.9	81	2.55	48.8	3.74	260.9
2.	105.3	0.9	30.3	2.4	2.5	052	39.8	81	2.38	49.3	2.65	278.0
	107.9	1.2	31.9	2.4	2.5	056	39.1	81	2.52	49.3	3.40	279.0
	118.3	1.2	53.9	2.6	2.7	052	40.8	81	2.60	49.5	3.37	234.7
3.	095.1	3.3	30.2	2.1	3.5	104	43.0	89	2.55	51.3	3.39	241.4
	102.8	4.9	45.6	2.5	3.4	104	43.5	91	2.47	51.3	5.69	223.4
	109.2	4.3	40.5	2.5	3.5	104	42.2	88	2.66	51.4	4.98	268.3
4.	095.9	2.4	30.4	2.8	2.5	068	38.2	81	2.60	47.4	2.87	253.7
	105.6	2.6	35.3	2.8	2.6	072	37.9	82	2.48	47.4	4.06	315.1
	107.9	2.6	37.3	3.0	2.7	072	38.3	82	2.65	47.6	4.77	329.2
5.	107.6	2.2	24.4	2.4	3.1	066	41.7	80	2.75	45.3	3.77	268.7
	115.3	2.6	52.1	2.5	3.6	096	39.7	82	2.50	45.5	4.25	341.5
	099.6	2.4	43.0	2.2	3.3	112	43.2	82	2.55	45.4	2.95	233.0
6.	106.2	3.0	40.7	2.6	2.6	060	42.6	81	2.45	49.8	3.76	281.3
	098.3	3.6	28.2	2.5	2.6	056	41.7	81	2.47	49.8	2.62	293.2
	110.9	5.2	56.9	2.1	2.5	064	43.1	81	2.34	49.8	4.55	373.0
7.	102.5	1.8	21.5	2.6	3.1	096	39.2	90	2.69	49.4	3.35	193.0
	096.9	0.7	24.2	2.5	3.1	080	39.1	87	2.31	49.6	2.62	21300
	116.5	2.0	37.6	2.6	2.4	096	39.8	89	2.72	49.5	3.45	233.0
8.	091.0	1.4	18.6	2.4	4.0	104	38.3	81	2.58	50.8	3.64	310.4
	095.7	1.5	16.7	2.5	3.8	112	40.3	80	2.78	50.8	2.96	295.6
	110.4	1.5	26.0	2.5	3.8	112	38.1	81	2.76	50.9	1.95	245.5
9.	103.8	3.7	48.0	2.5	2.5	056	40.2	81	2.44	49.1	4.13	218.6
	091.0	2.9	31.4	2.4	2.5	052	39.9	81	2.54	49.3	2.88	265.1
	124.7	2.9	48.2	2.6	2.6	056	41.2	82	2.27	49.2	3.58	299.8
10.	115.0	0.0	32.0	3.2	2.7	084	39.2	83	3.05	45.8	4.62	247.2
	126.5	0.2	51.8	3.2	2.6	080	39.2	83	2.67	45.8	2.98	291.2
	122.4	0.0	38.4	2.8	2.7	060	36.5	83	2.72	45.9	4.58	294.5
11.	103.5	5.9	42.7	2.7	2.6	048	41.7	91	3.03	49.3	4.65	203.3
	102.1	4.5	38.1	2.5	2.5	056	40.2	90	2.91	49.3	3.07	218.2
	109.9	5.3	45.9	2.5	2.5	048	42.4	91	2.63	49.3	3.22	207.7
12.	133.0	3.0	46.1	2.4	2.6	052	46.1	94	2.54	43.9	3.94	223.9
	117.9	3.1	41.1	2.5	2.4	064	42.7	93	2.63	43.8	3.15	178.0
	121.6	3.4	44.0	2.4	2.7	048	45.5	94	2.39	43.9	3.47	209.2
13.	097.3	1.3	23.5	2.5	2.5	048	45.3	82	2.47	46.2	1.32	136.2
	112.8	2.8	36.4	2.1	2.5	068	44.3	82	2.55	46.3	2.69	177.9
	121.7	2.6	36.2	2.6	2.7	056	45.3	82	2.00	46.2	2.79	226.9
14.	113.2	3.6	49.4	2.3	2.6	044	45.2	82	2.38	44.4	2.88	193.3
	125.1	5.6	68.8	2.2	2.5	048	42.9	89	3.13	44.7	3.53	121.8
	108.9	3.5	36.0	2.5	2.6	060	42.9	88	2.78	44.4	2.78	144.3
15.	097.2	2.3	28.6	2.5	2.7	060	40.9	88	3.05	50.2	2.60	217.5
	122.4	3.4	48.1	2.5	2.6	052	40.9	90	2.87	50.2	3.25	251.0
	123.1	3.2	49.7	2.6	2.8	060	40.5	88	2.70	50.3	4.31	212.6
16.	097.8	2.5	28.2	2.5	3.3	108	41.9	90	2.56	46.6	3.50	194.5
	087.8	2.5	28.2	2.5	3.4	128	48.4	88	2.69	26.6	3.82	197.7
	081.2	2.0	29.5	2.5	3.1	096	44.5	91	2.29	46.8	3.31	222.6
17.	117.5	3.2	37.1	2.5	2.5	060	40.6	91	2.91	46.6	4.35	212.0
	113.3	3.7	44.0	2.6	2.7	060	41.1	89	2.89	46.6	2.83	225.8
	110.0	3.5	51.1	2.7	2.8	064	44.3	91	2.48	46.8	4.31	239.6
18.	101.8	3.5	41.4	2.4	2.5	052	39.9	82	2.94	48.9	4.12	307.7
	091.0	3.0	24.2	2.4	2.5	052	41.1	82	3.04	48.9	2.62	254.8
	105.3	3.3	34.2	2.6	2.6	060	39.6	82	2.38	48.9	3.27	260.7
19.	102.2	1.3	27.8	2.5	2.6	056	33.6	83	2.94	47.0	3.20	211.5
	114.5	0.9	31.9	2.6	2.7	060	39.6	82	3.31	47.3	3.35	221.5
	119.3	0.2	43.0	3.1	2.4	064	38.7	82	2.66	47.1	4.32	264.7
20.	112.5	2.3	30.2	3.6	2.8	076	40.5	81	3.05	44.6	3.50	321.5
	117.7	2.4	23.5	3.8	2.7	076	35.4	82	3.16	44.5	4.25	271.5
	106.9	2.4	28.7	3.7	2.7	076	40.0	82	2.53	44.6	2.54	215.4

… on twelve characters of twenty sesame varieties for the locat- (ii) ion at Vellayani.

	1	2	3	4	5	6	7	8	9	10	11	12
	149.7	3.2	27.9	2.5	2.5	048	35.1	78	2.58	45.2	2.58	213.6
1.	139.0	2.4	26.0	3.0	2.5	056	35.7	79	2.59	45.3	3.05	326.8
	146.3	2.4	27.4	2.5	2.6	044	36.8	78	2.50	45.2	2.79	221.9
	155.4	1.2	37.2	2.4	2.6	048	39.0	77	2.41	45.6	3.10	192.3
2.	162.5	1.4	33.3	2.7	2.7	056	37.7	78	2.58	45.6	4.30	274.3
	154.4	1.2	32.8	2.3	2.5	048	36.9	78	2.81	45.5	4.48	366.6
	118.4	3.0	23.4	2.6	3.8	112	39.5	85	2.73	48.8	3.90	296.8
3.	136.9	3.3	32.4	2.5	3.5	120	39.2	87	2.95	48.7	5.45	260.0
	136.5	2.5	20.8	2.6	4.0	112	40.1	87	3.21	48.8	3.76	333.7
	137.3	3.2	34.4	3.2	2.8	072	37.0	81	2.57	47.3	4.90	288.4
4.	127.5	2.6	34.3	3.2	3.0	072	37.5	85	2.32	47.5	4.25	314.0
	127.9	1.4	24.2	2.9	2.4	056	33.5	81	3.09	47.3	4.20	352.5
	150.7	3.7	33.5	2.5	3.0	072	37.1	76	2.48	43.2	4.30	312.6
5.	137.0	3.1	27.7	2.4	2.9	072	37.7	77	2.70	43.4	3.45	277.5
	137.0	2.0	19.8	2.5	2.8	060	36.7	71	2.69	43.3	2.89	349.5
	192.5	3.0	42.7	2.6	2.5	060	39.3	81	2.72	45.3	6.49	475.1
6.	156.1	3.8	45.6	2.6	2.5	064	37.7	82	2.67	45.4	7.43	485.4
	154.2	3.5	41.5	2.6	2.7	056	39.4	85	2.99	45.3	7.35	353.2
	158.7	1.9	23.3	2.7	3.8	096	29.7	81	2.45	46.6	4.51	353.9
7.	155.0	2.7	27.0	3.0	3.5	136	31.1	85	2.46	46.6	4.06	346.0
	143.2	1.5	21.1	3.2	3.8	120	31.3	81	2.94	46.7	4.08	349.4
	151.1	2.4	28.4	2.6	3.6	096	34.9	75	2.44	44.1	4.38	352.4
8.	138.7	2.6	21.3	2.7	3.4	112	34.4	77	2.58	44.4	4.70	377.9
	124.5	2.0	16.8	2.5	3.5	088	34.7	76	3.25	44.1	3.39	361.0
	140.3	2.6	38.3	2.6	2.5	056	34.8	80	2.72	44.8	3.61	278.7
9.	141.2	3.3	35.3	2.6	2.4	044	37.4	82	2.50	44.8	4.50	239.0
	135.9	3.1	28.0	2.5	2.4	044	36.7	80	2.98	44.9	2.80	239.7
10.	168.7	0.0	41.6	3.0	2.8	068	34.0	82	3.23	45.0	3.66	209.4
	137.5	05	35.2	3.0	3.0	076	37.0	87	3.55	45.2	3.92	234.1
	156.8	0.0	28.8	3.3	2.7	072	33.4	80	3.38	45.1	5.15	304.9
	157.5	4.6	33.9	2.6	2.7	048	38.4	83	3.46	45.3	5.20	250.0
11.	149.5	4.4	28.3	2.9	2.6	064	39.4	85	3.14	45.4	3.20	360.5
	120.3	3.9	29.7	2.5	2.6	056	41.3	82	3.57	45.3	3.49	136.1
	187.5	3.6	58.4	2.3	2.5	052	39.7	90	3.08	42.7	7.71	531.7
12.	162.9	3.8	40.3	2.5	3.0	056	40.2	90	3.29	42.8	6.93	327.3
	167.3	3.1	29.1	2.4	2.6	048	41.0	91	3.52	42.7	4.30	271.5
	140.5	1.8	32.9	2.3	2.5	044	36.1	79	2.50	43.0	4.94	359.0
13.	140.5	1.8	28.1	2.4	2.7	044	38.8	81	2.78	43.0	3.05	204.5
	135.1	1.3	21.6	2.6	2.5	049	38.8	79	2.87	43.2	1.77	223.1
	195.8	3.7	55.1	2.5	2.5	048	38.8	80	2.70	47.1	6.56	364.4
14.	162.6	3.4	33.9	2.5	2.5	044	40.1	82	2.92	47.3	4.26	368.1
	156.5	4.0	43.0	2.6	2.5	052	41.2	82	3.09	47.1	5.21	420.0
	178.0	2.6	35.7	2.6	2.5	060	35.2	81	2.86	44.7	5.30	284.4
15.	132.2	2.8	27.8	2.9	3.0	060	40.7	84	3.29	44.8	5.10	273.3
	160.3	2.9	32.0	3.2	3.2	076	38.7	85	3.57	44.7	5.00	428.0
	137.6	2.2	23.6	3.0	3.5	064	39.1	85	2.69	44.7	3.98	352.9
16.	159.8	1.7	18.2	2.6	3.7	128	37.9	87	2.81	44.7	5.84	394.1
	142.5	2.3	29.3	3.2	3.7	128	39.9	85	2.78	44.7	5.62	381.4
	183.6	2.9	33.2	2.8	2.5	056	39.0	82	2.86	46.4	5.22	290.1
17.	165.1	3.4	35.9	2.7	2.7	064	39.0	85	2.91	46.5	5.44	353.0
	135.1	2.6	25.8	2.6	2.6	064	39.6	85	3.07	46.6	3.60	202.7
	152.4	3.5	29.3	2.7	2.7	056	38.0	81	2.70	47.4	4.45	274.0
18.	147.6	3.8	40.0	2.9	2.7	064	35.5	81	2.79	47.3	6.30	220.9
	123.2	3.6	25.1	2.5	2.5	044	38.7	80	2.78	47.3	2.55	159.9
	164.4	1.7	39.9	2.9	2.5	060	29.7	80	2.87	46.8	3.89	213.3
19.	159.7	0.9	46.4	2.8	2.7	068	30.2	80	2.79	46.8	6.29	425.7
	146.4	0.9	38.0	3.0	2.5	064	31.8	80	2.98	46.8	3.99	258.0
	156.5	3.0	30.4	3.2	3.1	064	35.1	81	3.08	44.1	4.75	358.5
20.	142.9	3.1	27.8	3.5	3.0	072	35.7	85	3.07	44.2	4.31	408.4
	158.5	2.3	28.1	3.8	3.0	072	35.0	83	3.09	44.2	5.12	406.8

APPENDIX III: Data on twelve characters of twenty sesame varieties for the location at Kayamkulam.

	095.6	2.7	32.8	2.6	2.5	056	30.1	76	2.01	48.6	3.90	347.0
1.	086.8	1.9	26.1	2.8	2.5	060	30.6	76	2.03	48.6	3.25	272.5
	079.5	2.0	19.5	2.7	2.7	060	30.6	76	2.08	48.7	2.00	328.0
	118.8	1.1	21.6	2.7	3.0	056	31.7	78	2.16	48.7	2.70	319.0
2.	121.6	077	33.8	2.5	2.7	052	31.3	78	2.14	48.6	3.90	364.0
	095.8	0.7	33.4	2.4	2.6	048	33.9	79	2.09	48.8	4.20	364.0
	106.8	4.0	32.2	2.3	3.5	112	31.2	86	2.58	50.1	5.90	414.0
3.	109.8	2.6	24.9	3.0	4.0	128	35.3	85	2.33	50.1	5.30	345.0
	083.5	4.7	35.7	2.6	3.7	112	38.4	87	2.41	50.2	5.90	379.5
	104.7	1.6	22.1	2.6	2.7	060	32.7	77	2.10	46.4	3.00	315.0
4.	115.3	2.8	39.4	2.7	3.0	064	30.9	77	2.02	46.4	5.50	409.0
	101.9	3.5	39.3	3.3	3.1	060	30.4	79	2.03	46.5	5.30	309.0
	105.0	2.5	25.7	2.4	3.3	072	39.1	78	2.04	47.5	4.75	300.5
5.	075.8	1.1	14.5	2.2	3.4	080	39.6	78	2.14	47.6	3.15	241.5
	100.0	1.1	16.8	2.3	3.2	052	37.3	77	2.28	47.5	3.90	413.0
	099.6	2.4	27.0	2.4	2.4	052	33.8	77	1.81	49.5	3.10	412.0
6.	106.2	2.5	27.6	2.4	2.4	052	38.2	37	2.02	49.5	3.70	449.0
	088.8	2.4	24.4	2.2	2.5	044	32.4	78	1.99	49.5	3.10	384.0
	109.0	3.4	33.7	2.5	096	096	38.6	86	2.01	50.1	7.10	264.0
7.	109.	2.0	38.8	3.0	3.4	128	32.7	84	2.02	50.1	6.90	421.0
	095.2	1.9	31.0	2.9	3.6	112	32.8	86	2.00	50.0	5.70	342.5
	107.7	2.6	22.6	2.4	4.0	104	33.0	77	2.21	5055	5.80	298.0
8.	113.2	3.0	28.3	2.4	4.0	088	37.9	78	2.10	50.4	6.25	259.5
	078.5	2.2	18.7	2.5	4.0	104	37.9	78	2.05	50.5	3.50	278.8
	097.8	1.9	38.5	2.3	2.7	052	31.6	77	1.96	48.7	4.10	380.4
9.	094.4	2.5	28.8	2.4	2.7	052	32.6	78	1.95	48.7	3.26	404.0
	102.0	1.7	26.7	2.5	2.7	044	36.7	79	1.95	48.8	3.60	360.0
	117.4	0.2	39.5	3.3	2.8	096	31.2	85	2.34	48.4	5.60	331.0
10.	129.4	0.2	20.0	3.0	2.9	128	35.9	86	2.26	48.6	3.40	320.0
	136.5	0.1	30.1	3.2	2.9	112	32.6	88	2.23	48.5	5.70	341.0
	097.3	3.1	16.4	2.9	2.7	104	41.6	85	2.52	43.8	2.50	344.0
11.	109.2	4.4	16.1	2.5	2.7	088	39.5	85	2.40	43.7	2.40	360.0
	102.0	4.4	24.0	2.7	2.6	104	39.0	84	2.40	43.8	4.30	339.0
	134.5	2.7	34.0	2.1	2.7	052	4066	79	2.03	45.8	3.70	332.0
12.	113.0	1.8	14.8	2.3	2.8	052	41.1	80	2.02	45.8	1.70	303.0
	095.9	2.4	23.7	2.3	2.6	056	39.7	78	2.05	45.8	3.00	263.0
	111.0	1.3	26.7	2.3	2.9	076	35.3	75	2.12	44.1	2.80	307.0
13.	124.4	0.7	28.2	2.4	2.4	072	34.5	75	2.17	44.2	3.08	419.8
	101.4	0.5	17.3	2.3	2.6	068	36.6	76	2.10	44.2	1.95	380.5
	118.5	1.6	22.6	3.2	2.6	074	41.5	82	2.30	46.1	2.85	432.5
14.	100.0	1.8	19.5	2.5	2.6	052	40.8	82	2.12	46.3	2.60	288.0
	099.0	3.4	37.4	2.7	2.6	056	39.3	82	2.06	46.1	4.50	349.0
	097.8	2.3	17.7	2.7	2.8	048	40.1	86	2.39	44.1	2.50	298.0
15.	115.9	2.4	24.5	2.6	2.8	048	36.8	83	2.24	44.3	3.90	441.0
	092.2	3.7	33.6	2.5	2.7	048	38.4	83	2.19	44.1	5.75	316.5
	098.0	1.4	16.0	2.5	3.7	042	36.3	85	2.10	46.7	3.90	335.0
16.	120.0	3.3	33.2	3.0	3.7	042	39.2	89	2.10	46.7	7.20	278.0
	107.5	2.6	31.5	2.7	3.7	060	38.3	86	2.07	46.7	7.40	306.5
	089.0	2.7	27.7	2.3	2.8	044	41.3	81	2.10	45.3	3.00	226.0
17.	089.0	1.9	21.2	2.5	2.6	056	42.7	84	2.08	45.3	2.47	213.0
	103.0	2.4	23.5	2.4	2.8	048	39.5	80	2.06	45.5	2.50	175.0
	111.4	3.8	34.3	2.4	2.9	052	37.0	77	1.96	42.8	4.05	387.5
18.	091.1	2.7	25.2	2.7	2.8	060	35.6	75	2.15	42.7	3.90	269.0
	086.7	3.5	32.8	2.8	2.7	052	39.6	77	1.98	42.9	4.40	232.0
	104.9	2.0	24.4	2.5	2.9	048	29.5	78	2.15	43.7	3.20	235.0
19.	112.2	2.0	63.7	2.7	3.1	056	29.7	78	2.09	43.8	7.50	279.0
	095.0	220	23.8	2.4	3.3	048	29.1	77	2.17	43.8	3.00	285.0
	120.3	3.0	30.0	3.6	3.3	064	34.1	77	2.05	43.7	4.90	397.0
20.	107.2	3.4	38.0	3.6	3.5	064	35.3	77	2.18	43.6	6.40	346.0
	100.4	1.2	16.0	3.3	3.2	064	36.5	79	[illegible]	[illegible]	[illegible]	[illegible]

A COMPARATIVE STUDY OF GENOTYPE-ENVIRONMENT INTERACTIONS IN SESAME

By

MINI. C. J.

ABSTRACT OF A THESIS

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ABSTRACT

The present study has been conducted to choose a consistent variety for all the regions and all seasons in the light of genotype-environment interaction with the following objectives.

(i) to evaluate the existing techniques available for studying GE interaction in sesame

(ii) to develop new concepts and methods to solve some problems peculiar to crop sesame like non-linearity of interactions, non-orthogonality of data and different patterns of genotype-environment (GE) interactions that are encountered while studying the stability of varieties simultaneously for several traits.

The data used for this study was from the experiment conducted by the Plant Breeding Department of Kerala Agricultural University, Vellayani at three different locations - Kayamkulam, Pattambi and Vellayani for the year 1982-83. The genotypic stability analysis of Eberhart and Russell (1966), Perkins and Jinks (1968), Freeman and Perkins (1971), Wricke (1966) and Shukla (1972) were studied. The multivariate procedures - selection index method and principal component method were also used to have a complete idea of GE interactions by taking into considerations all the characters simultaneously.

Stable varieties were located in two ways (i) from the examination of stability parameters (ii) by graphical method. Considering all the characters together it was concluded that the varieties k.2, IS 284 and Vayalathur were more stable. The variety IS 284 was found to be more stable in the case of majority of characters. Hence the variety IS 284 is the most stable variety from among the twenty varieties under consideration.