STUDIES ON STABILITY, GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS UNDER SIX SOWING DATES FOR YIELD AND YIELD COMPONENTS IN SOYBEAN [*Glycine max* (L.) Merrill]

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[*Glycine max* (L.) Merrill]

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Affectionately Dedicated

to my

Beloved Parents

Department of Agricultural Botany
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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON STABILITY, GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS UNDER SIX SOWING DATES FOR YIELD AND YIELD COMPONENTS IN SOYBEAN [Glycine max (L.) MERRILL]"** submitted by **Mr.M.P.Rajanna**, for the degree of **MASTER OF SCIENCE** in **AGRICULTURAL BOTANY (PLANT BREEDING AND GENETICS)** of the University of Agricultural Sciences, Bangalore, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Bangalore
November 15, 1989.

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Major Advisor and Soybean Breeder

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[M.P.RAJANNA]

C O N T E N T S

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

I. INTRODUCTION

Pulses constitute the main source of protein and essential amino acids for predominantly vegetarian population and low income group of this country. The position of pulses appears to be rather dismal in the production of food grains. Between 1967-68 and 1981-82 the production of food grains in the country increased at the rate of one per cent per annum while the corresponding figure for pulses was only 0.09 per cent (Singh and Swarup, 1988).

The reason for this dismal performance in pulse production are not hard to find. The crop is grown almost entirely on marginal and rainfed areas and is therefore, dependent on the emerging refinements in dryland farming technology. Pulses are also highly prone to pests and diseases. As a result, the element of risk is more pronounced. The gross area under pulses has hovered around 23 million hectares since 1960-61 and the production has levelled off at 12-13 million tonnes. The production of pulses since 1985-86 has declined by 0.28 per cent and productivity has fallen by 0.50 per cent. On the other hand, due to continuous increase in population, the demand for pulses has been rising. The present demand is around 18 million tonnes while average annual production is around 11 million tonnes (Sharma, 1988). With this widening gap between supply and demand, the per capita availability has been on decline over the years. The per capita availability of pulses was 69 g per day in 1961 while it stood at 33.4 g per day in 1988, a fall of almost 52 per cent in a span of 26 years.

Soybean [*Glycine max* (L.) Merrill], with its rich nutritional value (40 per cent protein and 20 per cent edible oil) has a coveted place among pulse crops being cultivated all over the world. In realization of its utility, intensive research and developmental programmes have been undertaken in this crop. As a result, its area and production in India have tremendously increased in about a decade and presently it is being cultivated on 1.7 million hectares with a production of about 0.9 million tonnes (Bhatnagar, 1989). Karnataka is one of the major soybean cultivating states with an area of about 16,000 hectares and a production of about 5000 tonnes. Nevertheless, the state has vast potentialities for extending the area to 0.2 million hectares in the near future (Viswanatha, 1989). In order to achieve this goal, the crop provides an unique opportunity since it can be cultivated throughout the year in all the seasons in the state. However the low production achieved demands the identification of suitable genotypes for different environments to realise increased production. In order to achieve this goal, a breeder needs to have information on the variability, mode of inheritance, heritability, direction and magnitude of association between various traits and their stability in genotypes. The present study was envisaged to throw light on the above aspects.

Normally genotypes exhibit a wide range of variation within and between environments because of genotype - environment interactions. This may cause differences in relative ranking of varieties when they are compared over a series of environments. As a result establishing significant superiority of a genotype becomes difficult due to interactions. Although stratification of environments has been used effectively to reduce the genotype-environment interaction, it may not be pragmatic since fluctuations across the environments will be of considerable magnitude. Yet other tool in the hands of plant breeder is identification of stable genotypes that interact less with environment in which they are to be grown. Since, stability of performance, or the ability to show a minimum of interaction with the environment is a genetic phenomenon, planning for preliminary evaluation to identify stable genotypes of wider adaptability or productive genotypes for a specific environment is imperative.

The present investigation was undertaken in six environments (seasons) utilizing twentyfour diverse genotypes of soybean with the following objectives.

1. Assessment of genetic parameters like variability, heritability and genetic advance.

2. Establishment of the effect of contributing characteristics on yield through correlation and path analysis studies.

3. To find out the extent of vulnerability with reference to genotype x environment interaction of different characters.

4. Identification of stable as well as specific genotypes for different environments.

5. Identification of stable characters which could be utilized for selection in breeding programmes.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Plant Breeders are mainly interested in increasing overall level of production. In a short period of time, within the available genetic resources this can be attempted by adopting following measures.

1. Estimating the magnitude of genetic variability available in the crop species.
2. Identifying the genotypes which perform uniformity over the environments/seasons (i.e., stable genotypes) through stability analysis.
3. Identifying the yield contributing characters and their association among the genotypes through correlation studies.
4. Estimating relative contribution of traits towards seed yield in the genotypes through path coefficient analysis.

Thus the present investigation was taken up in soybean [Glycine max (L.) Merrill] in order to maximise the production. This is the first investigation of its kind in this region. The literature available on the main objectives of the present study have been comprehensively reviewed in this chapter and the same has been presented under the following heads.

1. Studies on genetic variability in soybean.
2. Studies on correlation between yield and yield attributes in soybean.

3. Studies on path coefficient analysis in soybean.

4. Studies on genotype x environment interaction and its importance.

5. Studies on stability models and parameters.

6. Studies on stability (GE-interaction) in soybean and related crops.

2.1. STUDIES ON GENETIC VARIABILITY IN SOYBEAN

Malhotra (1973) observed highest coefficient of genetic variability for pods per plant which was followed by seed yield. These two characters in addition to 100 seed weight exhibited high heritability and high genetic advance. Seeds per pod showed little genetic variation, low genetic advance and high heritability.

Dai (1981) in a study of twnetytwo characters in thirtyone local varieties of soybean showed lower coefficient of genotypic variation than coefficient of phenotypic variation for growth period, number of seeds per pod and plant height. Average heritability values were high for eleven characters, genetic advance was relatively high for yield components with the exception of seed number per pod.

Miku and Damaskin (1982) in a genetic variability studies found high coefficient of heritability for plant height, pods per plant, seeds per plant, seeds per plant, 100 seed weight, seed weight per plant, height of insertion of lowest pod, number of fruiting nodes on the main stem, in three F_2 hybrid population.

High heritability for branches per plant, plant height, pods per plant, seeds per pod, 100 seed weight, yield per plant and days to maturity has been observed by Rashid and Islam (1982). They also observed high values of genetic advance for seed yield per plant, branches per plant, plant height and pods per plant, low genetic advance for days to maturity, seeds per pod and 100 seed weight.

Alam et al. (1983) found high heritability for days to flowering, plant height and number of seeds per pod. So, they concluded that selection in these characters would be particularly effective in producing increased yield.

Konwar and Talukdar (1984) obtained high genotypic and phenotypic variance for days to flowering, plant height at 50 per cent flowering, days to maturity and plant height at 50 per cent maturity. While high genetic advance with high heritability was revealed for traits days to maturity and plant height at 50 per cent maturity.

Ala and Gamalin (1985) reported that the coefficient of variation for stem length was lowest in *Glycine max*, while highest in *Glycine soja* and intermediate in the hybrid.

Sharma *et al*. (1986) found high genetic variability, heritability and genetic advance, for seed yield per plant and fourteen agronomic and quality characteristics, except for oil.

Chan *et al*. (1986) in a study of eleven yield related characteristics in two F-2 populations, grown at four sites found greater heritability values for vegetative earliness than seed number, seed weight and total pods.

Ecochard (1986) reported high heritability for leaf area per plant, plant height, seed yield per plant and number of pods per plant.

Yao *et al*. (1987) observed high estimates of heritability for growth period, number of clusters per plant, 100-seed weight, plant height, number of single seeded pods and number of seeds per pod.

Malik and Singh (1987) in their heritability studies of soybean found highest mean heritability (0.98) for seed weight followed by seed number per pod, oil, protein content and pod number per plant.

High heritability for plant height, seed weight and days to flowering were observed by Pushpendra and Ram (1987). They suggested that selection for these traits would be effective.

Yao (1988) reported high estimates of heritability for seed weight per plant, clusters per plant, pods per plant, 100-seed weight and growth period.

2.2. STUDIES ON CORRELATION BETWEEN YIELD AND YIELD ATTRIBUTES IN SOYBEAN

A knowledge of correlation, that exists among important characters may facilitate the interpretation of results that already exists/obtained and provide a basis for planning more efficient breeding programmes. The extent of observed relationship between two characters is known as simple, total or phenotypic correlation.

The association between the various characters in soybean has been studied by a number of investigators are reviewed here.

Shih (1948) found positive correlations between yield and plant height, number of branches, seed size, seed number, seed weight and pod number.

Weber and Moorthy (1952) reported that positive association was found between yield and height, yield and maturity. Relatively high positive correlations were found between flowering time and maturity date.

In a study conducted by Anand and Torrie (1963) genotypic and phenotypic correlations indicated that high seed yield tended to be associated with tallness and lateness to maturity. Also number of pods per plant was more closely related to seed yield.

Prakash *et al*. (1966) observed positive correlation between seed yield per plant and pods per plant. Strohm (1966) found that seed weight, plant height and maturity were positively correlated with seed yield in four soybean crosses.

Gopani and Kabaria (1970) found high positive association of seeds per pod, branch number and pod number with seed yield.

Lal and Haque (1971) found high positive association between seed yield and number of leaves, plant height, number of nodes and pod number.

In an association analysis conducted by Rohewal and Koppar (1973) grain yield had positive correlation with days to maturity and 100 seed weight. Hundred seed weight showed negative correlation with other characters. Days to flowering showed highly significant correlations with all the characters but had positive correlations only for plant height.

Veeraswamy et al. (1973) found that the soybean yield was positively and significantly correlated with number of pods, nodes, primary branches and plant height.

In a character association analysis, Veeraswamy and Rathnaswamy (1975) obtained positive association between seed yield and number of pods, number of nodes and height of the plant.

Aristarkhova (1976) found close positive intra-varietal correlation between yield and number of pods per plant, number of leaves per plant and inverse correlation between seed size and number of pods per plant.

Gautam and Singh (1977) found that the yield was positively and significantly correlated with the days to maturity, days to flowering, plant height, number of branches and pods per plant at phenotypic level.

Chen (1978) in regression analysis of eight agronomic characters showed that the improvement in yield could be best achieved by selection based on days to maturity and height at flowering.

Funnah and Mak (1978) revealed that seed yield was positively and significantly correlated with plant height at flowering and at maturity and negatively correlated with 100-seed weight, pods per plant and tall stature.

Correlation and regression studies conducted by Barbind _et al_. (1981) in 16 varieties in soybean revealed that only number of days to maturity was significantly and positively correlated with yield. Zhou (1983) reported that seed yield per plant as being closely correlated with height, pod number per plant.

Alam _et al_. (1983) found the phenotypic and genotypic correlations between characters like earliness, height, the number of branches per plant, number of seeds per plant, number of seeds per pod and seed oil content.

Dixit and Patil (1984) indicated that number of pods per plant, number of seeds per plant and 100-seed weight were most closely correlated with yield.

Akhanda _et al_. (1981) in a correlation study conducted for two planting dates revealed that seed yields for July and August plantings were positively correlated with flowering period and also with the plant height.

In an evaluation fo the relative influence of the morphological characters and yield components on yield done by Rajasekharan _et al_. (1980), plant height and days to flowering showed significant positive correlation with yield due to high positive direct and indirect effects via other characters. Further, due to interrelated positive and negative direct and indirect effects via other characters, yield components showed low correlation values with yield.

Fontes _et al_. (1980) noted low and negative correlations between oil and protein content and between both of them and grain yield, days to flowering and earliness.

Zhou (1983) reported that seed yield per plant as being closely correlated with height, pod number per plant and seed number per plant.

Number of pods per plant, number of seeds per plant and 100 seed weight were more correlated with seed yield (Dixit and Patil, 1984).

Diazearrasco _et al_. (1985) found the significant correlation between height and lateness, the number of pods per plant, lateness and tallness having significant correlations with seed yield.

Amaranath (1986) through his correlation studies observed significant and positive correlation between seed yield and days to 50 per cent flowering, days to maturity, plant height, number of branches per plant, number of pods per plant, number of seeds per plant and 100 seed weight. He also noticed positive and significant correlation of number of pods per plant and number of clusters per plant with days to 50 per cent flowering, days to maturity, plant height, number of branches per plant, number of seeds per plant, seed yield per plant, but significant and negative correlation with 100-seed weight. He recorded negative and significant correlation between 100 seed weight and plant height, number of branches per plant, number of pods per plant, number of seeds per plant, seeds per pod, negative and non-significant correlations were observed for 100 seed weight and days to 50 per cent flowering and days to maturity.

Tong (1986) detected positive correlations between seed yield per plant and number of productive branches per plant, pods per plant, seeds per plant, 100 seed weight, aerial plant mass and harvest index. Seed yield per plant was negatively correlated with height and internodes per main stem.

Chen (1987) observed that protein and oil contents were closely associated with growth period, flowering date and number of seeds per pod.

Gyusova and Ichera (1987) found close association between seed number per plant and plant height. Seed weight per plant was associated with seed number per plant and seed yield per unit area.

Pfeiffer and Pilcher (1987) found the association between delayed flowering and increased height, vegetative size but, did not provide a yield benefit in late plantings.

Sichkar et al. (1987) reported that genotypes giving high yields owing to a high degree of nitrogen fixation by producing more number of branches, clusters and pods.

Chen (1988) noticed the negative correlation between seed weight and leaf index, leaf length, positive correlation between seed weight and leaf width and leaf area. He also observed high degree of association between yield and number of pods per plant, and number of clusters per plant.

2.3. STUDIES ON PATH COEFFICIENT ANALYSIS

Path coefficient analysis is a standardised partial regression coefficient analysis and as such measures that the direct influence of one variable upon other and permits the separation of correlation coefficients into components of direct and indirect effects. According to Dewey and Lu (1957) path coefficient analysis is very valuable tool in detecting the real merit of characters contributing towards a particular dependent variable. This technique also helps to separate the individual effects of characters in question, rather than evaluating it only on the basis of its correlation with the final and most important characters.

Lal and Haque (1971) reported in soybean, two characters viz., number of days taken to maturity and number of leaves per plant as having a potent role in making up the seed yield.

Malhotra et al. (1972) conducted partial regression and path coefficient analysis, that which revealed that the pods per plant is the most important yield contributing characters.

Kaw and Menon (1973) observed in soybean through a path coefficient analysis that number of pods per plant and maturity contributed most, both directly and indirectly to yield. Days to 50 per cent flowering had a sizeable negative influence on yield both directly and indirectly.

Yap and Lee (1975) through path coefficient analysis found that the plant height and number of nodes per plant as the important components of yield.

Veeraswamy and Rathanaswamy (1975) revealed that the number of pods per plant as the major factor contributing to yield followed by 100 seed weight and number of nodes.

Gautam and Singh (1977) indicated through path coefficient analysis that the number of pods, 100 seed weight and number of seeds per pod as having direct effect on yield, plant height, number of branches, days to flowering and maturity had indirect effect on yield via the number of pods per plant.

Srivastava _et_ _al_. (1976) reported that the days to flowering and seed number per pod as having both direct and indirect contributions on seed yield.

Sharma (1979) reported that through the direct effect of plant height on yield was negligible, its indirect effects through number of pods per plant were fairly marked. Number of pods per plant and number of pod clusters per plant made important direct and indirect contributions to seed yield.

In an evaluation of the relative influence of the morphological characters on yield done by Rajasekaran et al. (1980), plant height and days to flowering showed significant positive correlation with yield due to high positive direct and indirect effects via other characters.

Ma (1983) studied the yield and eleven of its components and reported the direct and indirect effects of these components on yield, number of seeds per plant and 100 seed weight were found to have high direct effects on yield.

Sharma et al. (1983) through path coefficient analysis recorded the maximum contribution of pod number per plant and days to maturity to seed yield.

Zhou (1983) through path analysis showed that 100 seed weight and seed number per plant as having relatively major effects on seed yield.

Fundora _et al_. (1985) indicated through path coefficient analysis days to maturity as the greatest direct influence on protein percentage and seed yield, while the direct influence of seed weight, though slight was greater than that of either of the other traits.

Path coefficient analysis revealed that number of seeds per plant and 100 seed weight had a positive direct effect on seed weight per plant as reported by Liu _et al_. (1985). Hwang and Kim (1986) observed through path coefficient analysis that number of seeds had highest direct effect on seed yield.

Path coefficient analysis conducted by Amaranath (1986) revealed that 100 seed weight has got highest positive direct effect on seed yield followed by number of seeds per plant, number of pods per plant and number of seeds per pod. He noticed direct and negative effect of days to maturity and plant height on seed yield. He also recorded the highest indirect effect of days to 50 per cent flowering, days to maturity, plant height and number of branches per plant on seed yield via number of seeds per plant and number of pods per plant.

Choulwar and Borikar (1987) noticed the direct effect of 100 seed weight, pod length and number of seeds per pod on seed yield per plant.

Yao *et al*. (1988) through path analysis showed that 100 seed weight, nodes per main stem and seeds per plant had the highest direct effects on seed yield.

2.4. STUDIES ON GENOTYPE X ENVIRONMENT INTERACTION AND ITS IMPORTANCE

The complete meaning of the term "phenotype" was first explained by Johannsen (1909) which he related to the appearance or form arising as a result of interaction of genotype, the genetic constitution of the organism, with the environment in which it is grown. He was the pioneer in profounding the importance of environment in developmental processes.

The existence of genotype x environment interaction was for the first time reported by Fisher and Mackenzie (1923) from the results of a varietal trial on potato.

Sprague and Federer (1951) showed how various components could be used to separate out the effects of genotype, environment and their interaction in equating the observed mean squares in ANOVA to their expectations on the random model.

Allard (1961) observed relationship between genetic diversity and consistent performance in different environments with pure line populations being less stable in productivity than mixed populations owing to the lack of operation buffering in pure lines.

The genotype x environment interaction is usually present irrespective of whether the material under test is pure line, hybrid, top cross etc. This interaction reduces progress from selection (Comstock and Moll, 1963).

Allard and Bradshaw (1964) reviewed in detail focusing the implication of genotype x environment (GE) interaction in applied plant breeding. Further they have classified different types of GE interactions and have discussed the basic causes of adaptations. They have also categorised environments into predictable and unpredictable types.

Eberhart and Russell (1966) noticed the importance of genotype x environment interaction in their study and developed a model to partition the total variability due to GE-interaction into predictable and unpredictable sources of variation.

Breese (1969) opined that the GE interaction is a challenge in obtaining fuller understanding of the genetic control of variability as interaction poses serious problems in interpreting evolutionary trends and rationalisation of policy and procedure in breeding for improved performances in economic crop.

2.5. STUDIES ON STABILITY MODELS AND PARAMETERS

2.5.1. Stability models

Having realised the importance of GE interactions many statisticians and geneticists have developed several biometrical models to analyse the stability of a genotype. Such models have been discussed critically and reviewed comprehensively by several workers (Knight, 1970; Freeman, 1973; Hill, 1975; Westcott, 1986; Gautam et al., 1986).

The stability models are basically described through the procedure adopted by Yates and Cochran (1938) and the model is,

$$Y_{ij} = \mu + d_i + e_j + G_{ij} + e_{ij}$$

where, Y_{ij} = the observed performance of the $_i$th line (i = i.....v) in the $_i$th environment (j = 1, ...n)

μ = The grand mean over all lines and environments

d_i = The additive genetic contribution of the line calculated as the difference between the and the mean of its line averaged over all environments (d_i = 0)

e_j = The additive environmental contribution of the jth environment ($e_j = 0$)

G_{ij} = The GE interaction of the ith line in the jth environment ($G_{ij} = 0$)

e_{ij} = The error attached to the ith line in the jth environment

In the joint regression approach, the phenotype regression coefficient is estimated. To estimate this phenotypic regression coefficient. For a particular genotype, its Y_{ij} values are regressed on to the mean of the jth environment i.e., $\mu + e_j$. This approach in effect is regressing $e_j + G_{ij}$ as the dependence variate against e_j as the independent variate. If a linear relationship is established between these two variates, then $G_{ij} = \beta_i e_j + \delta_{ij}$, where β_i is the linear coefficient of the ith line and d_{ij} is the deviation from the fitted regression line of the ith line in the jth environment. Although this approach was described by Yates and Cochran (1938), it came into wider use only after Finlay and Wilkinson (1963) in Australia employed it to analyse 277 barley varieties for their stability (Hill, 1975).

The linear regression approach was also used by Eberhart and Russell (1966) and they regarded the deviation from the regression line as the important component of varietal stability model developed is as follows.

$$Y_{ij} = \mu + \beta_i I_j + \delta_{ij} \quad (i=1,2....t \text{ and } j=1,2....S)$$

Where, Y_{ij} = Mean of $_i$th variety in $_j$th environment.

μ = Mean of all the varieties over all the environments.

β_i = The 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 the varieties at a given location from the overall mean.

$$\frac{\sum_i Y_{ij}}{t} \quad \frac{\sum_i \sum_j Y_{ij}}{ts} \quad \text{with} \sum_j I_j = 0$$

δ_{ij} = deviation from regression of the variety of $_j$th environment.

2.5.2. Stability parameters

To avoid the deficiency of conventional analysis in quantifying G x E interaction of individual genotype, many regression models have been proposed.

A stable genotype has been defined in many ways by different workers based on stability parameters considered by them.

Lewis (1954) defined the phenotypic stability on the ability of an individual to produce a certain narrow range of phenotype in different environments. He suggested a simple measure of phenotypic stability which he termed as stability factor (SF). Accordingly the stability factor for the $_{i}$th genotype is given by the formula -

$$S.F. = \frac{\bar{X}\ HE}{\bar{X}\ LE} \quad \text{where } \bar{X} = \text{mean},$$

HE = High yielding environment

LE = Low yielding environment

A unit value of S.F. indicates maximum phenotypic stability in this computation.

Finlay and Wilkinson (1963) suggested that the stability parameter of a genotype is its phenotypic regression coefficient (bi). A genotype with a unit bi value and higher mean yield ($\bar{X}_i$ or μ_i) is said to be a stable variety for a range of environments. As the mean yield decreases, genotypes with high or low slopes are regarded as being adopted to favourable and unfavourable environments respectively.

Eberhart and Russell (1966) proposed stability parameters to describe the performance of a variety over an array of environments. They showed that the regression of each variety on an environmental index and a function of the squared deviation from this regression would provide useful estimates of cultivar stability parameters. They considered the ideal variety as the one with high mean (μ_i) response (bi)=1.00 and σ^2di (Mean square deviation from regression)=0. Breese (1969), Tai (1971) and many others in recent years have discussed the utility of this model in predicting the relative performance of a population over years and locations to find out differences in stability.

Joppa et al. (1971) used this (Eberhart and Russell, 1966) method on the yield stability of the selected spring wheat cultivars in the uniform spring wheat nurseries. For 10 years and they inferred that the use of regression analysis of such data could materially assist the plant breeder in arriving at the decision regarding the release of a cultivar.

Luthra and Singh (1974) and Verma and Virk (1983) compared some stability models and parameters. They have inferred that relative rankings of the genotype in Eberhart and Russell's and Perkins and Jink's models would be same.

2.6. STUDIES ON STABILITY GE-INTERACTION IN SOYBEAN AND RELATED CROPS

2.6.1. Stability (GE-Interaction) studies in soybean

Rohewal (1970) conducted stability experiments using six exotic varieties of soybean. The results indicated that the varieties 'Bragg' and 'Lee' showed their suitability for cultivation for high yielding environments and Punjab-1 and 'Improved Pelican' for low yielding environments for the northern and central plains. He did not found any variety stable for all the 14 environments.

Gopani et al. (1972) from their stability analysis (with 6 varieties of soybean) found that (i) average stability for yield in 'J 231' and 'N49S212'; for number of pods in 'Lee'; for seed weight in 'N49S212', '6A5833' and 'Bragg' and fodder yield in 'J 231'; (ii) below average stability for yield in 'Geduld' and 'N49S212'; for number of pods in 'J 231', 'GA58-33' and 'N49S212'; for seed weight in 'Geduld' and 'J 231'; for number of branches in 'GA 58-33', 'Lee' and 'J 231'; for fodder yield and height in 'Geduld' and 'N49S212'.

Lal et al. (1973) studied 11 varieties of soybean, grown in two different years at five locations, for their protein and oil content, their correlations along with the phenotypic stability as influenced by different environments. They observed and reported that, oil content differed in different years and protein content differed under different locations. Protein and oil content differed from variety to variety. They also observed that the significant difference with respect to year x location interaction effect on oil and protein content.

Kaw and Menon (1978a) evaluated ~~the~~ 31 soybean cultivars for eight agronomic characters at two locations for six seasons in Tamil Nadu, showed that genotype mean squares in the pooled analysis significantly exceeded the mean squares for genotype x location and genotype x season interactions for all the traits. Sowing in May gave the highest seed yield.

Kaw and Menon (1978b) grown 31 soybean cultivars at two months intervals throughout the year at two locations, and observed that the Genotype x environment/ location interaction was relatively large for plant height, number of nodes, pods and seed yield. It was highly significant for other yield attributing characters evaluated except for days to 50 per cent flowering. The genotype x season interaction was significant for days to first flower, 50 per cent flowering and maturity and plant height. They also told that in testing soybean cultivars, one should consider the effect of location.

Funnah and Mak (1980a) studied two varieties grown at six locations for two seasons and reported that, seed yield, 100 seed weight, plant height at maturity, nodes per plant, pods per plant and pods per node significantly differed between varieties, between environments and genotype x environment interactions. But, genotype x season did not show significant differences, whereas, genotype x location x season and genotype x location showed significant differences for all the characters evaluated.

Funnah and Mak (1980b) used regression analysis, stability variance method and genotype grouping technique to investigate relative yield stability of 20 soybean genotypes grown in 12 diverse environments. With the regression analysis they found four unstable genotypes for grain yield. Using genotype grouping technique they classified the genotypes into four groups for seed yield viz., group-I (average stability) with 7 genotypes, Group-II (below average stability) with 4 genotypes, Group-III (above average stability) with 1 genotype, and Group-IV (unstable ones) with 8 genotypes.

Saini _et al_. (1980) studied the effect of planting date and variety on subsequent seed quality of soybean. They observed and reported that delayed planting from June to Septem,ber produced higher percentage of sound seeds with higher germinability and storability. Seeds obtained from August and September planting gave significantly higher germination and maintained higher viability and vigour during storage than seeds obtained from June and July planting.

Khurana and Yadava (1982) studied 55 soybean genotypes in six artificial environments. They observed the significant environment interactions in eight out of nine traits in all six environments. The linear components of GxE were larger for days to flowering, plant height, seeds per pod, branches per plant, 100 seed weight, seed yield per plant, protein content and oil content. The non-linear component in pods per plant and N, exceeded the linear component. Stability and general adaptability to all environments were exhibited by seven cultivars, for seed yield two cultivars and for oil content by two cultivars.

Konwar and Talukdar (1986) conducted an experiment to know stability of yield and its components in soybean. Their experimental results revealed the following inferences. The genotype Bragg exhibited average stability for seed yield per plant followed by

DS-73-16 and Kalitur; JS-72-375 for number of pods per plant and number of clusters per plant. The strain PK-327 for 100 seed weight exhibited above average stability.

2.6.2. Stability (GE-interaction) studies in other crops

Ojama and Adelana (1970) reported significant variety x environment interactions for yield in groundnut and none of the variety was widely stable.

Bliss et al. (1973) showed significant genotype x environment interactions for 50 seed weight and per cent protein in cowpea, using eleven pure lines under the field study in Nigeria.

Malhotra and Singh (1973) from their study concluded that GxE interactions were more important for pod number and yield than for other characters in Bengalgram.

Gupta et al. (1974) reported that in the majority of the thirtyfive diverse genotypes of Chickpea grown in six diverse environments the GxE interactions with respect to seed yield was linear and their response to changes in the environment was therefore predictable.

Malhotra et al. (1974) in lentil showed GxE interactions for most of the yield attributing characters.

Singh et al. (1974) showed genotype x sowing date, genotype x location and genotype x location x sowing date interactions for seed yield, pods per plant, plant height and 100 seed weight in Bengalgram.

Abrams (1975) reported high variety x year interactions in Pigeonpea and concluded that evaluation of the traits; yield, flowering date, plant height and seed weight should be undertaken for atleast three years. Similar significant variety x year interaction effects were observed by Chaudary and Haque (1977) in greengram and Saini et al. (1977) in cluster bean.

Khan and Erskine (1978) reported significant GxE interactions for grain yield by joint regression analysis and concluded that variation in grain yield was largely due to fluctuations in pod number in winged bean.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

Various material and methods used during the course of present investigations are presented in this chapter.

3.1. MATERIAL

The basic material used in the study comprised of twenty four soybean genotypes obtained from the All India Coordinated Research Project on Soybean, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bangalore. The genotypes were diverse with respect to days to maturity (85-140 days), yield (3-20 q/ha), plant height (10-150 cm) and other yield attributing characters. The list of genotypes used are presented in Table 3.1.

The investigations were carried out in the experimental fields of Department of Genetics and Plant Breeding, Agricultural College, Hebbal, Bangalore. The salient geographical features and soil characteristics of the location are presented in Table 3.2.

3.1.1. Environments (seasons)

The main objective of the study being identification of stable high yielding genotypes suitable

Table 3.1. Name and source of the genotypes used in the study

Sl. No.	Name	Source	Sl. No.	Name	Source
1	Hardee	U.S.A.	13	PK-416	G.B.P.U.A.T., Panthnagar
2	Bragg	U.S.A.	14	PK-471	G.B.P.U.A.T., Panthnagar
3	Monetta	U.S.A.	15	PK-472	G.B.P.U.A.T., Panthnagar
4	KB-78	U.A.S., Bangalore	16	KB-32	U.A.S., Bangalore
5	KHSb-2	U.A.S., Bangalore	17	KB-38A	U.A.S., Bangalore
6	MACS-13	Maharastra (Pune)	18	KB-60	U.A.S., Bangalore
7	MACS-124	Maharastra (Pune)	19	KB-74	U.A.S., Bangalore
8	MACS-125	Maharastra (Pune)	20	DS-2	I.A.R.I., New Delhi
9	MACS-189	Maharastra (Pune)	21	DS-76-1-37-1	I.A.R.I., New Delhi
10	UGM-21	T.N.A.U., Coimbatore	22	JS-79-277	J.N.K.V.V., Jabalpur
11	UGM-30	T.N.A.U., Coimbatore	23	JS-81-303	J.N.K.V.V., Jabalpur
12	UGM-34	T.N.A.U., Coimbatore	24	JS-81-714	J.N.K.V.V., Jabalpur

Table 3.2. Geographical features and soil characteristics of the location (Experimental Plot, Department of Plant Breeding and Genetics, U.A.S., Hebbal, Bangalore)

Sl. No.	Particulars	Value	Remarks
I	Geographical features		
	a) Latitude	12°58' North	
	b) Longitude	77°35' East	
	c) Altitude	899 m. above MSL	
	d) Annual average rainfall	829 mm	Semi arid region
II	Soil characteristics		
	a) Sand (%)	63.00	
	b) Silt (%)	30.00	
	c) Clay (%)	07.00	Sandy loam
	d) pH	05.70	Slightly acidic

Source: Office of the Senior Farm Superintendent, M.R.S., Hebbal, Bangalore-560 024.

for different environments. Thus the twentyfour genotypes were sown in six sowing dates representing all possible seasons of an year. Each sowing represented a separate environment, which are as follows:

E_1 (May, 1988)	:	Late summer/early kharif
E_2 (July, 1988)	:	Kharif
E_3 (September, 1988)	:	Early rabi/late kharif
E_4 (November, 1988)	:	Rabi
E_5 (January, 1989)	:	Early summer/late rabi
E_6 (March, 1989)	:	Summer

Rainfall, temperature and other weather parameters prevailed during crop growth period are presented in Table 3.3 and illustrated in Figure 3.1.

3.2. METHODS

3.2.1. Experimental layout

The whole experiment was laid out in a single homogenious block following the Randomised Block Design (RBD) with three replications separately for each environment. The genotypes were allotted randomly in the 24 plots of each replication.

3.2.2. Crop management

In all the environments (seasons) the crop was raised following all the agronomic practices recommended

Table 3.3. Meteorological data during crop growth period at Experimental Plot, Department of Plant Breeding and Genetics, Hebbal, Bangalore-560 024

Month	Total Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Sunshine (Hours)
		Maximum	Minimum	Maximum	Minimum	
May 1988	117.90	32.80	21.80	87.00	48.00	8.40
June	2.50	30.90	20.40	88.00	49.00	7.90
July	276.90	28.40	20.10	92.00	66.00	4.50
August	278.30	28.10	20.00	95.00	69.00	4.20
September	442.40	28.10	19.50	94.00	68.00	6.30
October	68.60	28.00	17.70	86.00	50.00	8.50
November	10.00	27.50	15.50	90.00	45.00	8.40
December	33.90	26.00	14.90	92.00	47.00	8.70
January 1989	0.00	26.90	13.90	93.00	40.00	8.20
February	0.00	30.50	12.30	84.00	22.00	10.70
March	0.00	31.80	17.30	81.00	36.00	10.00
April	0.50	34.10	21.20	83.00	36.00	9.00
May	47.40	33.90	21.40	86.00	45.00	9.00
June	51.50	30.30	20.00	93.00	57.00	6.60
July	182.20	28.00	19.90	96.00	71.00	5.50

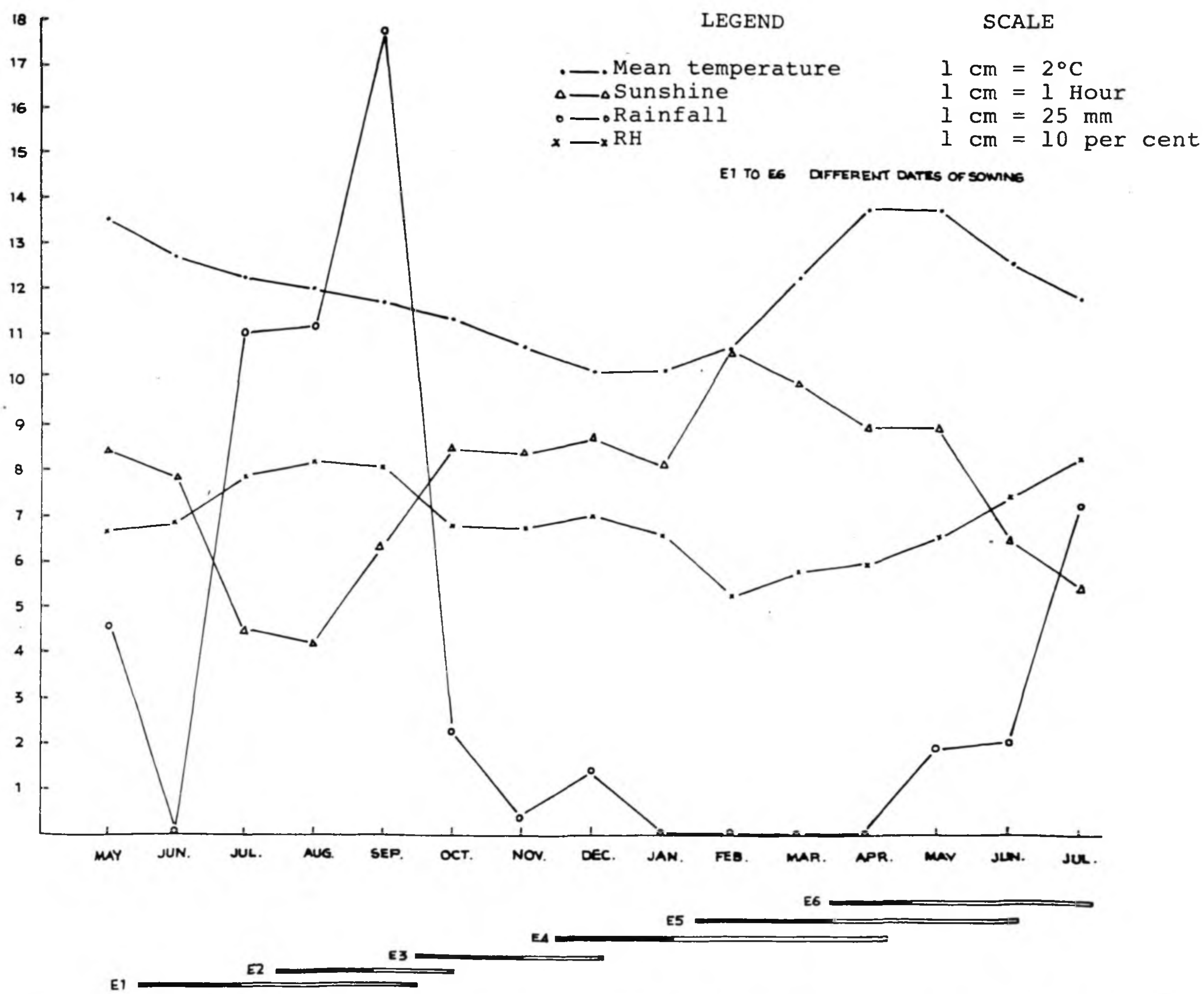

FIG. 3.1 ROUND THE YEAR WEATHER PARAMETERS SUPERIMPOSED ON DIFFERENT DATES OF SOWING OF SOYBEAN GENOTYPES

for soybean given in the package of practices for high yields, published jointly by U.A.S., Bangalore and the Department of Agriculture, Karnataka. A brief description of agronomic practices followed are as follows. Sowing was taken each time when soil reached optimum soil moisture condition after irrigation. Each genotype (treatment) was grown in five rows of 2 m. length with a spacing of 30 cm between rows and 10 cm between plants within a row. Before sowing, the seeds were treated with Rhizobium japanicum at the rate of 150 g per kg of seed. Two to three seeds were planted in each hill to facilitate emergence and to provide uniform stand of plants. The seedlings were thinned 12 days after sowing to one plant per hill. It was followed by earthing up operation when the soil moisture condition was optimum. The crop was protected against leaf minor and hairy caterpillers using quinolphos 25 EC at the rate of 30 ml per 18 litre water. Yellow mosaic virus disease was checked by controlling aphids and white flies using monocrotophos at the rate of 18 ml per 18 litre water. Irrigation was given at an interval of 6 to 8 days depending on the soil and weather conditions. Harvesting was done when the crop attained physiological maturity as indicated by the leaves turning to yellow followed by shedding along with blackening/darkening of the pods. All the above mentioned practices were similar in all the environments/seasons.

3.2.3. Recording of observations

The experimental data were observed and recorded on five randomly selected plants in each replications. Observations were recorded on the following eight characters as indicated under each of the traits. Except the first trait i.e., days to 50 per cent flowering, all the other observations were taken at maturity.

3.2.3.1. Days to 50 per cent flowering: The date on which 50 per cent of the plants had reached flowering/blooming was recorded and expressed as the number of days taken for 50 per cent flowering from the date of sowing.

3.2.3.2. Days to maturity: It is the number of days taken from the day of sowing to physiological maturity of the plants as indicated and identified by the yellowing of plants coupled with senescence of leaves.

3.2.3.3. Plant height: The length of the plant from the base of the plant at the ground level (surface of the soil) to the tip of the main stem, at the time of harvesting was measured and recorded in centimeters.

3.2.3.4. Number of branches per plant: This was recorded by the counting the total number of branches on each of the selected plant at the time of harvest.

3.2.3.5. Number of clusters per plant: The total number of nodes or fruit (pod) bearing points on main stem and branches are counted on plant samples and recorded.

3.2.3.6. Number of pods per plant: The total number of pods on main stem and branches was counted in each of the five plant samples and recorded.

3.2.3.7. Hundred seeds weight: It was computed by counting 100 randomly chosen filled seeds from a dried composite sample made by mixing the yield of all the five selected plants in each replication. The weights in grams was recorded using an electrical balance.

3.2.3.8. Seed yield per plant: The total seeds obtained from each of the randomly selected plant was weighed in grams and then averaged.

3.3. STATISTICAL METHODS USED FOR ANALYSIS

The statistical analysis of the data on individual characters was carried out on the mean values of five randomly selected plants from each of the three replications. Different statistical methods employed for the analysis are as follows.

3.3.1. Analysis of variance (ANOVA)

The analysis of variance for different characters were carried out for each season separately in order to assess the variability among the genotypes, following RCBD as given by Sundararaj et al. (1972).

3.3.2. Estimation of genetic parameters

In order to identify and ascertain the genetic variability among the genotypes, for the characters under study in all the environments and to confirm the presence of environmental effect on various characteristics of the genotypes in all the environments different genetic parameters were estimated by adopting following formulae.

3.3.2.1. Estimation of variance components: Phenotypic and genotypic components of variance were estimated with the help of following formulae.

$$\text{Genotypic variance } (\sigma g^2) = \frac{\text{MSS (treatment) - MSS (error)}}{\text{No.of replications}}$$

$$\text{Phenotypic variance } (\sigma p^2) = \sigma g^2 + \text{MSS (error)}$$

3.3.2.2. Coefficient of variability: Both genotypic and phenotypic coefficients of variability for all the characters considered were computed by making use of the method suggested by Burton and Devane (1953).

Genotypic coefficient of variability(GCV) = $\frac{\sigma g}{\bar{x}}$ x 100

Phenotypic coefficient of variability(PCV) = $\frac{\sigma p}{\bar{x}}$ x 100

where, σg = genotypic standard deviation

σp = phenotypic standard deviation

$\bar{x}$ = general mean of the character

3.3.2.3. Heritability (h^2): Heritability in broad sense for all the characters were computed as the ratio of genetic variance to the total variance as suggested by Hanson *et al*. (1956).

$$h^2 = \frac{V_g}{V_p} \times 100$$

where, V_g and V_p are genotype and phenotype variances respectively.

3.2.2.4. Genetic advance (GA): Genetic advance for each character was worked out by adopting the formulae given by Johnson *et al*. (1955).

$$GA = h^2 \times k \times \sigma p$$

where, h^2 = heritability estimated

k = selection differential which is equal to 2.06 at 5 per cent intensity of selection (Lush, 1940)

σp = phenotypic standard deviation.

3.3.3. Two way analysis of variance

The data obtained for eight quantitative characters from twenty four genotypes over six environments viz., May, 1988 (E_1), July, 1988 (E_2), September, 1988 (E_3), November, 1988 (E_4), January, 1989 (E_5) and March, 1989 (E_6) were subjected to two way analysis of variance following the method outlined by Sundararaj et al. (1972). This was done for each character to find out the differences among the genotypes, environments and to reveal the existence of significant genotype x environments interaction, if any. Only after ascertaining that genotype x environment (GE) interaction was significant in the two way analysis of variance, the data was proceeded to carry out stability analysis.

3.3.4. Analysis of variance for stability

The analysis of variance for stability as per the Eberhart and Russell's (1966) model is algebrically represented as shown below.

Source	d.f.	S.S.	M.S.	F-ratio
Total	(nv-1)	$\sum_i \sum_j Y^2_{ij}$ - CF		
Varieties(v)	(v-1)	$\frac{1}{n} \sum_i Y^2_{i.}$ - CF	MS_1	MS_1/MS_3
Environments(Env) + (V x Env.)	v(n-1)	$\sum_i \sum_j Y^2_{ij} - \sum Y^2_{i.}/n$		
Env. (Linear)	1	$\frac{1}{v} (\sum_j Y_{.j} I_j)^2 \sum_j I^2_j$		
V x Env(Linear)	(v-1)	$\sum_i \left[(\sum_j Y_{ij} I_j)^2/\sum_j I^2_j\right]$ - Env (linear) S.S.	MS_2	MS_2/MS_3
Pooled deviation	v(n-2)	$\sum_i \sum_j \delta^2_{ij}$	MS_3	
Variety-1	(n-2)	$\left[\sum_j Y^2_{ij} - \frac{(Y_{1.})^2}{n}\right] - (\sum_j Y_{ij} I_j)^2/\sum_j I^2_j$		
Variety-V	(n-2)	$\left[\sum_j Y^2_{vj} - \frac{(Y_{v.})^2}{n}\right] - (\sum_j Y_{vj} I_j)^2/\sum_j I^2_j = \sum_j \delta^2_{vj}$		
Pooled error	n(r-1)(v-1)			

where, n = No.of environments

v = No.of genotypes

r = No.of replications

cf = correction factor

In this model the total sum of squares has been partitioned into (a) SS due to genotypes (b) SS due to environments and genotype x environment (linear) and (c) pooled error. The sum of squares due to environments plus genotype x environment (linear) has been further partitioned into (a) SS due to environments linear, (b) SS due to genotype x environment linear and (c) pooled deviation. Furthermore, the SS due to pooled deviation has been divided into deviation from regression due to each genotype.

3.3.5. Stability analysis

The stability analysis was carried out employing the linear regression model suggested by Eberhart and Russell (1966) and the model is presented below.

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

where, Y_{ij} = The mean of the $_i$th genotype at $_j$th environment

($i = 1, 2, 3......24$; $j = 1, 2, 3, 4, 5, 6$)

μ_i = The mean of $_i$th genotype over all the environment

β_i = The regression coefficient of the $_i$th genotype on the environmental index which measures the response of the $_i$th genotype to varying environments.

I_j = The environmental index obtained as the deviation of mean of all the genotypes at the $_j$th environment from the grand mean.

δ_{ij} = Deviation from the regression of the $_i$th genotype at $_j$th environment.

3.3.6. Stability parameters

The mean (μ), the regression coefficient (bi) and the mean square deviation from linear regression line (S^2 di) are the three stability parameters proposed by Eberhart and Russell (1966) in their stability model. These parameters were computed using following formulae.

$$\mu_i \text{ (Mean)} = \sum_j Y_{ij}/n$$

$$\text{bi (regression coefficient)} = \sum_j Y_{ij} I_j / \sum_j I^2_j \text{ and}$$

$$S^2\text{di (deviation from the regression coefficient)} = \left[\sum_j \delta^2_{ij}/(n-2)\right] - (S^2e/r)$$

where, n = number of environments.

Y_{ij} = Performance of $_i$th genotype at $_j$th environment

$\sum_j \delta^2_{ij}$ = Sum of squares of deviations from the regression line.

S^2e/r = Estimate of pooled error.

I_j = Environmental index (i.e., Grand mean - Environmental mean)

3.3.7. 'F' and 't' tests

Appropriate 'F' and 't' tests were used as per the model illustrated above to find out the significance of various stability parameters viz., mean, regression coefficient and deviation from regression.

(a) In order to test the significance of the differences among variety, means the appropriate 'F' test is defined as:

$$F = MS_1/MS_3$$

(b) To test that the varieties do not differ for their regression on the environmental index the appropriate 't' test is defined as:

$$t = \frac{b_i - 1}{SE(b)} \quad \text{Where } SE(b) = \sqrt{\frac{\Sigma y^2 - \frac{(\Sigma y)^2}{n} - b^2 \Sigma(x-\bar{x})^2}{(n-2) \quad \Sigma(x-\bar{x})^2}}$$

where, y = yield

x = environmental index

n = number of environments

(c) Individual deviation from linear regression is tested as follows:

$$F = \left[(\sum_j \delta^2_{ij})/(S-2) \right] / \text{Pooled error}$$

where, S = No.of environments.

3.3.8. Stable genotype

A variety with unit regression coefficient (b-1) and the deviation not significantly different from zero ($S^2 di=0$) is said to be the stable one.

3.3.9. Correlation coefficient analysis

The correlation coefficients were calculated to determine the degree of association of characters with yield and also among the yield components in each environments. Phenotypic correlation coefficients were compared against 'r' values given in Fisher and Yates (1963) table at (n-2) d.f. at the probability levels of 0.05 and 0.01 to test their significance.

Phenotypic correlations were compared by using the formulae given by Weber and Moorthy (1952).

$$r_p = \frac{\text{Cov } X\ Y_p}{\sqrt{X^2_p \times Y^2_p}}$$

where, r_p is phenotypic correlation.

Cov x Y_p is phenotypic covariance between the characters X and Y.

X^2_p and Y^2_p are the phenotypic variances of the characters X and Y respectively.

3.3.10. Path coefficient analysis

Path coefficient analysis was carried out using the phenotypic correlation coefficients to know the direct and indirect effects of the yield components on yield in each environment as suggested by Wright (1921) and illustrated by Dewey and Lu (1957).

Standard path coefficients which are the standardized partial regression coefficients were obtained by solving the following set of 'P' simultaneous equation through the use of "Doolittle technique" as described by Goulden (1959).

$$P_{01} + P_{02}\, r_{12} + \ldots\ldots\ldots\ldots + P_{0p}\, r_{1p} = r_{01}$$
$$P_{01} + P_{02} \qquad + \ldots\ldots\ldots\ldots + P_{0p}\, r_{2p} = r_{02}$$
$$\vdots$$
$$P_{0p}\, r_{1p} + P_{02}\, r_{2p} + \ldots\ldots\ldots\ldots + P_{0p} = r_{0p}$$

Where, P_{01} , P_{02} ...... P_{0p} are the direct path coefficients of variables 1, 2, ... P on the dependent variable 0. r_{12} , r_{13} .... r_{1p} .... $r_{p(P-1)}$ are the possible correlation coefficients between various independent variables and r_{01} , r_{02} , ... r_{0p} are the correlations between dependent variable and independent variable.

The indirect effect of the $_i$th variable via the $_j$th variable is obtained as (P_{oj} x r_{ij}). The contribution of the remaining unknown factors is measured as the residual factor which is calculated as given below:

$$P^2_{0x} = 1 - (P^2_{01} + 2P_{01} P_{02} r_{12} + 2P_{01} P_{03} r_{13} + ... + P^2_{02} + 2P_{02} P_{03} r_{13} + ... + P^2_{0p})$$

Residual factor = P^2_{0x}

3.3.11. Tests of homogeneity of error-variance

The data obtained from each of the six environment for all the characters were subjected to 'Bartlett's test' to confirm the homogeneity of error variance. Only after confirming this all the data were pooled to estimate genetic variability, correlation coefficients and path coefficients over the environments. In addition this analysis of variance for stability has also been done using pooled data.

DISCUSSION

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of the experiments conducted to study the genetic variability, to assess the performance of genotypes in different environments (seasons), to determine the association of different characters with seed yield, to work out the relative contribution of different traits towards seed yield and mainly to analyse the genotype x environment interactions in order to identify stable genotypes for different characters among twentyfour diverse genotypes of soybean in six environments (viz., May 1988, July 1988, September 1988, December 1988, January 1989 and March 1989) are presented under the following main headings.

1. Variability and other genetic parameters,
2. Association of characters,
3. Path coefficient analysis,
4. Performance of genotypes in different environments,
5. Genotype x Environment interaction and
6. Stability analysis.

4.1. VARIABILITY AND OTHER GENETIC PARAMETERS

The data obtained for the eight quantitative characters in each environment were analysed individually to find out the differences among the twentyfour genotypes and the analysis of variance for each character is presented in Table 4.1. From the table it is very clear that the variance is highly significant for all the eight characters viz., days to 50 per cent flowering, days to maturity, plant height, number of branches per plant, number of clusters per plant, number of pods per plant, 100-seed weight and seed yield per plant in all the six environments.

The genotypic coefficient of variability (GCV), the phenotypic coefficient of variability (PCV), heritability (h^2) and genetic advance (Gs) were computed to know the extent of genetic variability existing in 24 genotypes for the eight quantitative traits.

The GCV, PCV, h^2 and Gs for eight characters in the six environments and over the environments are presented in Table 4.2, illustrated in Figure 4.1 and described in the following paragraphs.

There was little deviation of GCV from PCV for all the eight characters in all the six environments as well as over the environments indicating the reliability of PCV for selecting the genotypes. The GCV for days to 50 per cent flowering ranged from 7.22 to 15.76, the PCV

Table 4.1. Summary of the environmentwise analysis of variance

Environments	Sources	d.f.	Mean sum of squares due to							
			Days to 50 per cent flowering	Days to maturity	Plant height in cm	No.of branches per plant	No.of clusters per plant	No.of pods per plant	100-seed weight (g)	Seed yield per plant (g)
E_1(May 1988)	Replications	2	0.00	0.28	5.35	0.54	6.40	1.20	0.23	0.17
	Treatments	23	37.56**	258.34**	746.43**	2.55**	54.77**	369.53**	21.67**	34.91**
E_2(July 1988)	Replications	2	1.51	0.28	4.34	0.08	0.70	4.05	0.01	0.58
	Treatments	23	25.24**	233.91**	347.90**	2.21**	90.01**	508.12	13.02**	36.35**
E_3(Sept.1988)	Replications	2	1.26	3.87	4.22	0.04	0.42	0.89	0.30	0.11
	Treatments	23	54.35**	225.13**	252.41**	1.10**	17.27**	42.76**	18.80**	2.11**
E_4(Nov.1988)	Replications	2	0.05	2.53	2.86	0.11	0.52	0.30	0.20	0.07
	Treatments	23	159.71**	731.02**	1511.11**	1.67**	105.03**	330.24**	13.78**	17.79**
E_5(Jan.1989)	Replications	2	8.84	0.16	9.12	0.08	0.43	3.06	1.50	0.05
	Treatments	23	169.74**	292.06**	972.57**	1.23**	39.12**	153.45**	13.47**	14.51**
E_6(March 1989)	Replications	2	2.10	21.12	26.34	0.42	7.11	70.51	0.61	3.13
	Treatments	23	49.76**	261.64**	906.43**	1.37**	41.67**	381.42**	20.56**	43.94**

**Significant at 0.01 per cent probability level.
d.f.=Degree of freedom.

Table 4.2. Estimates of phenotypic and genotypic coefficients of variability, heritability and expected genetic advance in respect of eight characters in soybean [*Glycine max* (L.) Merrill]

	GCV	PCV	h^2	GA	GCV	PCV	h^2	GA
	Days to 50% flowering				Days taken for maturity			
May 1988	8.01	8.22	94.90	6.99	8.06	8.07	99.69	19.08
July 1988	7.22	7.59	90.72	5.60	8.84	8.86	99.52	18.13
September 1988	10.08	11.07	82.90	7.72	8.68	8.81	97.10	17.50
November 1988	15.76	15.80	99.49	14.98	13.99	14.18	97.35	31.58
January 1989	13.02	13.19	97.57	15.24	8.62	8.66	99.08	20.20
March 1989	11.53	12.64	83.19	7.41	8.84	9.12	93.88	18.44
Overall	20.33	20.54	97.93	18.09	11.35	11.45	98.21	24.88
	Plant height in cm				No.of branches per plant			
May 1988	36.56	37.10	97.16	31.87	30.79	35.76	74.14	1.55
July 1988	30.79	31.86	93.39	21.19	25.65	29.85	73.84	1.44
September 1988	35.08	38.71	82.12	16.53	81.22	88.37	84.47	1.50
November 1988	58.61	60.41	94.12	44.39	22.47	26.99	69.29	1.19
January 1989	33.64	36.69	84.10	32.99	31.98	35.52	81.06	1.57
March 1989	35.98	36.82	95.49	34.72	34.94	39.45	78.44	1.18
Overall	44.95	46.45	93.63	35.91	45.12	48.47	86.65	2.10
	No.of clusters per plant				No.of pods per plant			
May 1988	28.19	29.88	89.00	8.14	26.35	27.85	89.52	21.22
July 1988	38.63	40.47	91.09	10.60	43.96	44.37	98.18	26.48
September 1988	32.16	34.88	85.03	4.43	26.60	29.04	83.86	6.90
November 1988	45.19	46.45	94.64	11.75	42.50	43.88	93.82	20.71
January 1989	30.17	32.05	88.60	6.86	28.10	30.85	82.07	12.98
March 1989	35.14	38.10	85.08	6.88	34.92	36.83	89.89	21.62
Overall	41.72	43.37	92.55	9.79	46.76	46.37	95.05	25.62
	100 seeds weight (g)				Seed yield per plant (g)			
May 1988	15.68	15.79	98.60	5.49	24.95	25.85	93.12	6.71
July 1988	14.88	15.01	98.31	4.24	42.74	43.39	97.05	7.03
September 1988	19.04	19.26	97.74	5.08	21.65	27.73	60.95	1.23
November 1988	17.28	17.50	97.54	4.34	36.83	40.35	83.30	4.43
January 1989	16.13	18.78	73.80	3.55	34.05	38.65	77.61	3.81
March 1989	15.87	16.08	97.44	5.30	36.69	37.79	94.26	7.58
Overall	20.95	21.35	96.24	6.02	53.19	54.35	95.80	8.59

GCV=Genotypic coefficient of variation.
PCV=Phenotypic coefficient of variation.
h^2=Heritability.
GA=Genetic advance.

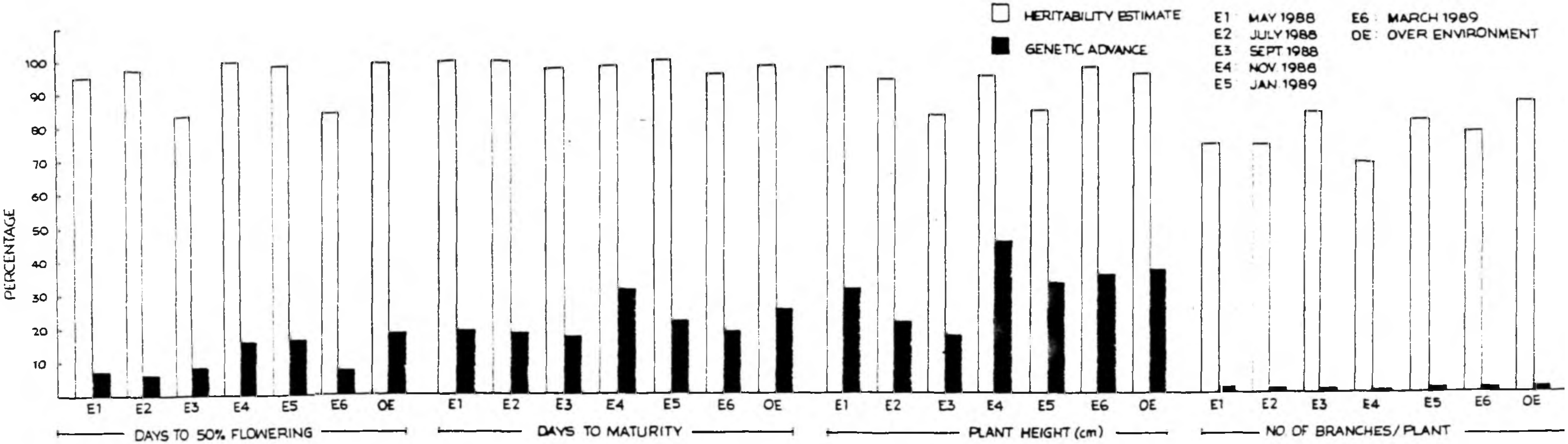

FIG. 4.1 HERITABILITY ESTIMATE AND GENETIC ADVANCE

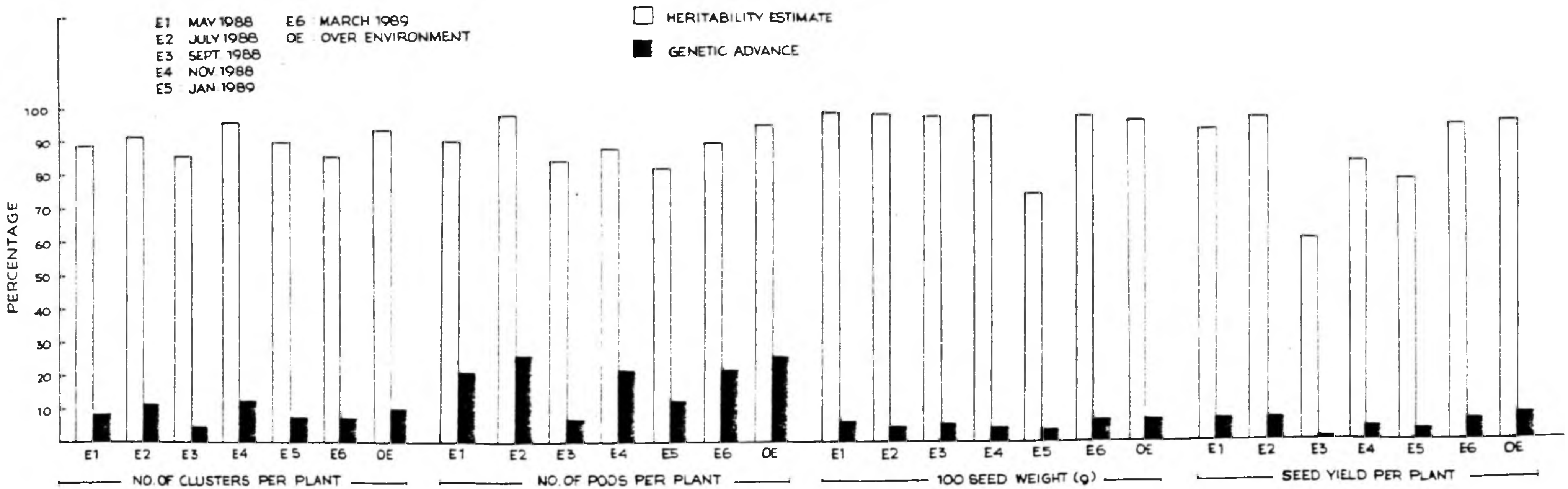
E1 MAY 1988
E2 JULY 1988
E3 SEPT 1988
E4 NOV 1988
E5 JAN 1989
E6 MARCH 1989
OE OVER ENVIRONMENT
HERITABILITY ESTIMATE
GENETIC ADVANCE
PERCENTAGE
100
90
80
70
60
50
40
30
20
10
E1 E2 E3 E4 E5 E6 OE
NO. OF CLUSTERS PER PLANT
E1 E2 E3 E4 E5 E6 OE
NO. OF PODS PER PLANT
E1 E2 E3 E4 E5 E6 OE
100 SEED WEIGHT (g)
E1 E2 E3 E4 E5 E6 OE
SEED YIELD PER PLANT

FIG 4.1 (Cont'd)

ranged from 7.59 to 15.80. The variability is low for this character in all the six environments but it is moderate over the environments (GCV=20.33 and PCV=20.54). Days to maturity had a GCV and PCV range of 5.93 and 6.11 respectively, indicating the lesser variability of the character in all the six environments, same trend has been observed over the environments (GCV=11.35 and PCV=11.45). The GCV for plant height ranged from 30.79 to 58.61, the PCV ranged from 31.86 to 60.41 indicating moderate variability of the character in all the six environments. Variability of this character found to be considerably high over the environments as indicated by GCV (44.95) and PCV (46.45) values. The GCV for number of branches per plant varied from 22.47 to 31.98, the PCV ranged from 26.99 to 35.76 representing higher variability of the character for all the six environments. The same trend has been observed over the environments also (GCV=45.12 and PCV=48.47). The GCV for number of clusters per plant lie between 28.19 and 45.19 whereas PCV ranged between 29.88 and 46.45 indicating the moderate variability of the character in all the six environments, the same trend has been observed over the environments also (GCV=41.72 and PCV=43.37). The GCV varied from 26.35 to 43.96 and PCV ranged between

37.85 ~~to~~ and 44.37 for number of pods per plant, exhibiting less variability of the character over all the six environments, variability was observed to be same over the environments as well (GCV=45.76 and PCV=46.37). The GCV for 100 seed weight ranged from 14.88 to 19.04, the PCV ranged from 15.01 to 19.76 representing lesser variability of the character over all the environments. Whereas, moderate variability has been observed over the environments (GCV=20.09 and PCV=21.35). The GCV of seed yield per plant varied from 21.65 to 42.74, PCV varied from 25.85 to 43.39, indicating comparatively higher variability of the character in all the six environments. The values of GCV and PCV for this character over all the environments narrowly differed indicating environmental effect to a lesser degree (GCV=53.19 and PCV=54.35).

The broad sense heritability was high for all the eight characters in all the six environments except for number of branches per plant (69.29 per cent) in the fourth environment (November, 1988) and for seed yield per plant (60.95 per cent) in the third environment (September, 1988).

The genetic advance was low to moderate (5.60 to 15.24) for days to 50 per cent flowering. While, for days to maturity it ranged from 17.50 to 31.58 indicating moderate to high genetic advance for this trait. Genetic advance for plant height was high in five environments while it was moderate in the third environment (September, 1988). For the number of branches per plant the genetic advance was very low (1.18 to 1.57). The genetic advance was lower for number of clusters per plant, 100-seed weight and seed yield per plant (4.43 to 11.75, 3.55 to 5.49 and 1.23 to 7.58 respectively). Number of pods per plant recorded low to high genetic advance (6.90 to 26.48).

4.2. ASSOCIATION OF CHARACTERS

The phenotypic correlation coefficients were determined to know the extent and nature of relationship between yield and its attributes as well as between the other characters in each of the six environments and over the environments. The correlation coefficient values are presented in Table 4.3 and illustrated in Figure 4.2.

Seed yield was positively and significantly correlated at one per cent level of significance with plant height, number of clusters per plant and number of pods per plant in all the six environments as well as over the environments, whereas with days to 50 per cent

Table 4.24. Phenotypic correlation coefficients for eight quantitative characters of soybean [Glycine max (L.) Merrill] in different environments

	Environments	Days to 50 per cent flowering	Days to maturity	Plant height in cm	No.of branches per plant	No.of clusters per plant	No.of Pods per plant	100 seed weight	Seed yield per plant
Days to 50 per cent flowering	May 1988	1.0000	0.6092**	0.6467**	0.3286**	0.5829**	0.3987**	-0.2134	0.2850
	July 1988	1.0000	0.3295**	0.5129**	0.5445**	0.5232**	0.4305**	-0.2262*	0.3392**
	September 1988	1.0000	0.5617**	0.4317**	0.4197**	0.4221**	0.4982**	0.1514	0.5105**
	November 1988	1.0000	0.8770**	0.6792**	0.3830**	0.6463**	0.6429**	0.1416	0.6454**
	January 1989	1.0000	0.7523**	0.5757**	0.1487	0.5533**	0.5804**	0.1929	0.4921**
	March 1989	1.0000	0.5242**	0.6973**	0.1460	0.6828**	0.7074**	0.0460	0.7182**
	Over Envt.	1.0000	0.6141**	0.4606**	0.3057**	0.3504**	0.1371**	-0.2648**	0.0028
Days to maturity	May 1988		1.0000	0.4850**	0.3404**	0.4964**	0.3484**	0.1247	0.5029**
	July 1988		1.0000	0.2163	0.4023**	0.3498**	0.2216	0.1260	0.2681*
	September 1988		1.0000	0.4498**	0.4509**	0.4164**	0.5634**	0.3222**	0.5203**
	November 1988		1.0000	0.8060**	0.2013	0.7340**	0.7565**	0.1589	0.7890**
	January 1989		1.0000	0.5114**	0.3056**	0.5178**	0.3751**	0.4419**	0.4976**
	March 1989		1.0000	0.5815**	-0.0005	0.5439**	0.5638**	0.3063**	0.7588**
	Over Envt.		1.0000	0.6049**	0.3455**	0.5371**	0.4675**	0.1903**	0.4710**
Plant height in cm	May 1988			1.0000	0.1347	0.6284**	0.7132**	-0.5458**	0.3384**
	July 1988			1.0000	0.4505**	0.7212**	0.6862**	-0.4255**	0.4733**
	September 1988			1.0000	0.7221**	0.9231**	0.8330**	-0.2338**	0.6131**
	November 1988			1.0000	0.1021	0.9033**	0.9044**	-0.1105	0.7791**
	January 1989			1.0000	0.4928**	0.8815**	0.7941**	0.1527	0.6942**
	March 1989			1.0000	0.0343	0.8662**	0.8198**	-0.1721	0.6921**
	Over Envt.			1.0000	0.2950**	0.7008**	0.6707**	-0.0516	0.5049**
No.of branches per plant	May 1988				1.0[illegible]	0.5189**	0.3950**	0.0733	0.5248**
	July 1988				1.0[illegible]	0.6277**	0.5440**	-0.0153	0.5816**
	September 1988				1.0000	0.7259**	0.5898**	-0.1386	0.4475**
	November 1988				1.0000	0.0965	0.0291	-0.0533	0.0321
	January 1989				1.0000	0.6412**	0.3837**	-0.1213	0.2867*
	March 1989				1.0000	0.2323*	0.2905*	0.2191	0.1704
	Over Envt.				1.0000	0.5920**	0.4353**	-0.0180	0.3653**
No.of clusters per plant	May 1988					1.0000	0.7991**	-0.3952**	0.6000**
	July 1988					1.0000	0.9443**	-0.2608*	0.8541**
	September 1988					1.0000	0.8700**	-0.2961*	0.5681**
	November 1988					1.0000	0.9635**	-0.2672*	0.8296**
	January 1989					1.0000	0.8964**	0.0965	0.7464**
	March 1989					1.0000	0.9236**	-0.2055	0.7042**
	Over Envt.					1.0000	0.8456**	-0.0633	0.6608**
No.of pods per plant	May 1988						1.0000	-0.4130**	0.7229**
	July 1988						1.0000	-0.2712*	0.8998**
	September 1988						1.0000	-0.1651	0.6680**
	November 1988						1.0000	-0.2338*	0.8655**
	January 1989						1.0000	0.0983	0.8073**
	March 1989						1.0000	-0.1545	0.7846**
	Over Envt.						1.0000	0.1932**	0.8816**
100 seed weight	May 1988							1.0000	0.2560*
	July 1988							1.0000	0.1032
	September 1988							1.0000	0.4267**
	November 1988							1.0000	0.1075
	January 1989							1.0000	0.4950**
	March 1989							1.0000	0.2962*
	Over Envt.							1.0000	0.5402**
Seed yield per plant	May 1988								1.0000
	July 1988								1.0000
	September 1988								1.0000
	November 1988								1.0000
	January 1989								1.0000
	March 1989								1.0000
	Over Envt.								1.0000

*Significant at 0.05 per cent probability level.
**Significant at 0.01 per cent probability level.

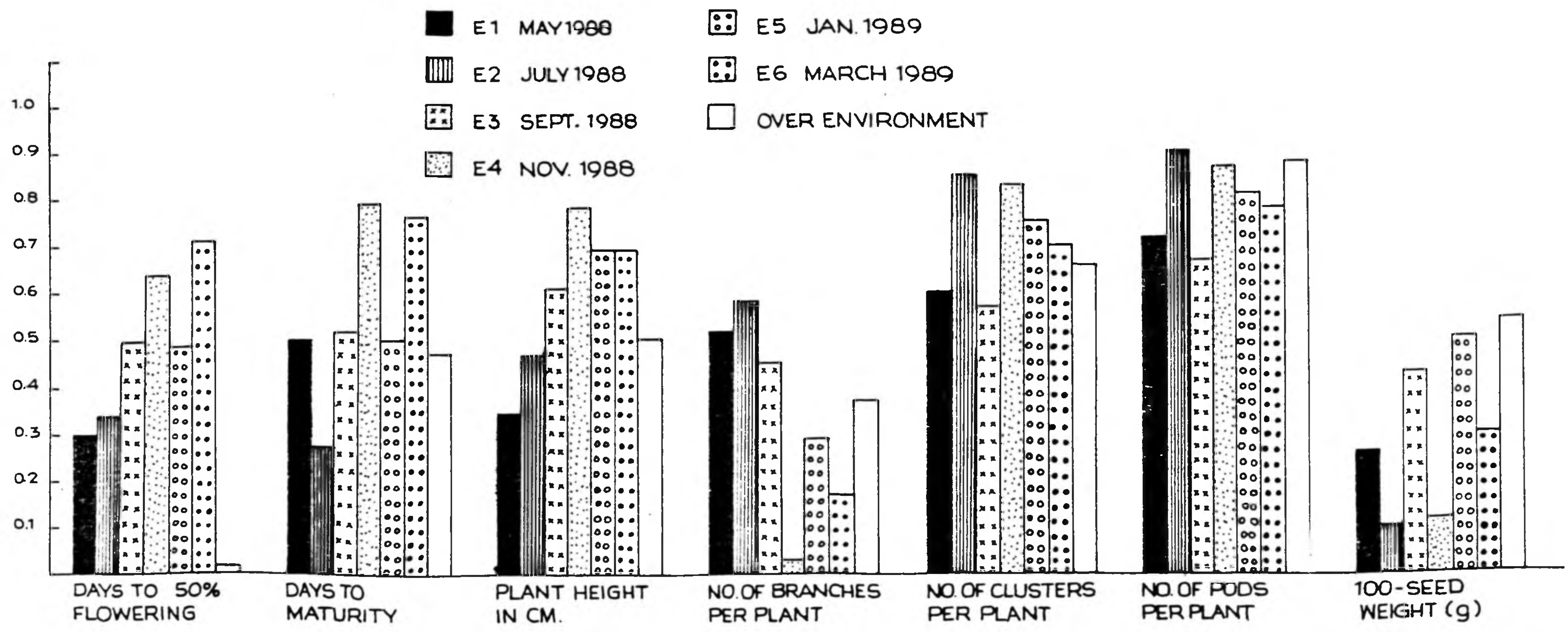

FIG. 4.2 PHENOTYPIC CORRELATION OF DIFFERENT CHARACTERS WITH SEED YIELD PER PLANT (g).

flowering it was significant at 5 per cent in the first environment (May, 1988), and not significant over the environments while for the remaining environments it was significant at one per cent. The correlation value with days to maturity was significant at 5 per cent in the second environment (July, 1988). Whereas it was significant at one per cent level in the remaining five environments and over the environments. Number of branches per plant was correlated at one per cent level in first three environments and over the environments, whereas it was significant at 5 per cent level in the fifth environment (January, 1989) and for the remaining environments namely fourth (November, 1988) and sixth (March, 1989) it was not significant. Hundred seed weight was correlated at one per cent level of significance in third environment (September, 1988), fifth environment (January, 1989) and over the environments. While the significance was at 5 per cent in first (May, 1988) and sixth environment (March, 1989), but for second (July, 1988) and fourth environment (November, 1988) it was not significant.

Days to 50 per cent flowering was significantly and positively correlated with days to maturity, plant height, number of branches per plant, number of pods per plant in all the six environments except with number of branches per plant in fifth environment (January, 1989) and sixth environment (March, 1989). While it was found significant at 5 per cent level with 100 seed weight in second environment (July, 1988) and in rest of the environments it was not significant. Over the environments the correlation values for this character were significant at one per cent for six characters (days to 50 per cent flowering, days to maturity, plant height, number of branches per plant, number of clusters per plant, number of pods per plant and 100 seed weight).

Days to maturity was significantly associated at one per cent level with plant height, number of branches per plant, number of clusters per plant and number of pods per plant in first environment (May, 1988); with number of branches and clusters in second environment (July, 1988); with plant height, number of branches per plant, clusters per plant, pods per plant and 100 seed weight in the third (September, 1988), fifth (January, 1989) and over the environments; with plant height, number of clusters per plant and number of pods per plant in the fourth environment (November, 1988); with plant height, number of clusters per plant, pods per plant and 100 seed weight in the sixth environment (March, 1989).

Plant height was significantly and positively associated with number of branches per plant, clusters per plant and pods per plant at one per cent level of significance in second environment (July, 1988), third environment (September, 1988), fourth environment (November, 1988) and over the environments. While it was negatively and significantly correlated with 100 seed weight in the first three environments (May, 1988; July, 1988 and September, 1988) and it was not significant in other three environments (November, 1988; January, 1989 and March, 1989) and over the environments. In the first four and sixth environments it was not significant with number of branches per plant.

Number of branches per plant was significantly correlated with number of clusters per plant and number of pods per plant in all the environments except in the fourth environment (November, 1988).

Number of clusters per plant was significantly and positively correlated with number of pods per plant in all the environments including over the environments, the relation was negative with 100 seed weight being significant in first four environments (May, 1988; July, 1988; September, 1988 and November, 1988) and not significant in the remaining environments.

The association between number of pods per plant and 100 seed weight was erratic. It was significant and negative in first (May, 1988), second (July, 1988) and fourth (November, 1988) environments, negative and non-significant in third and sixth environments, positive and non-significant in the fifth environment (January, 1989), positive and significant over the environments.

4.3. PATH COEFFICIENT ANALYSIS

The path coefficient analysis at phenotypic level was worked out to determine the direct and indirect contribution of different characteristics to the seed yield in all the six environments as well as over the environments. The nature and extent of direct and indirect contributions of different characteristics (days to 50 per cent flowering, days to maturity, plant height, number of branches per plant, clusters per plant, pods per plant and 100 seed weight) to seed yield in six different environments [May, 1988 (E_1); July, 1988 (E_2); September, 1988 (E_3); November, 1988 (E_4); January, 1989 (E_5); and March, 1989 (E_6)] and over the environments were presented in Table 4.4; illustrated in Figure 4.3 and the same has been described in the following paragraphs.

Table 4.4 . Path coefficient analysis showing the direct and indirect effects of different characters on seed yield in soybean [Glycine max (L.) Merrill] at phenotypic level

Seasons	X_1	X_2	X_3	X_4	X_5	X_6	X_7	Phenotypic correlations with seed yield
May 1988	-0.0395	0.0621	-0.0628	0.0152	0.0853	0.0532	-0.1285	0.2850
July 1988	0.0099	-0.0069	0.0755	0.0399	0.0493	0.4144	-0.0919	0.3392
Sept.1988	0.1050	-0.1286	0.1620	0.0095	-0.0134	0.2766	0.0996	0.5105
Nov.1988	-0.2224	0.2999	-0.2653	0.0191	0.2072	0.5602	0.0472	0.6454
Jan.1989	-0.1394	0.0819	0.0203	-0.0004	0.0127	0.4425	0.0751	0.4921
March 1989	0.1469	0.1073	0.0479	-0.0125	0.0890	0.5047	0.0159	0.7182
Over Envt.	-0.0427	0.0472	-0.0225	0.0080	-0.0060	0.1123	-0.0934	0.0028
May 1988	-0.0241	0.1019	-0.0471	0.0157	0.0726	0.3087	0.0751	0.5029
July 1988	0.0033	-0.0210	-0.0318	-0.0295	0.0329	0.2133	0.0419	0.2681
Sept.1988	0.0590	-0.2290	0.1688	0.0102	-0.0132	0.3127	0.2119	0.5203
Nov.1988	0.1950	0.3419	-0.3154	0.0100	0.2353	0.6592	0.0530	0.7893
Jan.1989	-0.1011	0.1130	0.0180	-0.0009	0.0105	0.2860	0.1720	0.4976
March 1989	0.0770	0.2047	0.0399	0.0001	-0.0709	0.4022	0.1057	0.7588
Over Envt.	-0.0262	0.0768	0.0296	0.0090	-0.0092	0.3830	0.0671	0.4710
May 1988	-0.0255	0.0494	-0.0971	0.0062	0.1022	0.6318	-0.3287	0.3384
July 1988	0.0051	-0.0045	-0.1471	0.0330	0.0679	0.6605	-0.1416	0.4733
Sept.1988	0.0453	0.1030	0.3752	0.0163	-0.0293	0.4624	-0.1538	0.6131
Nov.1988	-0.1510	0.2756	-0.3913	0.0051	0.2896	0.7880	-0.0368	0.7791
Jan.1989	-0.0802	0.0578	0.0352	0.0014	0.0180	0.6054	0.0595	0.6942
March 1989	0.1024	0.1190	0.0687	-0.0036	-0.1129	0.5849	-0.0594	0.6991
Over Envt.	-0.0197	0.0465	-0.0489	0.0077	-0.0120	0.5495	-0.0182	0.5049
May 1988	-0.0130	0.0347	-0.0131	0.0461	0.0759	0.3499	0.0441	0.5248
July 1988	0.0054	-0.0084	-0.0663	0.0732	0.0591	0.5236	-0.0051	0.5816
Sept.1988	0.0441	-0.1032	0.2709	0.0225	-0.0230	0.3274	-0.0912	0.4475
Nov.1988	-0.0852	0.0688	-0.0400	0.0498	0.0309	0.0254	-0.0177	0.3221
Jan.1989	-0.0207	0.0345	0.0174	-0.0028	0.0131	0.2925	-0.0472	0.2867
March 1989	0.0214	-0.0001	0.0024	-0.1059	-0.0303	0.2072	0.0756	0.1704
Over Envt.	-0.0131	0.0265	-0.0144	0.0261	-0.0102	0.3566	-0.0064	0.3653
May 1988	-0.0230	0.0506	-0.0678	0.0239	0.1463	0.7079	-0.2380	0.6000
July 1988	0.0052	-0.0073	-0.1061	0.0460	0.0942	0.9090	-0.0868	0.8541
Sept.1988	0.0443	-0.0954	0.3463	0.0164	-0.0317	0.4829	-0.1947	0.5681
Nov.1988	-0.1437	0.2510	-0.3535	0.0048	0.3206	0.8395	-0.0891	0.8296
Jan.1989	-0.0827	0.0585	0.0311	-0.0018	0.0204	0.6834	0.0376	0.7464
March 1989	0.1003	0.1113	0.0595	-0.0246	-0.1303	0.6589	-0.0709	0.7042
Over Envt.	-0.0150	0.0413	-0.0342	0.0155	-0.0172	0.6928	-0.0223	0.6608
May 1988	-0.0157	0.0355	-0.0692	0.0182	0.1169	0.8859	-0.2487	0.7229
July 1988	0.0043	-0.0047	-0.1010	0.0398	0.0889	0.9626	-0.0902	0.8998
Sept.1988	0.0523	0.1290	0.3125	0.0133	-0.0276	0.5551	-0.1086	0.6680
Nov.1988	-0.1430	0.2587	-0.3539	0.0015	0.3089	0.8713	-0.0780	0.8695
Jan.1989	-0.0809	0.0424	0.0280	-0.0011	0.0183	0.7624	0.0383	0.8073
March 1989	0.1039	0.1154	0.0563	-0.0308	-0.1203	0.7134	-0.0533	0.7846
Over Envt.	-0.0059	0.0359	-0.0328	0.0144	-0.0145	0.8193	0.0682	0.8816
May 1988	0.0084	0.0127	0.0530	0.0034	-0.0578	-0.3659	0.6022	0.2560
July 1988	-0.0027	-0.0026	0.0626	-0.0011	-0.0246	-0.2611	0.3327	0.1032
Sept.1988	0.0159	-0.0738	-0.0877	-0.0031	0.0094	-0.0916	0.6577	0.4267
Nov.1988	-0.0315	0.0543	0.0432	-0.0027	-0.0857	-0.2037	0.3334	0.1075
Jan.1989	-0.0269	0.0499	0.0054	0.0003	0.0020	0.0749	0.3893	0.4950
March 1989	0.0068	0.0677	-0.0118	-0.0232	0.0268	-0.1102	0.3452	0.2962
Over Envt.	0.0113	0.0146	0.0025	-0.0005	0.0011	0.1583	0.3528	0.5402

X_1=Days to 50 per cent flowering
X_2=Days to maturity
X_3=Plant height (cm)
X_4=Number of branches per plant
X_5=Number of clusters per plant
X_6=Number of pods per plant
X_7=100-seed weight (g)
Note:Underlined figures denote direct effects.

Environments	Residual effect
E_1(May 1988)	0.0862
E_2(July 1988)	0.0484
E_3(Sept.1988)	0.1920
E_4(Nov.1988)	0.1211
E_5(Jan.1989)	0.1653
E_6(March 1989)	0.1390
Overall	0.0775

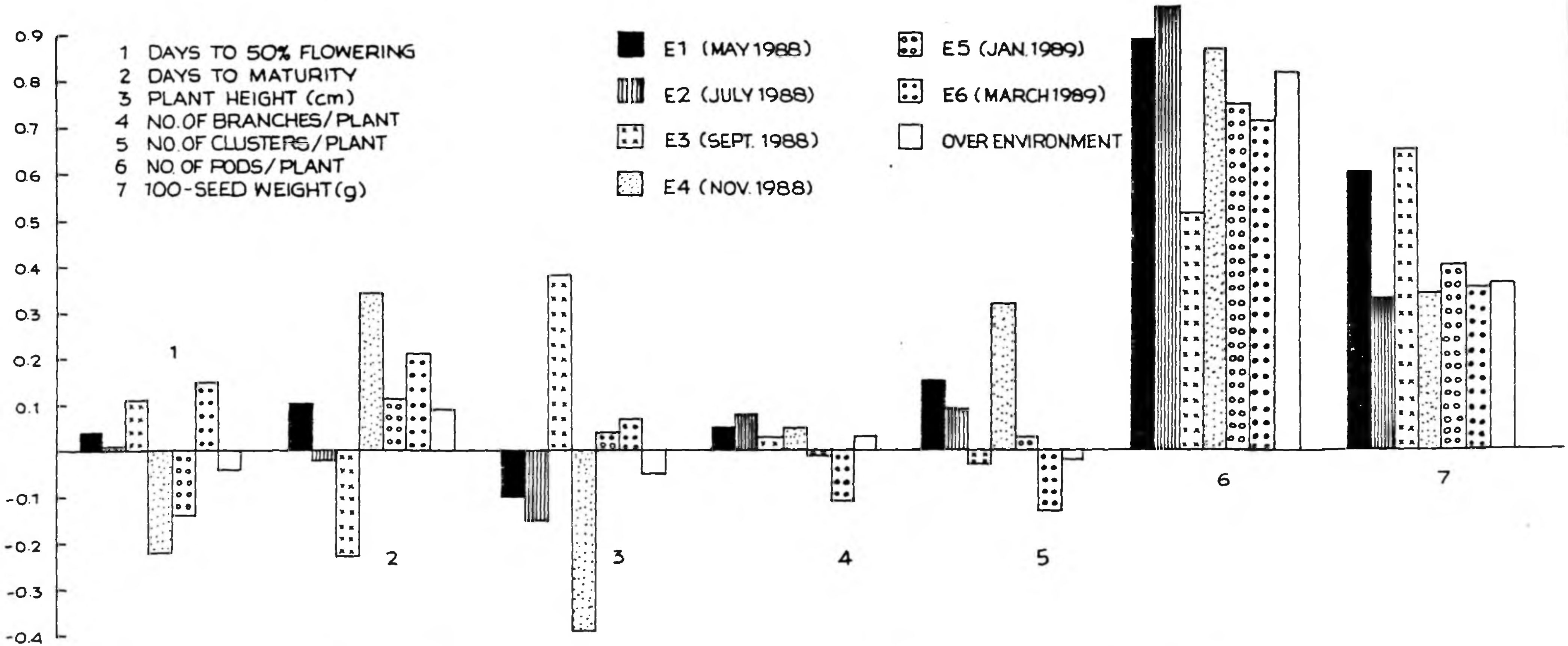

FIG. 4.3 DIRECT INFLUENCE OF DIFFERENT CHARACTERS ON SEED YIELD IN DIFFERENT ENVIRONMENTS

The direct effect of days to 50 per cent flowering on seed yield per plant was relatively high and positive in the sixth environment (0.1469), high and negative in the fourth environment (-0.2224). The indirect effect of this character on seed yield per plant was maximum through number of pods per plant and days to maturity in most of the environments.

Relatively high and positive direct effect of days to maturity on seed yield per plant were observed in the fourth (0.3419), sixth (0.2047), fifth (0.1130), first (0.1019) and over the environments (0.0768), high and negative direct effect was observed in the third environment (-0.2290) and second environment (0.0210). Indirect and positive effect was found to be more through number of pods per plant in most of the environments and it was maximum in the fourth environment (0.6592).

Among the six environments, three environments showed positive direct effect of plant height on seed yield per plant, viz., third environment (0.3752), sixth environment (0.0687) and fifth environment (0.0352) whereas rest of the environments showed negative direct effect of which second environment has got the highest (-0.1471). Over the environments showed negative direct effect on seed yield (-0.0489). In most of the environments and over the environments indirect positive effect of this character on seed yield per plant was observed through number of pods per plant and it was maximum in the fourth environment.

Number of branches per plant had very low direct effect on seed yield per plant compared to other yield attributing characteristics studied. In four out of six environments studied, it has positive direct effect viz., second environment (0.0732), fourth environment (0.0498), third environment (0.0225) and first environment (0.0461) whereas the direct effect in the other two environments were negative viz., fifth environment (-0.0028) and sixth environment (-0.1059). Indirect effect of this character on seed yield per plant was maximum through number of pods per plant in most of the environments and it was found to be maximum in the second environment (0.5236).

The direct contribution of number of clusters per plant on seed yield was positive in four out of six environments which included first (0.1463), second (0.0942), fourth (0.3206) and fifth (0.0204) environments, in the other two environments and over the environments the direct effect was negative as shown in Table 4.4. Its indirect influence on seed yield was observed to be maximum through number of pods per plant in all the environments.

Direct effect of pods per plant on seed yield was found to be positive in all the environments. Its effect on seed yield was highest among all the yield attributes. Its direct contribution to seed yield was maximum in the second environment (0.9626) and minimum in the third environment (0.5551). Its indirect effect through remaining characters were very low and also erratic.

Hundred seed weight showed comparatively high positive direct effect on seed yield in all the environments. Maximum being in the third environment (0.6577) and minimum being in the second environment (0.3327). The indirect contribution of this trait on seed yield through other characters was fairly low and negative in most of the environments. Over the environment it has got fairly low and positive direct effect (0.3528).

4.4. PERFORMANCE OF GENOTYPES IN DIFFERENT ENVIRONMENTS

The data obtained from 24 diverse genotypes of soybean for each of the eight characters were analysed individually to find out the performance of genotypes for all the six environments viz., May, 1988 (E_1), July, 1988 (E_2), September, 1988 (E_3), November, 1988 (E_4), January, 1989 (E_5) and March, 1989 (E_6). After the analysis of variance the genotypes were ranked based on their mean values to express their performances (Table 4.5 to 4.12). In order to facilitate testing the significant difference between any two genotypes the value of critical difference in respect of each character for each environment was furnished along with other statistical parameters like standard error of mean, coefficient of variability, environmental indices etc.

4.4.1. Days to 50 per cent flowering

The environments for days to 50 per cent flowering differed significantly as indicated by varying environmental indices (-0.13 to 13.88). Fifth environment had the maximum range (24 days) and mean value (57.51 days), whereas these two parameters were lowest in the second environment (9.00 and 39.48 days respectively). Considering the overall mean, the genotype KB-78 found to be earliest (36.33 days) whereas the genotype KHSb-2 found to be long durated (51.22 days). Across the environments the relative rankings of the genotypes differed when compared to overall rankings (Table 4.5).

Table 4.5. Mean values and relative rankings of the genotypes under different environments for Days to 50 per cent flowering

Sl. No.	Genotypes	E_1 (May)		E_2 (July)		E_3 (September)		E_4 (November)		E_5 (January)		E_6 (March)		Overall	
		Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
1	Hardee	40.00	5	41.33	5	42.33	7	51.00	5	64.00	4	35.00	8	45.61	8
2	Bragg	41.00	4	35.67	14	33.00	14	39.00	14	47.00	16	30.00	15	37.61	22
3	Monetta	38.00	6	35.00	16	35.00	13	38.00	15	52.33	11	29.33	16	37.94	21
4	KB-78	36.00	7	35.33	16	33.00	14	38.00	15	45.00	17	30.67	14	36.33	23
5	KHSb-2	48.00	1	41.00	6	47.00	1	60.00	1	69.00	1	42.33	3	51.22	1
6	MACS-13	48.00	1	41.33	5	46.00	2	56.00	4	67.00	3	37.67	4	49.33	4
7	MACS-124	48.00	1	43.33	2	44.33	3	46.00	6	64.00	4	36.67	6	47.06	6
8	MACS-125	48.00	1	42.00	4	44.33	3	44.67	8	61.00	6	37.33	5	46.22	7
9	MACS-189	42.00	3	44.00	1	44.33	3	41.00	13	62.00	5	34.00	9	44.56	10
10	UGM-21	42.00	3	40.00	8	43.33	4	45.33	8	54.00	9	32.67	12	42.89	14
11	UGM-30	48.00	1	43.00	3	46.00	2	58.00	3	68.00	2	43.00	1	51.00	2
12	UGM-34	48.00	1	43.00	3	42.33	7	58.00	3	68.00	2	42.67	2	50.33	3
13	PK-416	42.00	3	38.67	11	37.00	10	41.00	13	48.00	15	29.00	17	39.28	20
14	PK-471	46.00	2	40.00	8	42.00	8	43.00	10	59.00	8	34.00	9	44.00	12
15	PK-472	41.00	4	39.00	10	42.67	6	46.00	7	60.00	7	36.00	7	44.11	11
16	KB-32	42.00	3	40.67	7	42.00	8	51.00	5	51.67	12	33.00	11	43.99	13
17	KB-38A	42.00	3	40.00	8	42.33	7	41.00	13	56.00	10	33.00	11	42.39	15
18	KB-60	46.00	2	43.00	3	43.00	5	59.00	2	68.00	2	33.00	11	48.67	5
19	KB-74	46.00	2	39.33	9	42.00	8	50.00	6	59.00	8	33.67	10	45.00	9
20	DS-2	42.00	3	37.00	12	35.00	13	41.00	13	50.00	14	31.67	13	39.44	19
21	DS-76-1-37-1	46.00	2	35.00	16	36.33	11	38.00	15	52.67	11	29.00	17	39.50	18
22	JS-79-277	40.00	5	36.00	13	38.33	9	41.00	13	52.67	11	31.67	13	39.94	17
23	JS-81-303	42.00	3	37.00	12	43.00	5	42.67	11	50.33	13	33.67	10	41.44	16
24	JS-81-714	42.00	3	37.00	12	35.67	12	41.67	12	51.67	12	31.67	13	39.94	17
	Mean	43.50		39.48		40.84		46.26		57.51		34.19		43.63	
	S.Em.	0.45		0.53		1.08		0.30		0.68		1.02			
	CD (5%)	1.25		1.46		2.99		0.83		1.89		2.83			
	CD (1%)	1.64		1.91		3.91		1.08		2.50		3.73			
	C.V.(%)	1.79		2.31		4.57		1.12		2.05		5.18			
	Range	12.00		9.00		14.00		22.00		24.00		14.00			
	EI	-0.13		-4.15		-2.79		2.63		13.88		-9.44			

4.4.2. Days to maturity

Days taken for maturity differed significantly from environment to environment as indicated by varying environmental means and environmental indices (99.33 to 115.12 and -8.03 to 7.76 respectively). Third environment showed maximum range of variation (66.00 days) followed by fourth environment (54.00), fifth environment (40.00), sixth environment (35.00), second environment (34.00) and first environment (31.00). Considering the environmental means and environmental indices third environment was found to be more favourable for early maturity (99.33 days) followed by second environment (99.83), sixth environment (104.57 days), fourth environment (14.08 days), fifth environment (114.25 days) and first environment (115.12 days). Considering the overall means the genotype monetta was found to be earliest in maturity (87.72 days) whereas genotype KHSb-2 found to be long durated (124.33 days). It is interesting to note that the relative rankings of a genotype for this character varied across the environments when compared to overall rankings (Table 4.6).

Table 4.6. Mean values and relative rankings of the genotypes under different environments for Days to maturity

Sl. No.	Genotypes	E_1 (May) Mean	Rank	E_2 (July) Mean	Rank	E_3 (September) Mean	Rank	E_4 (November) Mean	Rank	E_5 (January) Mean	Rank	E_6 (March) Mean	Rank	Overall Mean	Rank
1	Hardee	120.00	4	113.00	2	109.00	3	124.00	5	127.00	3	111.33	5	117.39	5
2	Bragg	121.00	3	116.00	1	99.00	9	105.67	11	112.00	14	107.33	8	110.17	9
3	Monetta	92.00	11	79.00	15	82.00	14	92.33	20	98.00	16	83.00	17	87.72	24
4	KB-78	92.00	11	86.00	14	80.33	15	95.00	19	98.00	16	94.00	15	90.89	23
5	KHSb-2	120.00	4	113.00	2	118.00	1	146.00	1	132.00	1	117.00	2	124.33	1
6	MACS-13	123.00	1	106.00	5	116.00	2	119.00	6	125.00	4	118.00	1	117.83	4
7	MACS-124	119.00	5	104.00	6	100.67	8	114.00	8	115.33	9	112.00	4	110.83	8
8	MACS-125	121.00	3	108.00	4	102.33	7	117.00	7	114.00	12	112.00	4	112.44	7
9	MACS-189	104.00	10	93.00	13	99.00	9	110.00	10	113.00	13	98.67	12	102.94	20
10	UGM-21	104.00	10	95.00	11	93.33	12	99.00	17	100.00	15	94.00	15	97.56	21
11	UGM-30	122.00	2	103.00	7	105.67	5	143.00	2	125.00	4	114.33	2	118.83	2
12	UGM-34	122.00	2	101.00	9	107.00	4	142.00	3	124.33	5	112.00	4	118.06	3
13	PK-416	116.00	6	103.00	7	99.00	9	100.33	15	116.00	8	102.00	10	106.06	15
14	PK-471	120.00	4	94.00	12	99.00	9	105.67	11	114.33	11	105.33	9	106.39	13
15	PK-472	122.00	2	93.00	13	99.00	9	101.67	13	112.00	14	112.00	4	106.61	12
16	KB-32	115.00	7	93.00	13	99.00	9	105.00	12	113.00	13	95.33	14	103.39	19
17	KB-38A	111.00	8	96.00	10	96.00	10	105.00	12	115.00	10	98.67	12	103.61	18
18	KB-60	119.00	5	110.00	3	100.67	8	130.00	4	128.00	2	97.33	13	114.17	6
19	KB-74	111.00	8	101.00	9	99.00	9	112.00	9	113.00	13	98.67	12	105.78	16
20	DS-2	119.00	5	96.00	10	94.00	11	101.33	14	118.00	6	109.67	6	106.33	14
21	DS-76-1-37-1	123.00	1	103.00	7	94.00	11	98.00	18	117.00	7	107.67	7	107.11	11
22	JS-79-277	120.00	4	102.00	8	99.00	9	100.00	16	114.00	12	117.33	2	108.10	10
23	JS-81-303	105.00	9	93.00	13	89.00	13	95.00	19	98.00	16	93.00	16	95.50	22
24	JS-81-714	122.00	2	95.00	11	104.00	6	105.00	12	100.00	15	99.00	11	104.17	17
	Mean	115.12		99.83		99.33		111.08		114.25		104.57		107.37	
	S.Em.	0.29		0.36		0.86		1.48		0.55		1.36			
	CD (5%)	0.82		0.99		2.38		4.10		1.53		3.77			
	CD (1%)	1.08		1.29		3.14		5.38		2.01		4.94			
	C.V.(%)	0.44		0.62		1.50		2.30		0.83		2.25			
	Range	31.00		34.00		66.00		54.00		40.00		35.00			
	EI	7.76		-7.53		-8.03		3.72		6.88		-2.80			

4.4.3. Plant height in cm

The environments for plant height differed significantly as indicated by varying environmental indices ranged from -14.83 to 11.82 and environmental means ranged between 25.24 and 51.90. Fourth environment showed maximum range of variation (87.60 cm) followed by fifth environment (79.13 cm), first environment (73.00 cm), sixth environment (71.07 cm), second environment (53.07 cm) and third environment (35.83 cm). Considering the environmental mean and environmental indices fifth environment found to be more favourable for high plant height (51.90 cm). Considering the overall means of the genotypes, the genotype UGM-34 found to be tallest (82.47 cm) whereas genotype KB-78 found to be dwarfest (18.24 cm). Across the environments the relative rankings of the genotypes differed significantly when compared to the overall rankings (Table 4.7).

4.4.4. Number of branches per plant

The environments for number of branches per plant differed significantly as indicated by environmental means and environmental indices ranged from 0.97 to 3.16 and -1.45 to 0.73 respectively. The maximum range of variation was observed in the first environment (3.67)

Table 4.7. Mean values and relative rankings of the genotypes under different environments for Plant height in cm

Sl. No.	Genotypes	E_1 (May)		E_2 (July)		E_3 (September)		E_4 (November)		E_5 (January)		E_6 (March)		Overall	
		Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
1	Hardee	41.20	11	25.67	22	22.20	14	40.43	8	46.17	12	46.13	10	36.97	12
2	Bragg	29.20	20	28.27	16	18.40	21	21.47	20	47.03	11	37.43	17	30.30	21
3	Monetta	29.00	21	25.96	21	16.60	23	18.80	22	36.33	21	30.53	23	26.21	23
4	KB-78	18.20	24	13.20	23	15.17	24	14.77	23	27.17	24	20.93	24	18.24	24
5	KHSb-2	55.73	4	39.10	5	39.90	3	55.17	3	69.87	3	63.20	5	53.33	3
6	MACS-13	49.67	7	38.20	7	24.37	10	35.50	9	44.03	15	44.00	12	39.29	10
7	MACS-124	51.93	6	35.00	12	24.93	8	54.67	4	62.50	5	68.73	3	49.63	5
8	MACS-125	57.33	9	37.40	9	26.67	6	51.40	5	66.13	4	64.40	4	50.56	4
9	MACS-189	44.67	10	40.53	4	24.33	11	35.50	9	47.47	10	36.30	20	38.13	11
10	UGM-21	37.40	14	38.27	6	30.33	4	45.33	7	58.97	6	48.10	8	43.07	8
11	UGM-30	72.73	2	57.17	2	51.00	1	97.50	2	106.30	1	90.13	2	79.14	2
12	UGM-34	91.20	1	66.27	1	50.00	2	102.37	1	93.00	2	92.00	1	82.47	1
13	PK-416	28.80	22	27.73	19	24.67	9	23.83	16	40.63	20	40.60	14	31.04	19
14	PK-471	33.93	17	30.96	13	21.83	15	23.60	18	42.53	18	37.03	19	31.65	17
15	PK-472	36.00	15	27.50	2	19.43	18	25.37	14	35.90	23	32.53	22	29.46	22
16	KB-32	32.73	19	30.80	14	23.63	13	24.93	15	44.37	14	37.33	18	32.30	15
17	KB-38A	38.20	13	28.80	15	17.50	22	29.23	12	43.47	16	45.77	11	33.82	13
18	KB-60	53.40	5	36.83	10	25.83	7	50.03	6	57.20	7	40.27	15	43.93	7
19	KB-74	28.00	13	27.77	18	21.50	16	23.80	17	41.67	19	40.53	9	31.54	18
20	DS-2	45.13	9	44.57	3	29.67	5	35.17	10	55.33	8	58.03	6	44.65	6
21	DS-76-1-37-1	33.33	18	27.60	20	18.50	20	26.70	13	45.57	13	43.10	13	32.38	14
22	JS-79-277	47.40	8	37.93	8	23.87	12	31.53	11	55.20	9	53.43	7	41.56	9
23	JS-81-303	34.93	16	36.03	11	19.73	17	20.83	21	36.00	22	34.73	21	30.38	20
24	JS-81-714	40.20	12	28.20	17	18.83	19	22.17	19	42.90	17	39.20	16	31.92	16
	Mean	42.93		34.57		25.24		37.90		51.90		47.93		40.08	
	S.Em.	1.55		1.63		2.38		3.20		4.38		2.16			
	CD (5%)	4.30		4.53		6.61		8.88		12.15		6.00			
	CD (1%)	5.64		5.95		8.68		11.67		15.97		7.88			
	C.V.(%)	6.25		8.19		16.37		14.64		14.63		7.82			
	Range	73.00		53.07		35.83		87.60		79.13		71.07			
	EI	2.85		-5.51		-14.83		-2.18		1182		7.85			

and minimum was in sixth environment (2.77). Considering the environmental means and environmental indices second environment found to be more favourable for higher number of branches per plant (3.16). Considering the overall means of the genotypes the genotype KB-60 found to produce more number of branches per plant (3.53) whereas the genotype KB-78 found to produce less number of branches per plant (1.46). The other genotypes fell inbetween. Across the environments the relative rankings of the genotypes differed compared to the overall rankings (Table 4.8).

4.4.5. Number of clusters per plant

The maximum range of variation in respect of this character was observed in the fourth environment (23.04), while the minimum was in third environment (9.67) but, the environmental mean in first environment was maximum (14.85) and it was minimum in the third environment (7.25). Similarly when environmental indices were considered, first environment was found to be favourable for the expression of this character with a maximum environmental index of 3.01, while the third environment proved the other way with minimum environmental index of -4.59. Considering the overall means of the genotypes the genotype UGM-30 was found to bear maximum number of

Table 4.8. Mean values and relative rankings of the genotypes under different environments for No.of branches per plant

Sl. No.	Genotypes	E_1 (May)		E_2 (July)		E_3 (September)		E_4 (November)		E_5 (January)		E_6 (March)		Overall	
		Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
1	Hardee	4.20	2	3.07	11	1.23	6	3.70	4	3.20	6	1.80	13	2.87	7
2	Bragg	3.60	4	2.47	15	0.00	16	2.47	19	2.73	10	2.20	7	2.24	16
3	Monetta	0.93	21	2.07	18	0.00	16	2.63	17	2.73	10	1.03	19	1.57	23
4	KB-78	1.20	20	1.73	20	0.67	11	2.07	22	1.90	14	1.20	18	1.46	24
5	KHSb-2	3.13	9	4.07	4	2.17	3	2.80	16	3.83	3	2.77	1	3.13	4
6	MACS-13	3.50	6	4.40	3	1.67	4	4.30	2	2.50	11	2.07	9	3.07	5
7	MACS-124	1.67	18	2.33	17	0.83	8	3.33	7	1.67	17	0.47	20	1.72	20
8	MACS-125	2.40	15	3.53	17	0.80	9	2.13	21	1.50	18	0.00	21	1.73	19
9	MACS-189	3.67	3	3.40	8	0.80	9	3.13	11	1.80	15	2.53	3	2.56	11
10	UGM-21	3.07	10	3.60	6	1.67	4	3.30	8	4.00	2	2.30	5	2.99	6
11	UGM-30	3.07	10	4.47	2	2.33	2	1.83	23	4.43	1	2.73	2	3.14	3
12	UGM-34	2.80	12	3.40	8	3.17	1	4.13	3	4.00	2	2.00	10	3.25	2
13	PK-416	2.67	13	3.53	7	0.60	12	3.33	7	2.90	8	1.80	13	2.47	12
14	PK-471	3.33	8	3.20	9	0.30	13	3.20	9	1.43	19	1.93	11	2.23	17
15	PK-472	1.53	19	2.40	16	0.17	15	2.53	18	2.03	13	1.57	16	1.70	21
16	KB-32	2.87	11	3.10	10	0.70	10	3.40	6	3.40	5	2.13	8	2.60	9
17	KB-38A	3.53	5	3.40	8	0.20	14	3.50	5	2.93	7	2.53	3	2.68	8
18	KB-60	4.60	1	5.27	1	1.50	5	5.10	1	2.27	12	2.47	4	3.53	1
19	KB-74	3.67	3	3.00	12	0.30	13	3.19	10	1.70	16	2.27	6	2.35	14
20	DS-2	2.33	16	2.80	13	0.80	9	3.03	14	3.63	4	1.33	17	2.32	15
21	DS-76-1-37-1	3.40	7	2.73	14	1.67	4	3.07	13	2.77	9	1.87	12	2.58	10
22	JS-79-277	2.40	15	2.33	17	0.83	8	2.97	15	2.03	13	2.07	9	2.10	18
23	JS-81-303	2.53	14	3.67	5	1.00	7	3.10	12	2.50	11	1.60	15	2.40	13
24	JS-81-714	1.93	17	1.93	19	0.00	16	2.17	20	1.80	15	1.73	14	1.50	22
	Mean	2.83		3.16		0.97		3.10		2.65		1.85		2.43	
	S.Em.	0.29		0.28		0.20		0.27		0.24		0.19			
	CD (5%)	0.82		0.77		0.55		0.75		0.67		0.53			
	CD (1%)	1.08		1.00		0.72		0.98		0.87		0.69			
	C.V.(%)	18.01		15.17		24.19		15.10		15.09		17.92			
	Range	3.67		3.54		3.17		3.27		3.00		2.77			
	EI	0.40		0.73		-1.45		0.67		0.23		-0.58			

clusters per plant (23.61), while the genotype KB-78 beared minimum number of clusters per plant (6.51). Across the environments, the relative rankings of the genotypes differed when compared to the overall rankings (Table 4.9).

4.4.6. Number of pods per plant

There was a maximum range of variation for this character in second environment (63.10) while it was minimum in the third environment (16.67). However, the highest environmental mean was in the first environment (41.32) and the lowest was in the third environment (13.76). First environment found to have the favourable conditions for the expression of this character as indicated by highest environmental index value of 13.80, whereas the third environment proved to be on the other side with an environmental index of -13.76. On overall genotypic mean basis, the genotype UGM-30 found to produce maximum number of pods per plant (53.44) followed by UGM-34 (44.39) and KHSb-2 (38.36). Whereas the genotype KB-78 found to produce minimum number of pods per plant (17.45). Most of the genotypes differed very much in their relative rankings across the environments except UGM-30 which ranked first at four environments out of six environments (July, September, January and March)

Table 4.9. Mean values and relative rankings of the genotypes under different environments for No.of clusters per plant

Sl. No.	Genotypes	E_1 (May) Mean	E_1 (May) Rank	E_2 (July) Mean	E_2 (July) Rank	E_3 (September) Mean	E_3 (September) Rank	E_4 (November) Mean	E_4 (November) Rank	E_5 (January) Mean	E_5 (January) Rank	E_6 (March) Mean	E_6 (March) Rank	Overall Mean	Overall Rank
1	Hardee	18.93	5	13.13	12	6.27	15	10.67	3	14.57	5	11.27	8	12.47	8
2	Bragg	11.87	17	8.26	22	4.80	22	7.33	22	11.67	10	9.37	10	8.88	22
3	Monetta	7.13	22	8.13	23	5.20	21	11.00	11	8.53	19	5.53	22	7.59	23
4	KB-78	6.40	23	6.60	24	5.37	20	7.67	21	7.83	21	5.20	23	6.51	24
5	KHSb-2	17.67	7	22.67	2	8.43	3	19.67	3	16.17	3	13.73	3	16.39	3
6	MACS-13	17.73	6	18.00	3	7.93	5	10.80	12	12.43	7	9.33	11	12.71	7
7	MACS-124	15.33	12	11.27	18	7.50	7	12.67	9	11.93	9	12.60	5	11.88	10
8	MACS-125	15.13	13	16.87	4	7.17	9	8.67	19	12.60	6	10.80	9	11.87	11
9	MACS-189	15.47	11	13.60	10	7.60	6	13.73	6	9.37	18	8.13	18	11.32	12
10	UGM-21	16.67	9	15.87	7	7.97	4	13.67	8	14.80	4	12.40	5	13.56	6
11	UGM-30	20.13	4	33.40	1	14.40	2	30.87	1	21.73	1	21.60	1	23.61	1
12	UGM-34	21.13	1	16.40	6	14.47	1	28.43	2	19.73	2	18.67	2	19.81	2
13	PK-416	11.80	18	11.67	16	7.00	10	9.90	15	8.53	19	8.73	14	9.61	18
14	PK-471	14.33	15	11.87	15	5.70	19	9.80	16	10.33	13	8.40	15	10.07	15
15	PK-472	7.60	21	11.60	17	6.40	14	9.23	17	10.37	12	8.33	17	8.92	21
16	KB-32	12.27	16	11.93	11	5.80	18	11.43	10	10.20	15	8.00	19	9.94	16
17	KB-38A	17.00	8	13.20	11	5.70	19	10.43	14	9.70	17	7.90	20	10.65	13
18	KB-60	20.53	2	16.60	5	7.00	10	17.40	4	12.60	6	8.93	13	13.84	5
19	KB-74	15.87	10	11.00	19	7.33	8	19.67	3	6.60	22	7.80	21	9.71	17
20	DS-2	20.47	3	15.40	8	6.60	13	16.57	5	12.40	8	12.93	4	14.06	4
21	DS-76-1-37-1	14.80	14	9.80	21	6.67	12	10.80	12	10.23	14	9.00	12	10.21	14
22	JS-79-277	16.67	9	15.07	9	6.70	11	13.70	7	8.30	20	11.33	7	11.96	9
23	JS-81-303	10.13	20	12.53	13	5.83	17	9.20	18	9.87	16	8.50	15	9.94	19
24	JS-81-714	11.40	19	10.07	20	6.20	16	8.50	20	10.80	11	8.93	13	9.32	20
	Mean	14.85		13.96		7.25		12.97		11.72		10.31		11.84	
	S.Em.	0.85		0.97		0.56		0.81		0.73		0.87			
	CD (5%)	2.35		2.70		1.57		2.23		2.03		2.43			
	CD (1%)	3.09		3.53		2.06		2.94		2.68		3.19			
	C.V.(%)	9.92		12.07		13.51		10.77		10.83		14.71			
	Range	14.00		14.53		9.67		23.04		13.90		16.40			
	EI	3.01		2.12		-4.59		1.13		-0.12		-1.53			

and stood second in the fourth environment and third in the first environment (Table 4.10).

4.4.7. 100 seed weight (g)

The data on range of variation, mean values and the relative rankings of the genotypes under different environments in respect of 100 seed weight are presented in Table 4.11.

The range of variation for the character was maximum in the first environment (9.14), while it was minimum in the second environment (7.50). The environmental mean in the first environment was maximum (17.10) and it was minimum in the fourth environment (12.35). Similarly when environmental indices were considered, first environment was found to be more favourable for the expression of this character with a maximum environmental index of 2.87 while the fourth environment proved the other way (-1.88). Considering the means of each genotypes over the environments the genotype Hardee was found to give maximum 100 seed weight (16.94 g) followed by Bragg (16.41 g) and KHSb-2 (16.31 g). However 100 seeds weight of Bragg (16.41 g) and KHSb-2 (16.31 g) was found to be on par with each other. Minimum 100 seed weight over the environments and

Table 4.10. Mean values and relative rankings of the genotypes under different environments for No.of pods per plant

Sl. No.	Genotypes	E_1 (May) Mean	Rank	E_2 (July) Mean	Rank	E_3 (September) Mean	Rank	E_4 (November) Mean	Rank	E_5 (January) Mean	Rank	E_6 (March) Mean	Rank	Overall Mean	Rank
1	Hardee	55.93	2	20.50	19	13.33	12	18.53	17	29.43	7	35.47	8	28.87	9
2	Bragg	30.73	20	19.40	23	10.53	19	16.23	23	26.53	10	25.20	16	21.44	19
3	Monetta	23.80	24	20.27	20	8.43	23	21.10	11	17.47	20	18.47	23	18.26	22
4	KB-78	27.13	22	16.83	24	9.50	22	17.57	20	16.53	22	17.13	24	17.45	23
5	KHSb-2	53.86	4	42.20	2	14.63	7	42.57	3	30.53	6	46.06	3	38.36	3
6	MACS-13	32.73	19	41.40	3	16.97	3	23.40	10	24.47	12	31.67	11	28.44	11
7	MACS-124	33.60	17	20.67	18	13.20	13	25.20	7	28.60	8	36.53	7	26.30	12
8	MACS-125	39.60	13	38.40	4	16.60	4	18.43	17	30.87	4	31.60	12	29.25	8
9	MACS-189	51.73	5	32.20	8	13.80	9	25.37	5	22.06	15	33.00	10	29.69	6
10	UGM-21	46.60	9	31.53	9	13.67	10	24.43	8	30.33	6	36.73	5	30.55	4
11	UGM-30	55.67	3	79.93	1	25.10	1	52.17	2	42.70	1	65.07	1	53.44	1
12	UGM-34	60.00	1	31.27	10	22.00	2	55.17	1	32.60	2	54.70	2	44.39	2
13	PK-416	30.60	21	19.77	21	13.80	9	18.87	16	15.40	24	21.67	22	20.02	21
14	PK-471	40.93	11	28.23	11	12.50	14	17.87	19	22.30	14	34.13	9	25.99	13
15	PK-472	25.06	23	24.60	14	15.57	6	18.53	17	27.67	9	26.00	15	22.90	17
16	KB-32	34.27	16	22.50	16	13.57	11	19.77	13	18.57	17	22.30	21	21.83	18
17	KB-38A	33.33	18	26.10	13	10.50	20	19.60	15	18.77	16	22.67	20	21.83	18
18	KB-60	51.67	6	32.30	7	12.40	16	25.27	6	26.40	11	23.80	18	28.64	10
19	KB-74	37.33	15	21.83	17	12.47	15	17.27	22	16.60	21	23.00	19	21.42	20
20	DS-2	49.87	7	34.37	6	10.33	21	26.30	4	24.30	13	37.73	4	30.48	5
21	DS-76-1-37-1	44.53	10	19.43	22	10.57	18	19.67	14	18.20	19	27.60	14	23.33	16
22	JS-79-277	48.13	8	34.40	5	16.00	5	24.27	9	16.50	23	36.57	6	29.31	7
23	JS-81-303	38.73	14	27.60	12	10.80	17	20.73	12	18.40	18	24.53	17	23.47	15
24	JS-81-714	39.87	12	22.53	15	14.00	8	17.77	20	31.40	3	29.27	13	25.81	14
	Mean	41.32		29.51		13.76		24.42		24.41		31.70		27.56	
	S.Em.	2.15		1.02		0.93		1.54		1.81		2.14			
	CD (5%)	5.96		2.82		2.57		4.26		5.01		5.94			
	CD (1%)	7.83		3.71		3.37		5.59		6.59		7.80			
	C.V.(%)	9.01		5.98		11.67		10.91		12.83		11.71			
	Range	36.20		63.10		16.67		38.94		27.30		47.94			
	EI	13.80		1.99		-13.76		-3.10		-3.11		4.18			

Table 4.11. Mean values and relative rankings of the genotypes under different environments for 100-seeds weight in gms

Sl. No.	Genotypes	E_1 (May) Mean	Rank	E_2 (July) Mean	Rank	E_3 (September) Mean	Rank	E_4 (November) Mean	Rank	E_5 (January) Mean	Rank	E_6 (March) Mean	Rank	Overall Mean	Rank
1	Hardee	19.43	5	14.70	9	17.20	1	16.27	1	15.30	3	18.77	5	16.94	1
2	Bragg	18.13	10	14.67	10	16.37	3	16.10	2	15.53	2	17.67	10	16.41	2
3	Monetta	16.30	16	12.37	17	10.30	18	9.67	21	8.70	22	13.20	19	11.76	20
4	KB-78	15.13	19	11.13	10	9.47	22	10.07	20	8.40	23	12.20	22	11.07	23
5	KHSb-2	17.60	11	14.50	11	15.30	7	14.83	4	14.93	4	20.70	1	16.31	3
6	MACS-13	14.23	21	14.50	11	14.87	8	10.30	19	12.37	13	18.13	8	14.07	17
7	MACS-124	17.33	13	11.63	19	13.23	12	12.33	11	13.97	6	17.60	11	14.35	15
8	MACS-125	16.20	17	13.60	15	11.87	15	14.17	6	14.50	5	16.93	12	14.54	13
9	MACS-189	14.33	20	12.43	16	10.27	19	8.53	23	10.37	19	14.80	17	11.79	19
10	UGM-21	15.20	18	11.70	18	11.30	17	11.10	16	10.17	21	14.90	16	12.39	18
11	UGM-30	12.13	24	10.67	21	10.23	20	11.03	17	12.40	12	12.23	21	11.45	21
12	UGM-34	12.43	22	9.73	22	10.23	20	10.97	18	10.57	18	12.50	20	11.07	23
13	PK-416	20.10	4	16.17	3	16.33	4	15.20	3	13.37	9	15.17	15	16.06	5
14	PK-471	20.90	2	18.17	1	12.23	14	13.37	7	13.87	7	18.40	6	16.16	4
15	PK-472	20.36	3	15.03	8	16.00	5	14.30	5	11.27	16	18.80	4	15.96	7
16	KB-32	21.27	1	15.06	7	16.50	2	14.17	6	11.13	17	17.70	9	15.97	6
17	KB-38A	18.40	9	15.23	6	13.37	11	11.17	14	11.50	15	19.00	3	14.78	10
18	KB-60	17.47	12	14.13	14	12.73	13	12.23	12	13.20	10	18.37	7	14.69	11
19	KB-74	19.33	6	14.43	12	15.63	6	13.17	9	12.06	14	18.40	6	15.50	9
20	DS-2	12.17	23	12.43	16	11.30	17	9.37	22	10.33	20	11.67	23	11.21	22
21	DS-76-1-37-1	17.20	15	14.16	13	14.07	10	12.40	10	13.57	8	16.70	13	14.68	12
22	JS-79-277	18.50	8	17.13	2	11.60	16	11.13	15	16.33	1	19.40	2	15.68	8
23	JS-81-303	17.30	14	16.10	4	14.30	9	11.37	13	12.77	11	14.70	18	14.42	14
24	JS-81-714	18.97	7	15.43	5	9.53	21	13.20	8	11.50	15	16.32	14	14.16	16
	Mean	17.10		13.96		13.09		12.35		12.46		16.42		14.23	
	S.Em.	0.18		0.15		0.22		0.19		0.69		0.24			
	CD (5%)	0.51		0.42		0.60		0.53		1.91		0.68			
	CD (1%)	0.67		0.54		0.77		0.69		2.50		0.90			
	C.V.(%)	1.85		1.89		2.86		2.68		9.56		2.58			
	Range	9.14		7.50		7.73		7.74		7.93		9.03			
	EI	2.87		-0.27		-1.14		-1.88		-1.78		2.20			

among the genotypes was observed in case of Monetta and UGM-34 (11.07 g) which were on par with UGM-30 (11.45 g) and DS-2 (11.21 g) genotypes. Across the environments the relative rankings of the genotypes for this character found different when compared with overall rankings.

4.4.8. Seed yield per plant (g)

The range of variation for this character was maximum in the first environment (14.84) and minimum in the third environment (3.24). Similarly the environmental mean for this character was highest in the first environment (13.51) and the lowest in the third environment (3.52). First environment was found to be the most ideal environment for the expression of this trait with an environmental index of 5.48 while third environment gave a poor environmental index of -4.48. When overall means of genotypes were considered, the genotype UGM-30 was found to be the maximum seed yielder (12.80 g) followed by KHSb-2 (12.50 g) and Hardee (10.36 g) whereas the genotype KB-78 was found to yield minimum seed yield per plant (3.87 g). Across the environments the relative rankings of the genotypes for this character found, differed when compared to overall rankings (Table 4.12).

Table 4.12. Mean values and relative rankings of the genotypes under different environments for seed yield per plant (g)

Sl. No.	Genotypes	E_1 (May) Mean	Rank	E_2 (July) Mean	Rank	E_3 (September) Mean	Rank	E_4 (November) Mean	Rank	E_5 (January) Mean	Rank	E_6 (March) Mean	Rank	Overall Mean	Rank
1	Hardee	21.17	1	5.67	18	4.40	6	6.10	8	7.80	4	17.00	1	10.36	3
2	Bragg	10.30	21	5.07	21	3.37	10	5.67	11	8.83	3	8.47	17	6.95	19
3	Monetta	6.70	23	5.17	20	2.03	20	3.23	21	2.80	21	4.63	23	4.09	22
4	KB-78	6.33	24	4.00	24	1.83	21	3.93	20	3.03	20	4.07	24	3.87	23
5	KHSb-2	16.83	4	13.77	2	4.60	3	13.43	1	10.27	2	16.10	3	12.50	2
6	MACS-13	9.73	22	13.50	3	3.77	9	4.57	19	6.07	11	13.03	6	8.44	9
7	MACS-124	11.50	19	4.40	23	2.70	18	5.87	9	7.00	8	12.50	7	7.32	13
8	MACS-125	12.20	17	10.70	5	3.30	11	5.43	15	7.67	6	14.30	5	8.93	8
9	MACS-189	14.40	9	8.17	9	3.10	14	5.50	14	4.20	18	9.70	13	7.51	11
10	UGM-21	13.57	13	6.63	14	3.87	8	5.60	12	5.30	14	8.53	16	7.25	14
11	UGM-30	13.67	11	18.53	1	5.07	1	11.57	2	11.40	1	16.70	2	12.82	1
12	UGM-34	15.87	6	4.87	22	4.43	5	11.50	3	7.70	5	15.40	4	9.96	4
13	PK-416	13.10	15	5.80	17	3.90	7	5.87	9	5.63	12	6.07	21	6.73	20
14	PK-471	17.47	3	9.90	6	2.87	16	6.43	7	5.07	15	12.30	9	9.01	7
15	PK-472	10.50	20	7.53	12	4.67	2	5.03	16	6.87	8	10.10	11	7.45	12
16	KB-32	13.63	11	6.93	13	4.57	4	4.87	18	3.03	20	6.23	20	6.54	21
17	KB-38A	13.33	14	8.10	10	3.13	13	5.57	13	4.33	17	8.23	18	7.12	18
18	KB-60	16.57	5	9.57	7	3.57	10	7.90	4	7.37	7	11.27	10	9.37	6
19	KB-74	14.23	10	6.20	16	3.77	9	5.60	12	4.07	19	8.93	15	7.13	17
20	DS-2	12.17	18	7.77	11	2.67	19	6.90	5	4.43	16	9.57	14	7.25	14
21	DS-76-1-37-1	15.23	7	5.50	19	3.27	12	6.69	6	5.32	13	9.97	12	7.66	10
22	JS-79-277	18.10	2	11.03	4	3.07	15	5.57	13	6.27	9	12.43	8	9.41	5
23	JS-81-303	12.73	16	9.13	8	3.77	9	5.80	10	6.23	10	5.73	22	7.23	15
24	JS-81-714	14.97	8	6.53	15	2.73	17	5.00	17	7.37	7	6.60	19	7.20	16
	Mean	13.51		8.10		3.52		6.40		6.17		10.33		8.00	
	S.Em.	0.52		0.35		0.35		0.61		0.65		0.54			
	CD (5%)	1.44		0.96		0.97		1.69		1.80		1.49			
	CD (1%)	1.88		1.26		1.29		2.22		2.37		1.96			
	C.V.(%)	6.67		7.41		17.28		16.46		18.26		9.03			
	Range	14.84		14.53		3.24		10.20		8.60		12.93			
	EI	5.48		0.10		-4.48		-1.60		-1.83		2.33			

Suitable genotypes for different environments (seasons) for various characteristics are summarised and listed in Table 4.13.

4.5. GENOTYPE X ENVIRONMENTAL INTERACTION

The ability of a genotype to produce a narrow range phenotype in different environments can be called as 'stability' (Lewis, 1954). The statistical procedures used to find out the stability of genotypes can be termed as "Stability analysis".

As per the definition of stability according to Lewis (1954), and in general we may conclude that, genotypes will be stable in the absence of the environmental influence as well as genotype x environment interaction and vice-versa, thus identification of and confirmation of the presence of environmental influence and genotype x environment interaction is a pre-requisite for stability analysis.

In the present investigation the magnitude of genotype x environment interaction as well as the influence of environments on genotypes were assessed for each character using the procedure given by Sundararaj et al. (1972) for two way analysis of variance. The summary of analysis of variance showing the significant

Table 4.13. Suitable genotypes (characterwise) for different environments and over all the environments

Sl. No.	Characters	Genotypes with good performance during						Overall (Stable)
		May	July	September	November	January	March	
1	Days to 50 per cent	KB-78	Monetta	KB-78	KB-78	KB-78	Monetta	Monetta
	flowering	Monetta	KB-78	Bragg	Monetta	Bragg	Bragg	KB-74
		Hardee	Bragg	Monetta	Bragg	PK-416	KB-78	JS-81-714
		Bragg	JS-79-277	JS-81-714	DS-76-1-37-1	DS-2	DS-2	-
		MACS-189	JS-81-303	DS-76-1-37-1	JS-79-277	JS-81-303	JS-79-277	-
2	Days to maturity	-	Monetta	KB-78	-	-	Monetta	-
	(a) Early	-	KB-78	Monetta	-	-	-	-
	(Upto 90 days)	-	-	JS-81-303	-	-	-	-
		-	-	-	-	-	-	-
		-	-	-	-	-	-	-
	(b) Medium	Monetta	MACS-189	DS-2	KB-78	KB-78	KB-78	-
	(90-105 days)	KB-78	UGM-21	DS-76-1-37-1	Monetta	Monetta	MACS-189	-
		MACS-189	JS-81-303	KB-38A	UGM-21	UGM-21	UGM-21	-
		UGM-21	PK-472	MACS-189	JS-81-303	JS-81-714	JS-81-303	-
		JS-81-303	UGM-21	UGM-21	DS-76-1-37-1	JS-81-303	JS-81-714	-
	(c) Late	Hardee	MACS-13	UGM-30	Bragg	Bragg	Hardee	-
	(105-120 days)	KHSb-2	Hardee	MACS-13	KB-32	MACS-189	Bragg	-
		KB-38A	Bragg	KHSb-2	KB-38A	MACS-125	KHSb-2	-
		KB-74	KHSb-2	UGM-34	KB-74	PK-416	MACS-13	-
		PK-416	PK-416	MACS-125	JS-81-714	KB-38	MACS-124	-
	(d) Very late	Bragg	-	Hardee	KHSb-2	KHSb-2	-	-
	(120 days)	MACS-13	-	-	UGM-30	MACS-13	-	-
		MACS-125	-	-	UGM-34	UGM-30	-	-
		UGM-30	-	-	Hardee	UGM-34	-	-
		DS-2	-	-	-	KB-60	-	-
3	Plant height (cm)	Bragg	Hardee	Hardee	Bragg	KB-78	Monetta	Monetta
	(a) Dwarf upto	KB-78	Bragg	Bragg	Monetta	-	KB-78	
	30 cm	Monetta	Monetta	Monetta	KB-78	-	-	-
		PK-416	KB-78	KB-78	JS-81-303	-	-	-
		KB-74	PK-416	KB-38A	JS-81-714	-	-	-

Table 4.13 (Contd.)

Sl. No.	Characters	Genotypes with good performance during May	July	September	November	January	March	Overall (Stable)
	(b) Medium	Hardee	KHSb-2	KHSb-2	Hardee	Monetta	Bragg	Hardee
	(30-60 cm)	KHSb-2	MACS-13	UGm-21	KHSb-2	UGM-21	KB-78	Bragg
		MACS-13	MACS-124	UGM-30	MACS.13	JS-81-303	MACS.189	KHSb-2
		KB-32	MACS-125	UGM-34	MACS.189	PK-472	JS-81-303	MACS-13
		DS-76-1-37-1	JS-81-303	-	JS-79-277	PJ-416	PK-472	MACS-189
		-	-	-	-	-	-	UGM-21
	(c) Tall	UGM-34	UGM-34	-	UGM-30	KHSb-2	KHSb-2	PK-416
	60 cm	-	-	-	UGM-34	MACS-124	MACS-125	PK-471
		-	-	-	-	MACS-129	MACS-129	PK472
		-	-	-	-	UGM-30	UGM-30	KB-32
		-	-	-	-	UGM-34	UGM-34	-
4	No.of branches	KB-60	KB-60	UGM-34	KB-60	UGM-30	KHSb-2	KHSb-2
	per plant	Hardee	UGM-30	UGM-30	MACS-13	UGM-34	UGM-30	UGM-21
		KB-74	MACS-13	KHSb-2	UGM-34	KHSb-2	KB-38A	PK-416
		Bragg	KHSb-2	KB-60	Hardee	DS-2	KB-60	JS-81-303
		KB-38A	JS-81-303	Hardee	KB-38A	KB-32	UGM-21	DS-76-1-37-1
5	No.of clusters	UGM-34	UGM-30	UGM-34	UGM-30	UGM-30	UGM-30	MACS-124
	per plant	KB-60	KHSb-2	UGM-30	UGM-34	UGM-34	UGM-34	MACS-189
		DS-2	MACS-13	KHSb-2	KB-74	KHSb-2	KHSb-2	UGM-21
		UGM-30	MACS-125	UGM-21	KB-60	UGM-21	DS-2	DS-2
		Hardeen	KB-60	MACS-13	DS-2	Hardee	MACS-124	KB-38A
6	No.of pods	UGM-34	UGM-30	UGM-30	UGM-34	UGM-30	UGM-30	MACS-189
	per plant	Hardee	KHSb-2	UGM-34	UGM-30	UGM-34	UGM-34	UGM-21
		UGM-21	MACS-13	MACS-13	KHSb-2	JS-81-714	KHSb-2	PK-471
		KHSb-2	MACS-125	MACS-125	DS-2	MACS-125	DS-2	JS-81-303
		MACS-189	JS-79-277	JS-79-277	MACS-189	KHSb-2	UGM-21	KB-38A
7	100 seed weight	KB-32	PK-471	Hardeen	Hardee	JS-79-277	KHSb-2	UGM-21
	(g)	PK-471	JS-79-277	KB-32	Bragg	Bragg	JS-79-277	DS-76-1-37-1
		PK-472	PK-416	Bragg	PK-416	Hardee	KB-38A	-
		PK-416	JS-81-303	PK-416	KHSb-2	KHSb-2	PK-472	-
		Hardee	JS-81-714	PK-472	PK-472	MACS-125	Hardee	-
8	Seed yield per	Hardee	UGM-30	UGM-30	KHSb-2	UGM-30	Hardee	KB-60
	plant (g)	JS-79-277	KHSb-2	PK-472	UGM-30	KHSb-2	UGM-30	MACS-189
		PK-431	MACS-13	KHSb-2	UGM-34	Bragg	KHSb-2	UGM-21
		KHSb-2	JS-79-277	KB-32	KB-60	Hardee	UGM-34	PK-472
		KB-60	MACS-125	UGM-34	DS-2	UGM-34	MACS-125	KB-38A

differences of genotypes, environments and genotypes x environments along with error components are presented in Table 4.14 and the same has been described in the following paragraph.

Twenty four genotypes of soybean were tested in six environments in a randomised block design with three replications. Following two way analysis of variance the mean sum of squares for eight characters in six environments were analysised. The results revealed significant differences among genotypes, environments and genotypes x environments at one per cent level of significance for all the eight characters when their mean sums of squares tested against error sums of squares. But in the other way replications sums of squares found non-significant for all the characters.

Since genotype x environment interaction was found to be significant for all the characters, in order to know the magnitude of predictable and unpredictable sources of variation towards genotype x environments interaction, further partitioning of their total sums of squares was done employing the procedure of Eberhart and Russell (1966), the results of which have been summarised in the Table 4.15 and the same has been described below.

Table 4.14. Summary of two way analysis of variance (characterwise)

Sl. No.	Characters	Mean sum of squares due to				
		Replications (2)	Genotypes (23)	Environments (5)	Genotypes x Environments (115)	Error (286)
1	Days to 50 per cent flowering	0.375	351.919**	4516.750**	28.890**	1.660
2	Days taken for maturity	7.000	1407.478**	3610.300**	118.926**	2.708
3	Plant height in cm	0.563	4056.449**	6693.275**	136.083**	22.098
4	Number of branches per plant	0.389	6.294**	52.621**	1.166**	0.185
5	Number of clusters per plant	6.279	260.254**	550.693**	17.525**	1.967
6	Number of pods per plant	24.641	1211.368**	6037.687**	114.831**	8.510
7	Seed yield per plant (g)	0.990	79.060**	890.129**	14.111**	0.796
8	100-seed weight (g)	0.141	67.648**	305.828**	6.733**	0.347

**Significant at 0.01 per cent probability level.
Note: Figures in the parentheses indicate degrees of freedom.

Table 4.15. Analysis of variance for stability as per Eberhart and Russell (1966)

Sources of variance	d.f	Mean sum of squares of							
		Days to 50 per cent flowering	Days taken for maturity	Plant height in cm	Number of branches per plant	Number of clusters per plant	Number of pods per plant	100-seed weight (g)	Seed yield per plant (g)
Genotype (G)	23	117.31**	469.16**	1352.15**	2.10**	86.75**	403.79**	22.55**	26.35**
Environment+(GE)	120	71.96**	88.13**	136.43**	1.10**	13.25**	120.54**	6.40**	16.87**
Environment (Linear)	1	7527.88**	6017.07**	1115.51**	87.70**	917.82**	10062.78**	509.70**	1483.55**
GE (Linear)	23	17.04**	21.83	65.46*	0.34	6.96	50.35	3.15*	6.73*
Pooled deviation	96	7.45**	42.26**	38.65**	0.38**	5.33**	33.79**	1.93**	4.02**
Pooled error	276	1.62	2.65	22.47	0.18	1.97	8.38	0.34	0.80

*Significant at 0.05 per cent probability level.
**Significant at 0.01 per cent probability level.

Variance due to genotypes (G), variance due to environment + (Genotype x environment), environment (linear) were found significant for all the characters at one per cent level of significance when their mean sums of squares (MSS) tested against pooled deviation. Whereas, genotype x environment (linear) was highly significant only for days to 50 per cent flowering and found significant at five per cent level of significance for plant height, seed yield per plant and 100 seed weight when their MSS tested against MSS of pooled deviation. Pooled deviation, the non-linear portion of variance which is the unpredictable portion of GxE interaction was observed to be highly significant (at P=0.01) for all the characters when their MSS were tested against pooled error.

Since the genotype x environment interactions were found significant for all the eight characters, the data was considered for stability analysis by estimating stability parameters as per Eberhart and Russell (1966).

4.6. STABILITY ANALYSIS

In order to identify the stable genotypes for different characters, the stability analysis was carried out employing the linear regression model suggested by

Eberhart and Russell (1966). According to the model, three stability parameters viz., mean ($\bar{x}$), regression coefficient (bi) and mean square deviation from linear regression line (S^2di) were computed for each of the eight characters and the results obtained are presented characterwise in the following paragraphs.

4.6.1. Days to 50 per cent flowering

Stability parameters for days to 50 per cent flowering are summarised in Table 4.16 and illustrated in the Figure 4.4. Among the genotypes, the genotype KB-78 was found to be earliest in flowering, taking only 36.33 days. On the contrary genotype KHSb-2 took maximum number of days (51.22), while the other genotypes flowered inbetween.

The regression coefficient (bi) was found to be significantly different from unity (one) in respect of KB-78 and JS-79-277 genotypes while it was found to be non-significant in respect of other genotypes. The deviation from regression (S^2di) was not found to be significantly different from zero in respect of Monetta (1.61), KB-78 (0.74), KB-74 (1.83), JS-79-277 (0.12) and JS-81-714 (1.71) genotypes. While the other genotypes found to be significantly deviate from regression

Table 4.16. Stability parameters for "Days to 50% flowering"

Sl. No.	Genotypes	Mean	Rank	bi	SE(b)	S^2di
1	Hardee	45.61	8	1.27	0.17	8.79**
2	Bragg	37.61	22	0.72	0.13	4.78**
3	Monetta	37.94	21	0.96	0.09	1.61
4	KB-78	36.33	23	0.61++	0.07	0.74
5	KHSb-2	51.22	1	1.30	0.24	17.76**
6	MACS-13	49.33	4	1.32	0.14	4.23**
7	MACS-124	47.06	6	1.13	0.12	4.51**
8	MACS-125	46.22	7	0.98	0.14	5.20**
9	MACS-189	44.56	10	1.07	0.25	18.46**
10	UGM-21	42.89	14	0.85	0.11	3.02*
11	UGM-30	51.00	2	1.20	0.20	10.93**
12	UGM-34	50.33	3	1.24	0.24	15.97**
13	PK-416	39.28	20	0.74	0.14	6.29**
14	PK-471	44.00	12	1.03	0.12	4.39**
15	PK-472	44.11	11	1.04	0.13	3.78**
16	KB-32	43.39	13	0.79	0.20	11.72**
17	KB-38A	42.39	15	0.90	0.15	5.47**
18	KB-60	48.67	5	1.54	0.21	12.80**
19	KB-74	45.00	9	1.10	0.10	1.83
20	DS-2	39.44	19	0.78	0.11	2.79*
21	DS-76-1-37-1	39.50	18	0.97	0.22	15.13**
22	JS-79-277	39.94	17	0.89+	0.03	0.12
23	JS-81-303	41.44	16	0.68	0.12	3.81**
24	JS-81-714	39.94	17	0.86	0.08	1.71

+Significantly different from one at P=0.05 (2.776).
++Significantly different from one at P=0.01 (4.604).
*Significantly different from zero at P=0.05 (2.370).
**Significantly different from zero at P=0.01 (3.320).

L E G E N D

1	Hardee	13	PK-416
2	Bragg	14	PK-471
3	Monetta	15	PK-472
4	KB-78	16	KB-32
5	KHSb-2	17	KB-38A
6	MACS-13	18	KB-60
7	MACS-124	19	KB-74
8	MACS-125	20	DS-2
9	MACS-189	21	DS-76-1-37-1
10	UGM-21	22	JS-79-277
11	UGM-30	23	JS-81-303
12	UGM-34	24	JS-81-714

⊙ Indicates stable genotypes.

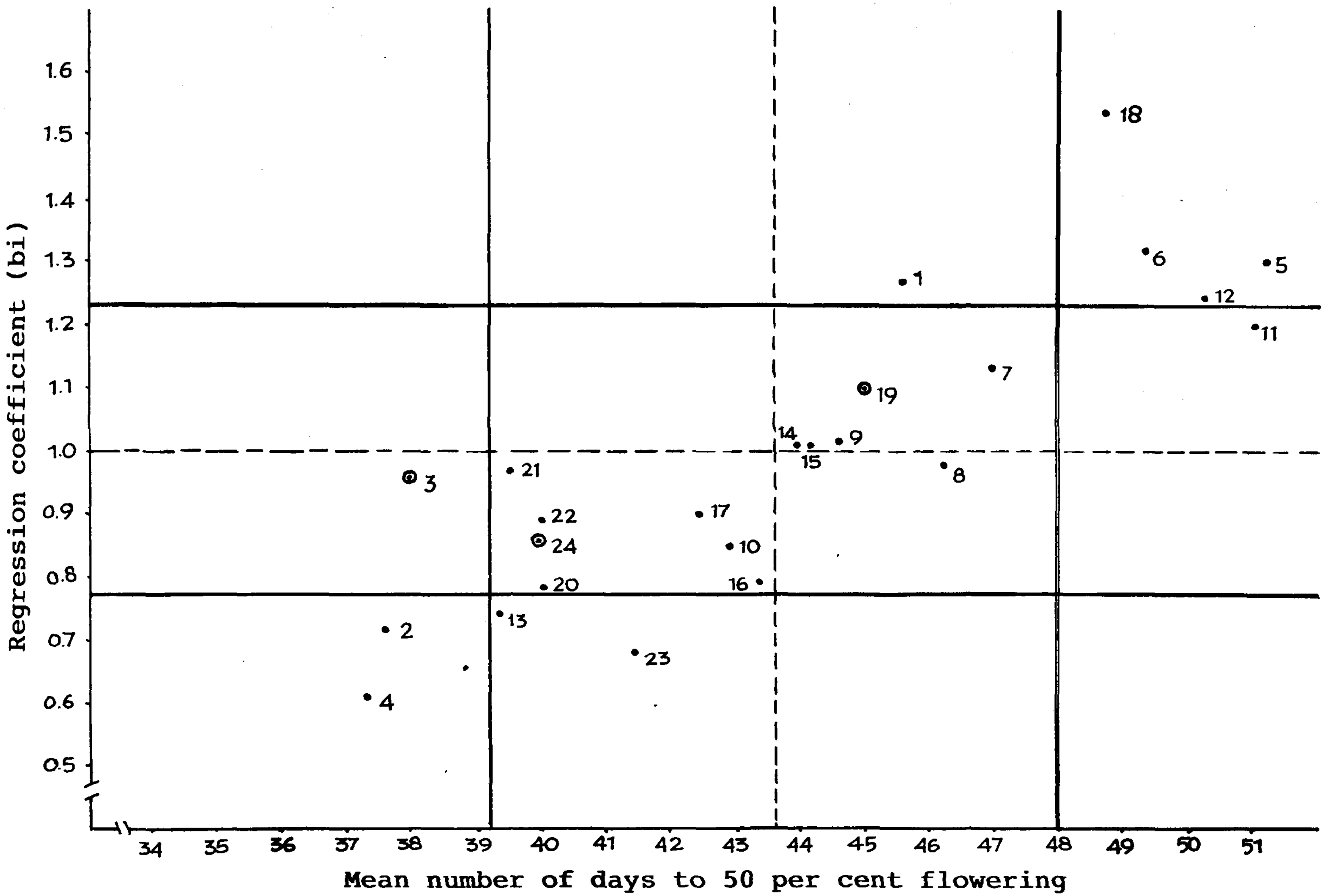

FIG. 4.4. RELATIONSHIP BETWEEN THE REGRESSION COEFFICIENT (bi) AND THE MEAN NUMBER OF DAYS TO 50 PER CENT FLOWERING FOR THE TWENTY FOUR GENOTYPES

($S^2di=0$). The genotypes Monetta, KB-74 and JS-81-714 were not significantly different from regression coefficient (bi=1) as well as deviation from regression ($S^2di=0$).

4.6.2. Days to maturity

Among the genotypes, Monetta was found to be mature early (87.72) whereas KHSb-2 took maximum number of days (124.33). While the other genotypes matured inbetween.

The regression coefficient (bi) was found to be significantly different from unity (one) in respect of only one genotype UGM-21 (0.54) while for the other genotypes it was found to be non-significant. The deviation from regression (S^2di) was not found to be significantly different from zero in respect of only one genotype UGM-21 (2.48) while the remaining genotypes were found to be significantly different from zero. No genotypes found non-significant for both, deviation from regression ($S^2di=0$) and regression coefficient (bi=1). Stability parameters for days taken to maturity are summarised in Table 4.17 and illustrated in Figure 4.5.

4.6.3. Plant height in cm

Table 4.18 and figure 4.6 illustrates the stability parameters of plant height. From the table and

Table 4.17. Stability parameters for "Days to maturity"

Sl. No.	Genotypes	Mean	Rank	bi	SE(b)	S^2di
1	Hardee	117.39	5	0.91	0.25	14.39**
2	Bragg	110.17	9	0.53	0.49	58.20**
3	Monetta	87.72	24	0.98	0.19	7.84**
4	KB-78	90.89	23	0.74	0.28	18.12**
5	KHSb-2	124.33	1	1.02	0.71	125.90**
6	MACS-13	117.83	4	0.79	0.24	16.03**
7	MACS-124	110.83	8	0.94	0.16	5.63*
8	MACS-125	112.44	7	0.84	0.19	10.11**
9	MACS.189	102.94	20	0.89	0.28	21.07**
10	UGM-21	97.56	21	0.54+	0.11	2.48
11	UGM-30	118.83	2	1.57	0.64	113.01**
12	UGM-34	118.06	3	1.58	0.63	111.40**
13	PK-416	106.06	15	0.86	0.33	29.32**
14	PK-471	106.39	13	1.25	0.24	15.68**
15	PK-472	106.61	12	1.14	0.46	57.66**
16	KB-32	103.39	19	1.19	0.24	15.77**
17	KB-38A	103.61	18	1.09	0.16	6.27**
18	KB-60	114.17	6	1.51	0.58	93.32**
19	KB-74	105.78	16	0.89	0.19	8.56**
20	DS-2	106.33	14	1.31	0.38	39.88**
21	DS-76-1-37-1	107.11	11	1.17	0.50	69.43**
22	JS-79-277	108.72	10	0.78	0.51	71.97*
23	JS-81-303	95.50	22	0.67	0.19	9.10**
24	JS-81-714	104.17	17	0.79	0.51	71.79**

+Significantly different from one at P=0.05 (2.776).
++Significantly different from one at P=0.01 (4.604).
*Significantly different from zero at P=0.05 (2.370).
**Significantly different from zero at P=0.01 (3.320).

LEGEND

1	Hardee	13	PK-416
2	Bragg	14	PK-471
3	Monetta	15	PK-472
4	KB-78	16	KB-32
5	KHSb-2	17	KB-38A
6	MACS-13	18	KB-60
7	MACS-124	19	KB-74
8	MACS-125	20	DS-2
9	MACS-189	21	DS-76-1-37-1
10	UGM-21	22	JS-79-277
11	UGM-30	23	JS-81-303
12	UGM-34	24	JS-81-714

⊙ Indicates stable genotypes.

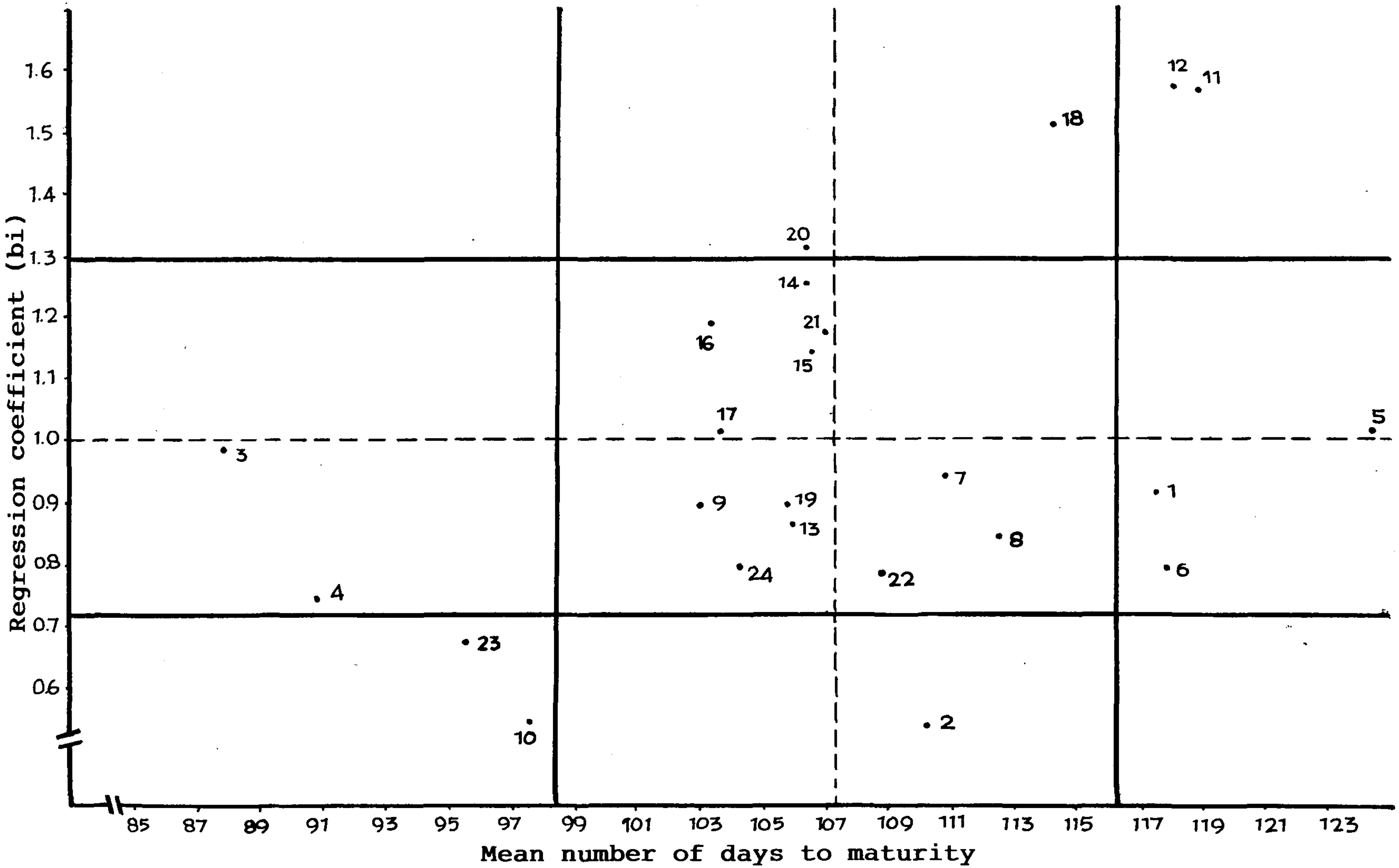

FIG. 4.5. RELATIONSHIP BETWEEN THE REGRESSION COEFFICIENT (bi) AND THE MEAN NUMBER OF DAYS TO MATURITY FOR THE TWENTY FOUR GENOTYPES

Table 4.18. Stability parameters for "Plant height in cm"

Sl. No.	Genotypes	Mean	Rank	bi	SE(b)	S^2di
1	Hardee	36.97	12	1.00	0.21	11.50
2	Bragg	30.30	21	0.98	0.24	18.77
3	Monetta	26.21	23	0.69	0.17	5.92
4	KB-78	18.24	24	0.45+	0.15	2.80
5	KHSb-2	53.33	3	1.29	0.21	13.27
6	MACS-13	39.29	10	0.77	0.25	21.10
7	MACS-124	49.63	5	1.60	0.32	40.47
8	MACS-125	50.56	4	1.59+	0.16	6.34
9	MACS-189	38.13	11	0.67	0.26	24.28
10	UGM-21	43.07	8	0.90	0.26	21.96
11	UGM-30	79.14	2	1.91	0.66	196.52**
12	UGM-34	82.47	1	1.62	0.64	186.19**
13	PK-416	31.04	19	0.67	0.21	13.60
14	PK-471	31.65	17	0.74	0.18	7.27
15	PK-472	29.46	22	0.62	0.14	1.79
16	KB-32	32.30	15	0.72	0.18	7.35
17	KB-38A	33.82	13	1.08	0.12	-0.15
18	KB-60	43.93	7	0.97	0.37	57.48**
19	KB-74	31.54	18	0.89	0.28	29.01
20	DS-2	44.65	6	1.02	0.26	22.50
21	DS-76-1-37-1	32.38	14	1.05	0.13	-0.02
22	JS-79-277	41.56	9	1.23	0.21	11.33
23	JS-81-303	30.38	20	0.56	0.30	32.73*
24	JS-81-714	31.92	16	0.96	0.23	15.86

+Significantly different from one at P=0.05 (2.776).
++Significantly different from one at P=0.01 (4.604).
*Significantly different from zero at P=0.05 (2.370).
**Significantly different from zero at P=0.01 (3.320).

L E G E N D

1	Hardee	13	PK-416
2	Bragg	14	PK-471
3	Monetta	15	PK-472
4	KB-78	16	KB-32
5	KHSb-2	17	KB-38A
6	MACS-13	18	KB-60
7	MACS-124	19	KB-74
8	MACS-125	20	DS-2
9	MACS-189	21	DS-76-1-37-1
10	UGM-21	22	JS-79-277
11	UGM-30	23	JS-81-303
12	UGM-34	24	JS-81-714

⊙ Indicates **stable genotypes.**

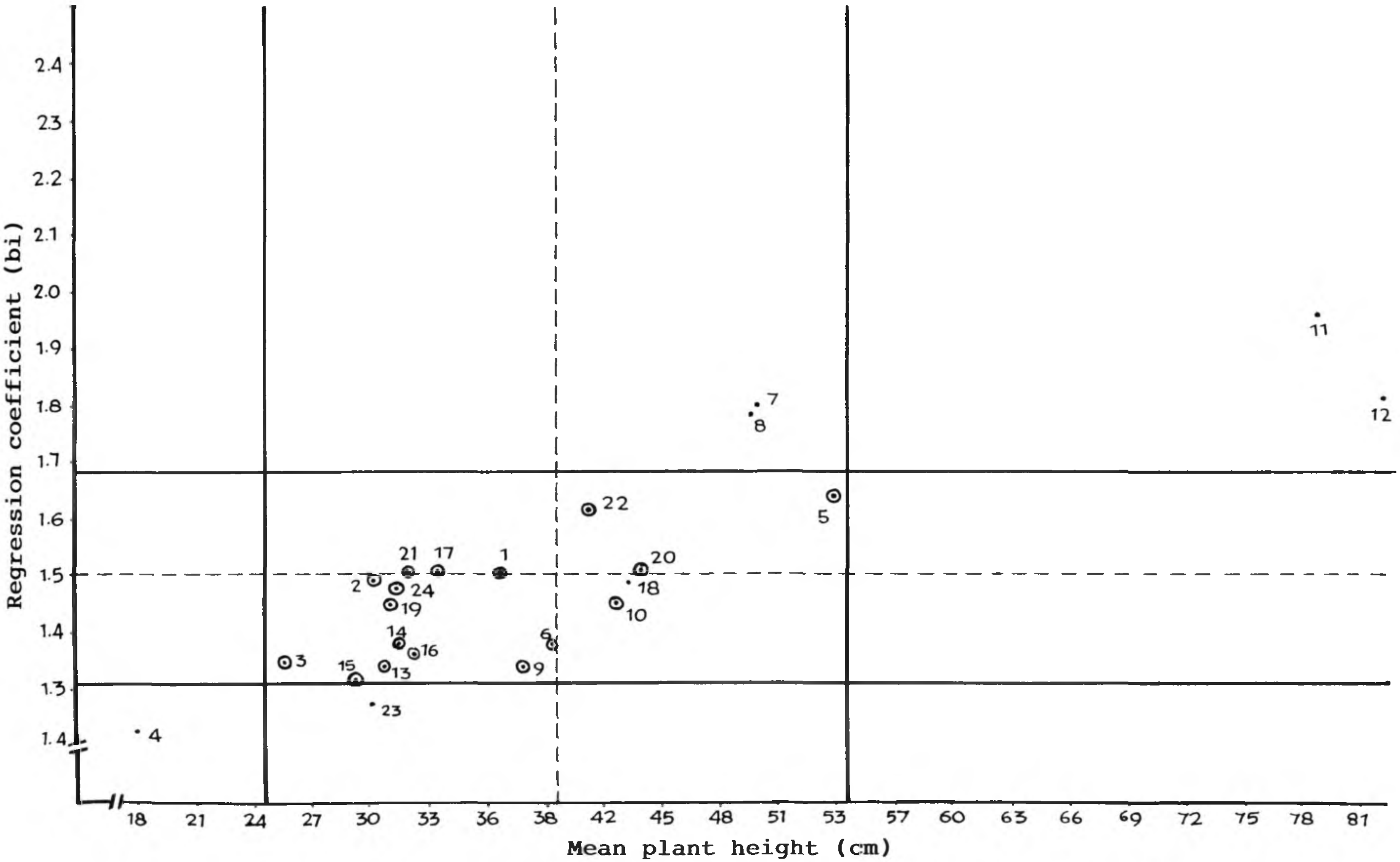

FIG. 4.6. RELATIONSHIP BETWEEN REGRESSION COEFFICIENT (bi) AND THE MEAN PLANT HEIGHT (CM) FOR TWENTY FOUR GENOTYPES

figure we can conclude that the genotype UGM-34 was found to be tallest (82.47). On the contrary the genotype KB-78 was found to be shortest (18.24), while the other genotypes fell inbetween.

The regression coefficient (bi) was found to be significantly different from unity (one) in only two genotypes, viz., KB-78 (0.45) and MACS-125 (1.59). While it was found to be non-significant in respect of the other genotypes. The deviation from regression (S di) was found to be significantly different from zero in respect of five genotypes viz., MACS-124 (40.47), UGM-30 (196.52), UGM-34 (186.19), KB-60 (57.48) and JS-81-303 (32.73). While it was found to be non-significant in respect of other genotypes. The genotypes Hardee, Bragg, Monetta, KHSb-2, MACS-13, MACS-189, UGM-21, PK-416, PK-471, PK-472, KB-32, KB-38A, KB-74, DS-2, DS-76-1-37-1, JS-79-277 and JS-81-714 were not significantly different from regression coefficient (bi=1) as well as deviation from regression ($S^2di=0$).

4.6.4. Number of branches per plant

Stability parameters for number of branches per plant are presented in Table 4.19 and illustrated in the Figure 4.7. Among the genotypes KB-60 found to contain

Table 4.19. Stability parameters for "No.of branches per plant"

Sl. No.	Genotypes	Mean	Rank	bi	SE(b)	S^2di
1	Hardee	2.87	7	1.18	0.31	0.27*
2	Bragg	2.24	16	1.17	0.39	0.50**
3	Monetta	1.57	23	1.01	0.39	0.49**
4	KB-78	1.46	24	0.52^{+}	0.17	0.04
5	KHSb-2	3.13	4	0.61	0.29	0.23
6	MACS-13	3.07	5	1.22	0.31	0.26*
7	MACS-124	1.72	20	0.96	0.37	0.43**
8	MACS-125	1.73	19	1.14	0.46	0.69**
9	MACS-189	2.56	11	1.05	0.37	0.41*
10	UGM-21	2.99	6	0.89	0.24	0.15
11	UGM-30	3.14	3	0.48	0.59	1.22**
12	UGM-34	3.25	2	0.42	0.41	0.56*
13	PK-416	2.47	12	1.27	0.11	-0.02
14	PK-471	2.23	17	1.26	0.35	0.37*
15	PK-472	1.70	21	0.92	0.20	0.08
16	KB-32	2.60	9	1.15	0.21	0.07
17	KB-38A	2.68	8	1.41	0.25	0.15
18	KB-60	3.53	1	1.65	0.50	0.80**
19	KB-74	2.35	14	1.22	0.38	0.45**
20	DS-2	2.32	15	1.07	0.33	0.33*
21	DS-76-1-37-1	2.58	10	0.70	0.19	0.07
22	JS-79-277	2.10	18	0.74	0.19	0.06
23	JS-81-303	2.40	13	1.09	0.17	0.04
24	JS-81-714	1.59	22	0.84	0.20	0.09

+Significantly different from one at P=0.05 (2.776).
++Significantly different from one at P=0.01 (4.604).
*Significantly different from zero at P=0.05 (2.370).
**Significantly different from zero at P=0.01 (3.320).

L E G E N D

1	Hardee	13	PK-416
2	Bragg	14	PK-471
3	Monetta	15	PK-472
4	KB-78	16	KB-32
5	KHSb-2	17	KB-38A
6	MACS-13	18	KB-60
7	MACS-124	19	KB-74
8	MACS-125	20	DS-2
9	MACS-189	21	DS-76-1-37-1
10	UGM-21	22	JS-79-277
11	UGM-30	23	JS-81-303
12	UGM-34	24	JS-81-714

⊙ Indicates stable genotypes.

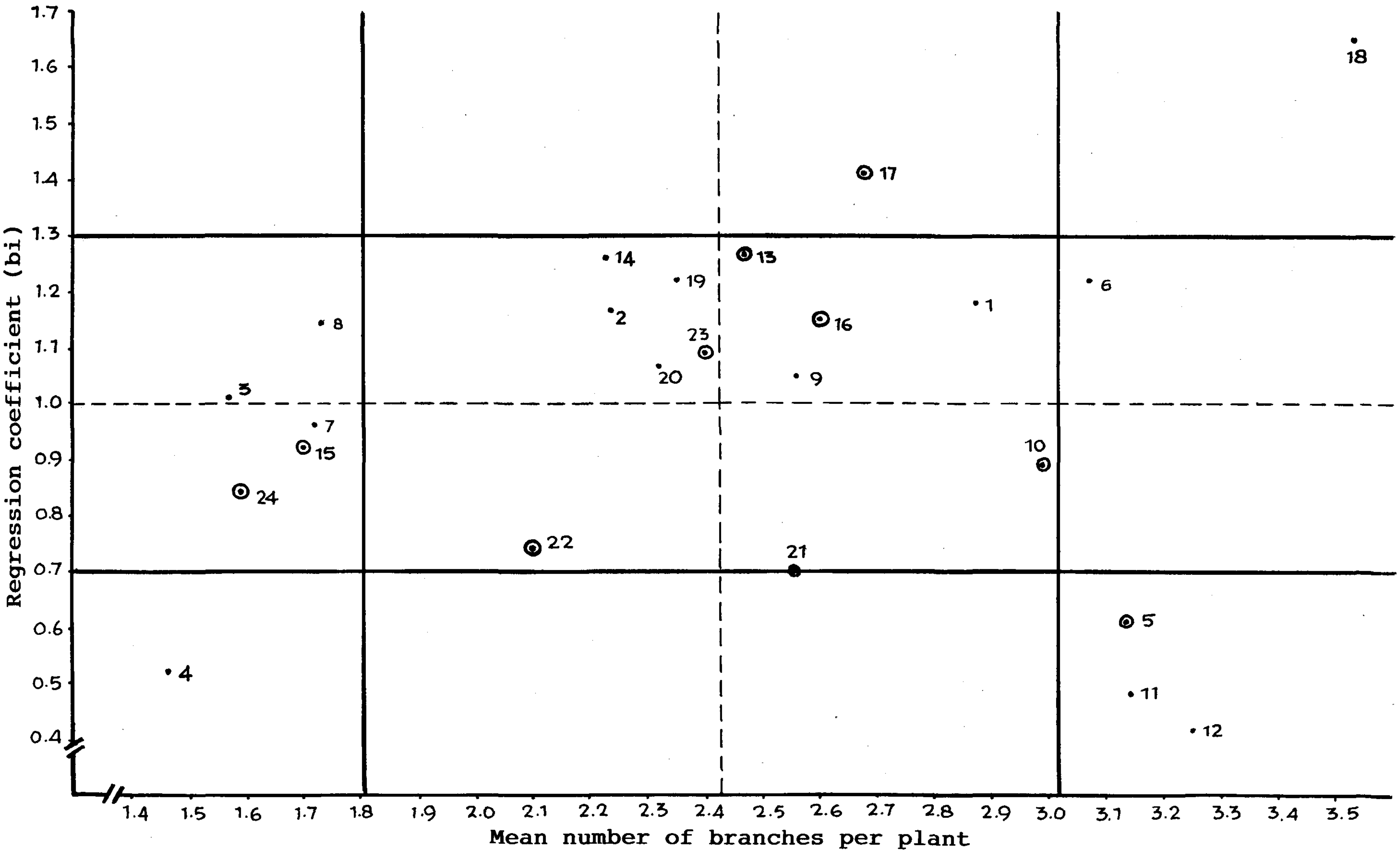

FIG. 4.7. RELATIONSHIP BETWEEN THE REGRESSION COEFFICIENT (bi) AND THE MEAN NUMBER OF BRANCHES PER PLANT FOR TWENTY FOUR GENOTYPES

more number of branches per plant (3.53). On the contrary genotype KB-78 found to contain less number of branches per plant (1.46). The other genotypes fell inbetween.

The regression coefficient (bi) was found to be significantly different from unity (one) in respect of only one genotype viz., KB-78 (0.52) while it was found to be non-significant with respect to other genotypes. The deviation from regression (S di) was found to be significantly different from zero in respect of thirteen genotypes viz., Hardee (0.27), Bragg (0.50), Monetta (0.49), MACS-13 (0.26), MACS-124 (0.43), MACS-125 (0.69), MACS-189 (0.41), UGM-30 (1.22), UGM-34 (0.56), PK-471 (0.37), KB-60 (0.80), KB-74 (0.45) and DS-2 (0.33). While it was found to be non-significant in respect of other eleven genotypes. The genotypes KHSb-2, UGM-21, PK-416, PK-472, KB-32, KB-38A, DS-76-1-37-1, JS-79-277, JS-81-303 and JS-81-714 were found to be not significantly different from regression coefficient (bi=1) and deviation from regression (S^2di=0).

4.6.5. Number of clusters per plant

Stability parameters for this character are presented in Table 4.20 and illustrated in Figure 4.8.

Table 4.20. Stability parameters for "No.of clusters per plant"

Sl. No.	Genotypes	Mean	Rank	bi	SE(b)	S^2di
1	Hardee	12.47	8	1.28	0.42	6.16**
2	Bragg	8.88	22	0.62	0.38	4.79**
3	Monetta	7.59	23	0.46	0.31	3.05*
4	KB-78	6.51	24	0.22+	0.17	0.43
5	KHSb-2	16.39	3	1.61	0.39	5.22**
6	MACS-13	12.71	7	1.34	0.40	4.94**
7	MACS-124	11.88	10	0.76	0.26	2.01
8	MACS-125	11.87	11	1.04	0.43	6.35**
9	MACS-189	11.32	12	1.10	0.25	1.69
10	UGM-21	13.56	6	1.09	0.16	0.29
11	UGM-30	23.61	1	1.66	0.96	34.53**
12	UGM-34	19.81	2	0.86	0.76	21.71**
13	PK-416	9.61	18	0.65+	0.11	-0.19
14	PK-471	10.07	15	1.02	0.15	0.30
15	PK-472	8.92	21	0.37	0.29	2.45
16	KB-32	9.94	16	0.91	0.08	-0.45
17	KB-38A	10.65	13	1.34	0.27	2.09
18	KB-60	13.84	5	1.81+	0.28	2.52
19	KB-74	9.71	17	0.92	0.41	5.77**
20	DS-2	14.06	4	1.60	0.27	2.12
21	DS-76-1-37-1	10.21	14	0.83	0.25	1.66
22	JS-79-277	11.96	9	1.26	0.32	3.19*
23	JS-81-303	9.34	19	0.69	0.20	0.85
24	JS-81-714	9.32	20	0.57	0.18	0.69

+Significantly different from one at P=0.05 (2.776).
++Significantly different from one at P=0.01 (4.604).
*Significantly different from zero at P=0.05 (2.370).
**Significantly different from zero at P=0.01 (3.320).

L E G E N D

1	Hardee	13	PK-416
2	Bragg	14	PK-471
3	Monetta	15	PK-472
4	KB-78	16	KB-32
5	KHSb-2	17	KB-38A
6	MACS-13	18	KB-60
7	MACS-124	19	KB-74
8	MACS-125	20	DS-2
9	MACS-189	21	DS-76-1-37-1
10	UGM-21	22	JS-79-277
11	UGM-30	23	JS-81-303
12	UGM-34	24	JS-81-714

⊙ **Indicates stable genotypes.**

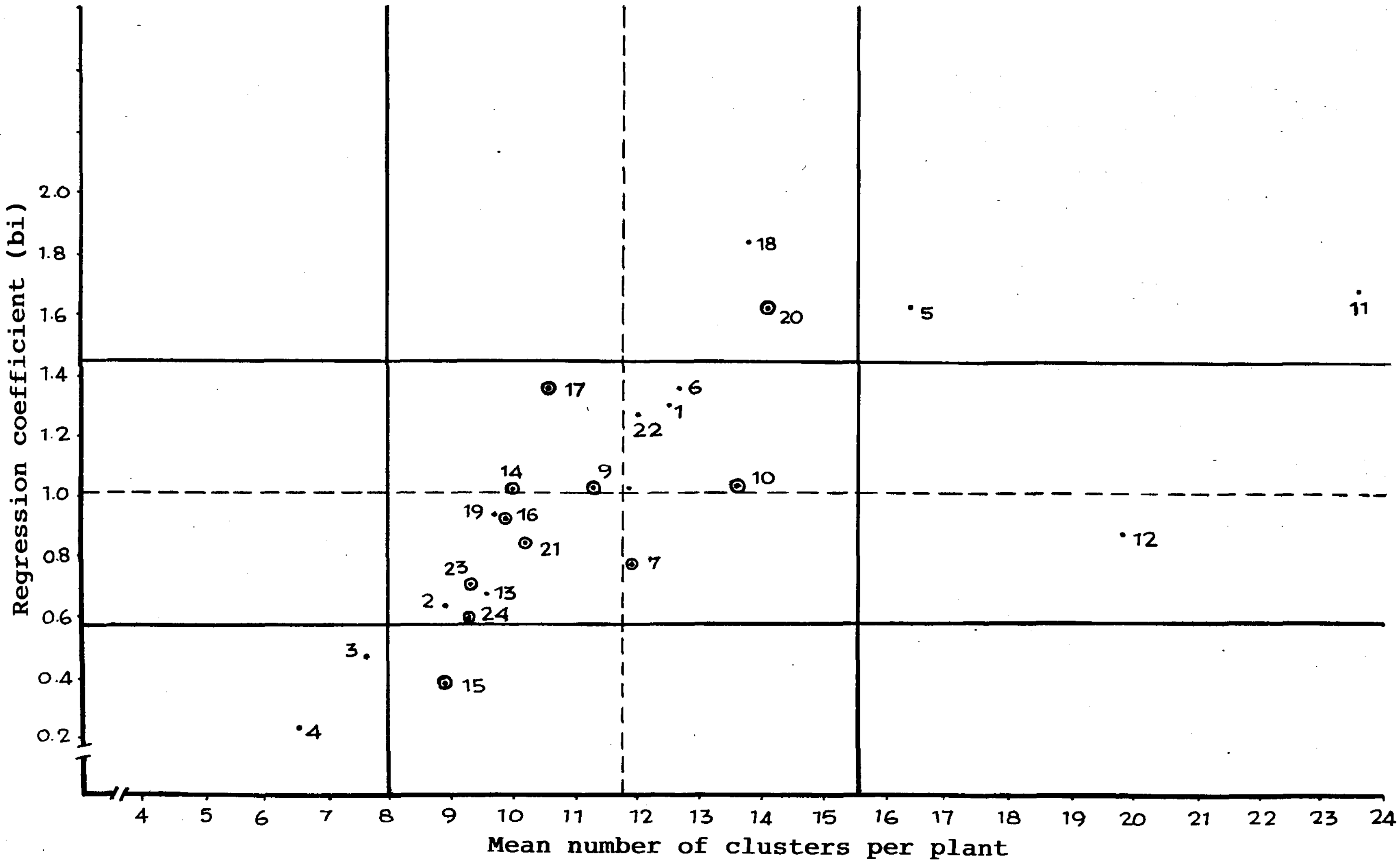

FIG.4.8. RELATIONSHIP BETWEEN THE REGRESSION COEFFICIENT (bi) AND THE MEAN NUMBER OF CLUSTERS PER PLANT FOR TWENTY FOUR GENOTYPES

Among the genotypes UGM-30 possessed more number of clusters per plant (23.61) while the genotype KB-78 had less number of clusters per plant, clusters in the other genotypes ranged inbetween these two.

The regression coefficient (bi) was found to be significantly different from unity (one) in respect of three genotypes viz., KB-78 (0.22), PK-416 (0.65) and KB-66 (1.81). While it was found non-significant in respect of the remaining genotypes. The deviation from regression (S di) was found to be significantly different from zero in respect of ten genotypes viz., Hardee (6.16), Bragg (4.72), Monetta (3.05), KHSb-2 (5.22), MACS-13 (4.94), MACS-125 (6.35), UGM-30 (34.53), UGM-34 (21.71), KB-74 (5.77) and JS-79-277 (3.19). While it was found to be non-significant in respect of other fourteen genotypes. The genotypes MACS-124, MACS-189, UGM-21, PK-471, PK-472, KB-32, KB-38A, DS-2, DS-76-1-37-1, JS-81-303 and JS-81-714 were not significantly different from regression coefficient (bi=1) as well as deviation from regression ($S^2di=0$).

4.6.6. Number of pods per plant

Stability parameters for number of pods per plant are presented in Table 4.21 and illustrated in Figure 4.9.

Table 4.21. Stability parameters for "No.of pods per plant"

Sl. No.	Genotypes	Mean	Rank	bi	SE(b)	S^2di
1	Hardee	28.87	9	1.50	0.38	60.20**
2	Bragg	21.44	19	0.69	0.21	15.75*
3	Monetta	18.26	22	0.50+	0.14	5.91
4	KB-78	17.45	23	0.58+	0.10	1.64
5	KHSb-2	38.36	3	1.40	0.28	28.23**
6	MACS-13	28.44	11	0.68	0.32	41.67**
7	MACS-124	26.30	12	0.74	0.29	32.11**
8	MACS-125	29.25	8	0.89	0.29	32.89**
9	MACS-189	29.69	6	1.38	0.14	6.66
10	UGM-21	30.55	4	1.19	0.12	2.22
11	UGM-30	53.44	1	1.33	0.78	252.67**
12	UGM-34	44.29	2	1.46	0.56	129.40**
13	PK-416	20.02	21	0.61+	0.11	2.47
14	PK-471	25.99	13	1.11	0.15	6.63
15	PK-472	22.90	17	0.35++	0.14	12.53*
16	KB-32	21.83	18	0.72	0.11	1.55
17	KB-38A	21.83	18	0.82	0.08	0.78
18	KB-60	28.64	10	1.30	0.29	31.74**
19	KB-74	21.42	20	0.90	0.15	6.55
20	DS-2	30.48	5	1.46++	0.07	-1.10
21	DS-76-1-37-1	23.33	16	1.20	0.22	16.80*
22	JS-79-277	29.31	7	1.28	0.26	25.68*
23	JS-81-303	23.47	15	1.00	0.12	2.82
24	JS-81-714	25.81	14	0.89	0.27	28.09**

+Significantly different from one at P=0.05 (2.776).
++Significantly different from one at P=0.01 (4.604).
*Significantly different from zero at P=0.05 (2.370).
**Significantly different from zero at P=0.01 (3.320).

LEGEND

1	Hardee	13	PK-416
2	Bragg	14	PK-471
3	Monetta	15	PK-472
4	KB-78	16	KB-32
5	KHSb-2	17	KB-38A
6	MACS-13	18	KB-60
7	MACS-124	19	KB-74
8	MACS-125	20	DS-2
9	MACS-189	21	DS-76-1-37-1
10	UGM-21	22	JS-79-277
11	UGM-30	23	JS-81-303
12	UGM-34	24	JS-81-714

⊙ Indicates stable genotypes.

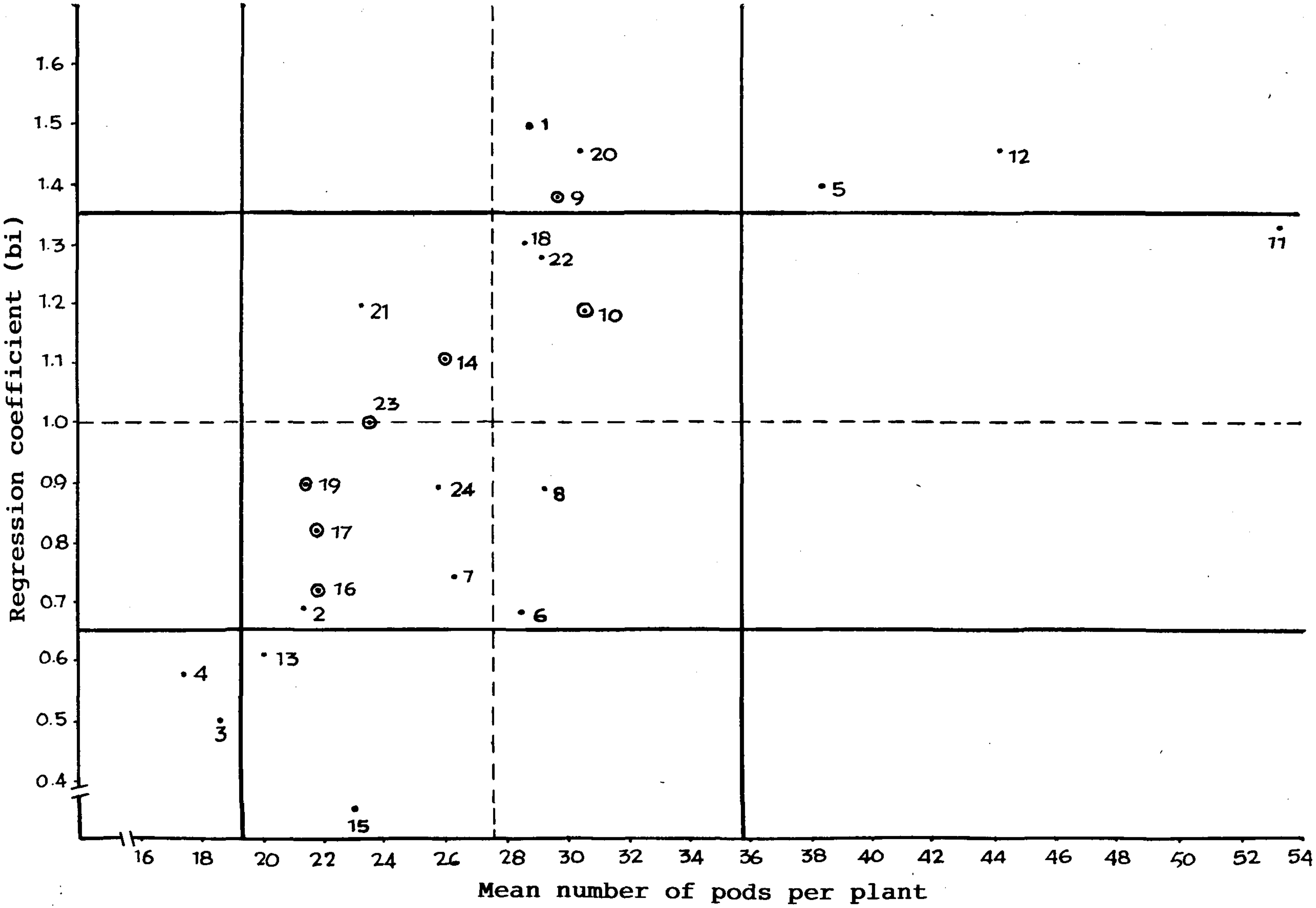

FIG.4.9 . RELATIONSHIP BETWEEN THE REGRESSION COEFFICIENT (bi) AND MEAN NUMBER OF PODS PER PLANT FOR TWENTY FOUR GENOTYPES

Among the twentyfour genotypes, UGM-30 found to contain more number of pods per plant (53.44) whereas less number of pods per plant was recorded in case of the genotype KB-78 (17.45), while the other genotypes found to contain varying number of pods per plant ranging from 17.45 to 53.44.

The regression coefficient (bi) was found to be significantly different from unity (one) in respect of five genotypes viz., Monetta (0.50), KB-78 (0.58), PK-416 (0.61), PK-472 (0.35) and DS-2 (1.46). While it was found to be non-significant in respect of other ninteen genotypes. The deviation from regression (S di) was found to be significantly different from zero in respect of thirteen genotypes viz., Hardee (60.20), Bragg (15.75), KHSb-2 (28.23), MACS-13 (41.47), MACS-124 (32.11), MACS-125 (32.89), UGM-30 (252.67), UGM-34 (129.40), PK-472 (12.53), KB-60 (31.74), DS-76-1-37-1 (16.80), JS-79-277 (25.68) and JS-81-714 (28.09) while it was found to be non-significant for the other eleven genotypes. The genotypes MACS-189, UGM-21, PK-471, KB-32, KB-38A, KB-74 and JS-81-303 were not significantly different from regression coefficient (bi=1) as well as for the deivation from regression (S^2di=0).

4.6.7. 100-seed weight (g)

Among the twentyfour genotypes, the genotype Hardee was found to give maximum 100 seed weight (16.94) while the genotypes KB-78 and UGM-34 were found to had minimum 100 seed weight of 11.07 grams. All the other genotypes were listed within this range (Table 4.22 and Figure 4.10).

The regression coefficient (bi) was found to be significantly different from unity (one) with respect to three genotypes viz., Monetta (1.28), UGM-34 (0.44) and KB-38A (1.59), while in case of other 21 genotypes it was not significantly different from unity. The deviation from regression (S di) was found to be significantly different from zero in respect of twentytwo genotypes viz., Hardee (1.43), Monetta (0.93), Bragg (0.73), KB-78 (0.96), KHSb-2 (2.39), MACS-13 (4.45), MACS-124 (2.17), MACS-125 (1.71), MACS-189 (0.73), UGM-30 (0.73), UGM-34 (0.49), PK-416 (3.25), PK-471 (2.93), PK-472 (2.07), KB-32 (3.43), KB-38A (0.61), KB!60 (0.50), KB-74 (0.96), DS-2 (0.76), JS-79-277 (6.14), JS-81-303 (2.18) and JS-81-714 (3.93), while it was found to be non-significant in respect of other two genotypes. The genotypes UGM-21 and DS-76-1-37-1 were not significantly

Table 4.22. Stability parameters for "100 seeds weight (g)"

Sl. No.	Genotypes	Mean	Rank	bi	SE(b)	S^2di
1	Hardee	16.94	1	0.74	0.27	1.43**
2	Bragg	16.41	2	0.49	0.20	0.73*
3	Monetta	11.76	20	1.28^+	0.22	0.93**
4	KB-78	11.07	23	1.07	0.22	0.96**
5	KHSb-2	16.31	3	0.95	0.35	2.39**
6	MACS-13	14.07	17	0.87	0.47	4.45**
7	MACS-124	14.35	15	1.04	0.33	2.17**
8	MACS-125	14.54	13	0.66	0.31	1.71**
9	MACS-189	11.79	19	1.14	0.20	0.73*
10	UGM-21	12.39	18	1.01	0.10	0.09
11	UGM-30	11.45	21	0.20	0.20	0.73*
12	UGM-34	11.07	23	0.44^+	0.17	0.49*
13	PK-416	16.06	5	0.74	0.40	3.25**
14	PK-471	16.16	4	1.50	0.38	2.93**
15	PK-472	15.96	7	1.44	0.33	2.07**
16	KB-32	15.97	6	1.45	0.41	3.43**
17	KB-38A	14.78	10	1.59^+	0.20	0.61*
18	KB-60	14.69	11	1.21	0.18	0.50*
19	KB-74	15.50	9	1.32	0.23	0.96*
20	DS-2	11.21	22	0.39	0.21	0.76*
21	DS-76-1-37-1	14.68	12	0.88	0.11	0.10
22	JS-79-277	15.68	8	1.31	0.55	6.14**
23	JS-81-303	14.42	14	0.81	0.33	2.18**
24	JS-81-714	14.16	16	1.42	0.44	3.93**

+Significantly different from one at P=0.05 (2.776).
++Significantly different from one at P=0.01 (4.604).
*Significantly different from zero at P=0.05 (2.370).
**Significantly different from zero at P=0.01 (3.320).

L E G E N D

1	Hardee	13	PK-416
2	Bragg	14	PK-471
3	Monetta	15	PK-472
4	KB-78	16	KB-32
5	KHSb-2	17	KB-38A
6	MACS-13	18	KB-60
7	MACS-124	19	KB-74
8	MACS-125	20	DS-2
9	MACS-189	21	DS-76-1-37-1
10	UGM-21	22	JS-79-277
11	UGM-30	23	JS-81-303
12	UGM-34	24	JS-81-714

⊙ Indicates stable genotypes.

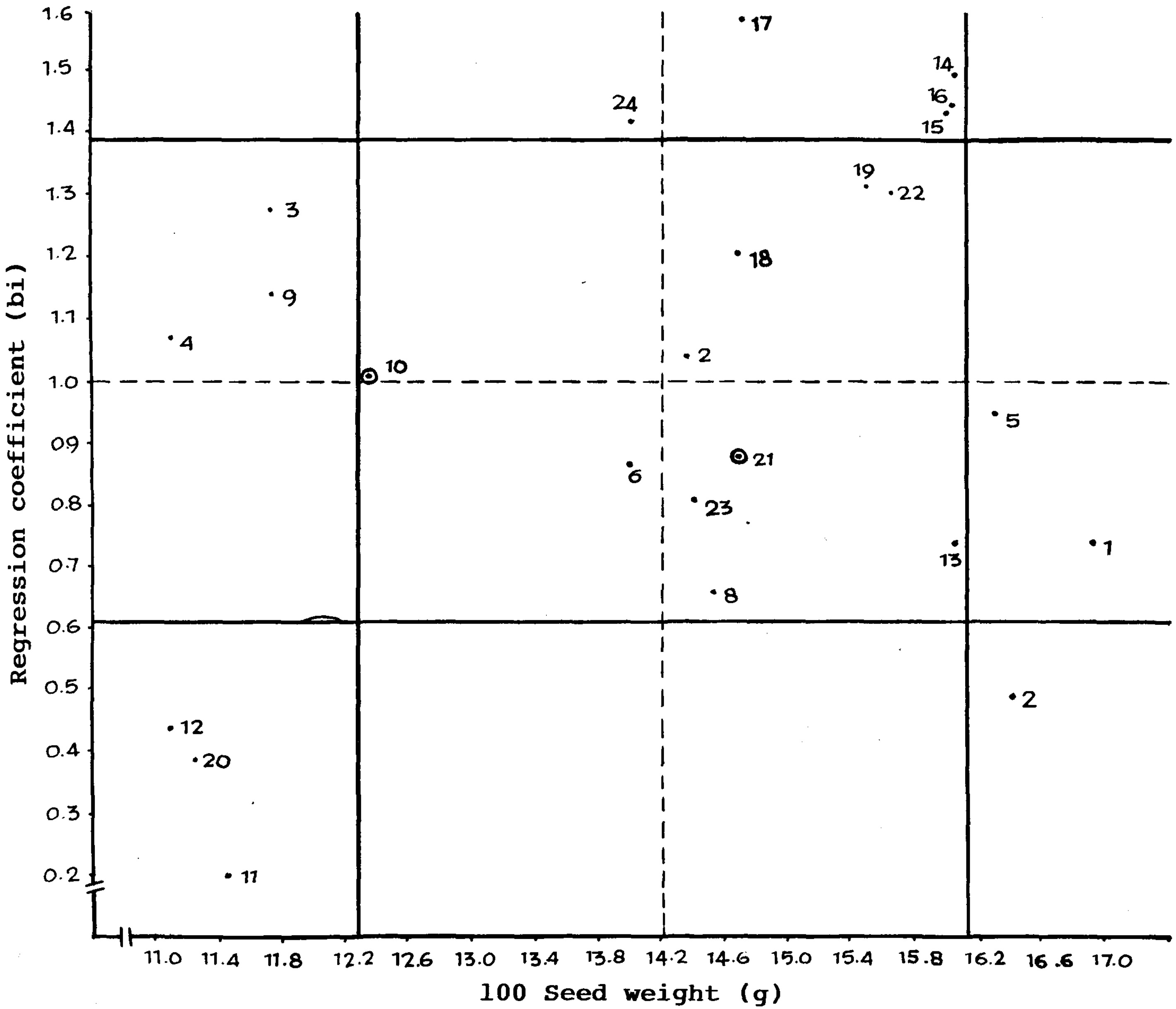

FIG. 4.10. RELATIONSHIP BETWEEN THE REGRESSION COEFFICIENT (bi) AND THE 100-SEED WEIGHT (g) FOR THE TWENTY FOUR GENOTYPES

different from regression coefficient (bi=1) as well as deviation from regression ($S^2di=0$).

4.6.8. Seed yield per plant (g)

Stability parameters for seed yield per plant are presented in Table 4.23 and illustrated in Figure 4.11. Among the genotypes UGM-30 was found to be highest yielder (12.82). While the genotype KB-78 proved the other way with only 3.87 grams per plant. Other genotypes fell inbetween.

The regression coefficient (bi) was found to be significantly different from unity (one) with respect to four genotypes viz., Monetta (0.46), KB-78 (0.35), PK-471 (1.50) and JS-79-277 (1.54). While the same in case of other twenty genotypes was found to be non-significant. The deviation from regression (S^2di) was found to be significantly different from zero in respect of 14 genotypes viz., Hardee (9.09), Bragg (3.12), KHSb-2 (5.09), MACS-13 (12.40), MACS-124 (5.02), MACS-124 (5.29), UGM-30 (16.12), UGM-34 (11.37), PK-416 (7.76), KB-32 (4.27), KB-74 (1.31), DS-76-1-37-1 (1.79), JS-81-303 (3.71) and JS-81-714 (4.35). Other ten genotypes revealed non-significant deviation from regression ($S^2di=0$). The genotypes MACS-189, UGM-21,

Table 4.23. Stability parameters for "Seed yield per plant (g)"

Sl. No.	Genotypes	Mean	Rank	bi	SE(b)	S^2di
1	Hardee	10.36	3	1.82	0.40	9.09**
2	Bragg	6.95	19	0.59	0.24	3.13**
3	Monetta	4.09	22	0.46++	0.09	0.12
4	KB-78	3.87	23	0.39++	0.08	0.03
5	KHSb-2	12.50	2	1.14	0.30	5.09**
6	MACS-13	8.44	9	0.81	0.45	12.40**
7	MACS-124	7.32	13	0.94	0.30	5.02**
8	MACS-125	8.93	8	1.03	0.31	5.29**
9	MACS-189	7.51	11	1.17	0.11	0.44
10	UGM-21	7.25	14	0.96	0.12	0.57
11	UGM-30	12.82	1	0.87	0.52	16.12**
12	UGM-34	9.96	4	1.15	0.44	11.37**
13	PK-416	6.73	20	0.80	0.23	7.76**
14	PK-471	9.01	7	1.50+	0.14	0.33
15	PK-472	7.45	12	0.65	0.13	0.69
16	KB-32	6.54	21	0.91	0.28	4.27**
17	KB-38A	7.12	18	1.01	0.13	0.71
18	KB-60	9.37	6	1.23	0.10	0.11
19	KB-74	7.13	17	1.07	0.17	1.31*
20	DS-2	7.25	14	0.95	0.12	0.46
21	DS-76-1-37-1	7.66	10	1.17	0.19	1.79*
22	JS-79-277	9.41	5	1.54+	0.16	0.94
23	JS-81-303	7.23	15	0.76	0.25	3.71**
24	JS-81-714	7.20	16	1.04	0.28	4.35**

+Significantly different from one at P=0.05 (2.776).
++Significantly different from one at P=0.01 (4.604).
*Significantly different from zero at P=0.05 (2.370).
**Significantly different from zero at P=0.01 (3.320).

L E G E N D

1	Hardee	13	PK-416
2	Bragg	14	PK-471
3	Monetta	15	PK-472
4	KB-78	16	KB-32
5	KHSb-2	17	KB-38A
6	MACS-13	18	KB-60
7	MACS-124	19	KB-74
8	MACS-125	20	DS-2
9	MACS-189	21	DS-76-1-37-1
10	UGM-21	22	JS-79-277
11	UGM-30	23	JS-81-303
12	UGM-34	24	JS-81-714

⊙ Indicates stable genotypes.

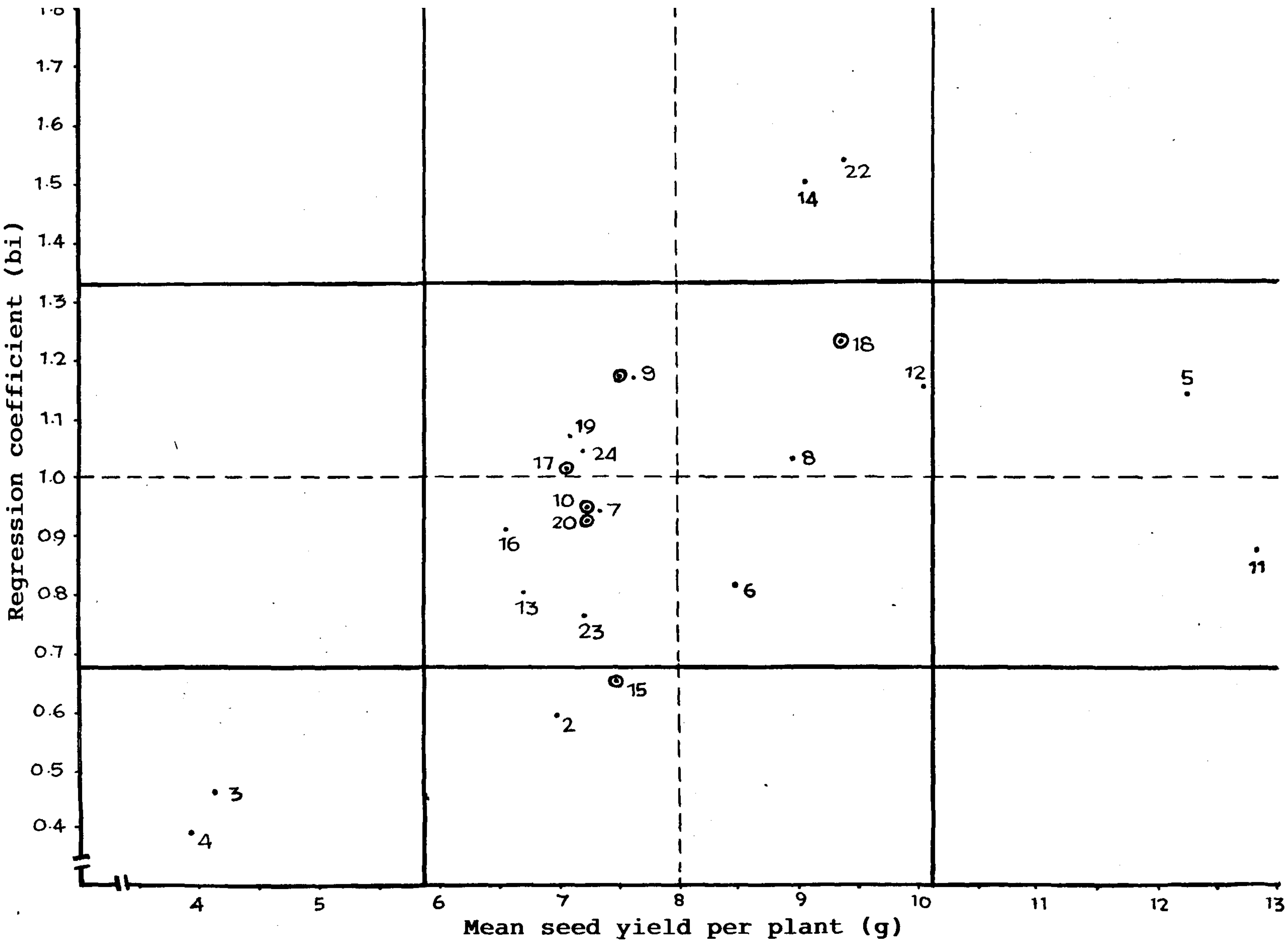

FIG.4.11. RELATIONSHIP BETWEEN THE REGRESSION COEFFICIENT (bi) AND THE MEAN SEED YIELD PER PLANT (g)

PK-472, KB-38A, KB-60 and DS-2 were not significantly different from regression coefficient (bi=1) as well as the deviation from regression ($S^2di=0$).

V. DISCUSSION

The knowledge about the amount of genetic variability present in a crop species, different characters attributing towards seed yield and their association, nature and extent of relative contribution of different traits towards seed yield and the extent of fluctuations of all these over environments are very important in successful planning of breeding programme for the rapid improvement of any crop plant. Besides, identification of genotypes possessing adequate stability for the economically important characters i.e., yield both over seasons and locations is also important. A good adopted variety is defined by Frey (1964) as the one which gives superior production over a range of environments. Thus naturally all the plant breeders are interested in developing varieties which would perform well under varied agroclimatic situations. But a specific genotype does not exhibit the same kind of performance under all environments and different genotypes do not respond in the same way to a specific environment. This kind of variation is attributed to the existence of interaction between genotype and environment. This has necessiated, for those engaged in crop improvement programme, to strive hard for reducing the magnitude of interaction between the genotype and the environment. To achieve this, some researchers have suggested stratification of the environment and developing suitable genotype for each of such environments. This again will not be a permanent solution for the problem as there exists considerable interaction of the genotype with the environment (season or location) and thus one cannot expect for the same climatic conditions to prevail over seasons/years (Eberhart and Russell, 1966). Some workers like Finley and Wilkinson (1963) have used and recommended logarithmic transformation of the data to reduce the interaction. But this remains a theoretical proposition and does not provide a practical solution. Later scientists tried to develop certain statistical and genetic models to facilitate identification of genotypes which interact to the minimum extent with the environments.

In the present investigation twentyfour diverse genotypes of soybean were grown in six different environments viz., E_1 (May, 1988; Early kharif/late summer), E_2 (July, 1988; kharif), E_3 (September, 1988; Late kharif/early rabi), E_4 (November, 1988; rabi), E_5 (January, 1989; Late rabi/early summer) and E_6 (March, 1989; Summer) by adopting completely randomised block design.

The study was aimed at estimating the magnitude of genetic variability, identifying the yield contributing characters and their association, estimating relative contribution of different traits towards seed yield and mainly identification of stable genotypes for different soybean growing environments (seasons), identification of such characters which exhibit least interaction with the environments so that they could be utilized in the future breeding programmes.

Discussions were made for each objective, based on the results obtained on twentyfour genotypes over six environments, under the following headings.

1. Variability, heritability and genetic advance
2. Correlation between yield and yield components
3. Path coefficient analysis
4. Performance of genotypes in different environments
5. Genotype x environment interaction
6. Stability for individual characters.

5.1. VARIABILITY, HERITABILITY AND GENETIC ADVANCE

5.1.1. Days to 50 per cent flowering

The genotypic and phenotypic coefficients of variability were low for this trait. This is in contrast to the findings of Konwar and Talukdar (1984). The heritability was high to very high while the genetic advance was low to moderate indicating non-additive gene action operating for this character. High heritability for days to flowering have been reported by Alam *et al*. (1983), Pushpendra and Ram (1987). There is considerable amount of variation between the six environments. This shows the extent to which this trait is influenced by the environment.

5.1.2. Days to maturity

Like days to 50 per cent flowering the variability for days taken for maturity is quite low. There is certain amount of fluctuations of variability in different environments. Konwar and Talukdar (1984) recorded high variability for this character. The heritability was very high while the genetic advance was moderate to high for this trait. This indicates the possibility of additive as well as non-additive gene actions. High heritability for days taken for maturity was observed by Rashid and Islam (1982), Konwar and Talukdar (1984), Yao *et al*. (1987) and Yao (1988).

5.1.3. Plant height (cm)

The variability for plant height is moderate to high. Similar results were obtained by Miku and

Damaskin (1981) and Konwar and Talukdar (1984). Considerable variation for this trait is noticed in different environment. This speaks about the extent to which this character can be altered. The high heritability and high genetic advance recorded for this trait indicates the operation of additive gene action. Similar observations were made by several workers (Alam *et al.*, 1983; Rashid and Islam, 1982; Eccchard, 1980; Yao *et al.*, 1987; Pushpendra and Ram, 1987).

5.1.4. Number of branches per plant

Moderate to very high variability was observed in different environments indicating higher influence of environment on this character. Further moderate heritability coupled with low genetic advance revealing influence of non-additive genetic factors operating in the expression of this trait. Similar results were obtained by Rashid and Islam (1982).

5.1.5. Number of clusters per plant

The variability was moderate with little fluctuation in different environments. High heritability in conjunction with low genetic advance indicates the operation of non-additive gene action for this character.

Yao *et al*. (1987) and Yao (1988) have also reported high heritability for this trait.

5.1.6. Number of pods per plant

The variability was moderate with considerable amount of fluctuations from one environment to another. Thus it is also influenced by the environment to a considerable extent. High GCV and PCV was observed for this character by Malhotra (1973). The heritability was high and genetic advance was moderate in five environments. This indicates the influence of environments on heritability and genetic advance. These results are in agreement with those of Malhotra (1973), Rashid and Islam (1982), Ecochard (1986) and Yao (1988).

5.1.7. 100 seed weight (g)

The GCV and PCV for this trait was low with little fluctuation over the environments. The present results are in contrast to the findings of Malhotra (1973); Miku and Damaskin (1981). The heritability was high while the genetic advance was low. Similar results were obtained by Rashid and Islam (1982), Yao *et al*. (1987) and Yao (1988).

5.1.8. Seed yield per plant (g)

The variability for seed yield per plant is moderate. There is considerable variation in GCV and PCV in different environments. High variability was recorded by Malhotra (1973); Miku and Damaskin (1921); Sharma et al. (1986). The heritability recorded was high while the genetic advance was low indicating non-additive gene action operating on this trait. Similar results were noticed by Malhotra (1973); Rashid and Islam (1982); Sharma et al. (1986); Ecochard (1986) and Yao (1988).

5.2. CORRELATION BETWEEN YIELD AND YIELD COMPONENTS

Seed yield per plant was associated positively and significantly with days to 50 per cent flowering, days to maturity, plant height, number of branches per plant, number of clusters per plant, number of pods per plant and 100-seed weight in all the six environments and over the environments. This indicates the stablity of association of seed yield with these characters. However there is slight variation in the significance of correlation values with number of branches plant and 100-seed weight with the change in the environments indicating the influence of environment on the association of these characters. Significant association of seed yield per plant with one or more of the above traits have been reported by several workers (Shih, 1948; Weber and Moorthy, 1952; Stohm, 1966; Prakash et al., 1966; Lal and Haque, 1971; Veeraswamy et al., 1973;

Lakshminarayana Rao, 1974; Veeraswamy and Rathnaswamy, 1975; Aristarkhova, 1976; Alam et al., 1983; Chen, 1988).

Days to 50 per cent flowering was positively and significantly correlated at one per cent level of significance, with days to maturity, plant height, number of clusters per plant, number of pods per plant and seed yield per plant in all the six environments. This indicates that the association of days to 50 per cent flowering with the above said traits is not much influenced by the environments. The association of this character with number of branches per plant and 100-seed weight has changed with changes in environment indicating the extent to which the association of these traits is influenced by the environment. Anand and Torrie (1963) and Rohewal and Koppar (1973) observed positive and significant correlations of days to 50 per cent flowering with palnt height.

Plant height was positively associated at one per cent level of significance with days to 50 per cent flowering and days to maturity in all the six environments and over the environments (pooled data). This indicates the stability of the association of this character with duration. Rohewal and Koppar (1973) observed positive significant correlation of plant height with days to flowering. Pfciffer and Pilcher (1987) also recorded strong and positive correlation between plant height and delayed flowering.

Number of branches per plant was positively and significantly correlated with days to 50 per cent flowering, days to maturity and plant height in few environments and the association with these characters was not significant over environments. This indicates the extent to which the association of this character with days to 50 per cent flowering, days to maturity and plant height can be modified. This is in conformation with the findings of Alam et al. (1983).

Number of clusters per plant and number of pods per plant were strongly and positively associated with days to 50 per cent flowering, days to maturity, plant height and number of branches per plant, in all the six environments except for association of number of pods with days to maturity and number of branches per plant in second and fourth environments respectively. This also speaks of the relative extent of the stability of association of these characters over the environments. Similar observations were made by Amaranath (1986).

Hundred seed weight was negatively correlated at one per cent level of significance with days to 50 per cent flowering over the environments, with plant height in first, second and third environments, with number of clusters per plant and number of pods per plant in first environment. It was negatively and non-significantly correlated with plant height in fourth, sixth and over the environments, with number of pods per plant in third and sixth environments. This indicates that the association of 100 seed weight with other characters fluctuates widely depending on the environment. Similar observations on character association were made by Amaranath (1986) but his studies were confined to only one environment.

5.3. PATH COEFFICIENT ANALYSIS

The direct effect of days to 50 per cent flowering on seed yield was negative in first, fourth, fifth and over the environments, while, it was positive for the second, third and sixth environments. This indicates the extent to which the direct effect of days to 50 per cent flowering on seed yield can be modified by the environment (Kaw and Menon, 1973). Srivastava et al. (1976) reported negative direct effect while Amaranath (1986) observed positive direct effect of days to

50 per cent flowering on seed yield. Days to 50 per cent flowering had highest indirect effect via number of pods per plant in fourth environment. Similar observations were made by Amaranath (1986).

The direct effect of days to maturity was positive in four environments viz., first, fourth, fifth and sixth and negative in the other two environments. The direct highest effect was seen in fourth environment (November). Fundosh et al. (1985), Lal and Haque (1971) noticed highest positive direct effect of days to maturity on seed yield whereas Amaranath (1986) observed negative effect of days to maturity on seed yield. Days to maturity had highest indirect effect via number of pods per plant in fourth environment. Similar observations were made by Gautam and Singh (1977).

The direct effect of plant height on seed yield varied from -0.0489 (over the environments) to 0.3752 (third environment). Yap and Lee (1975) observed positive direct effect of plant height on seed yield. Indirect effect of plant height on seed yield was highest through number of pods per plant. Similar observations were recorded by Gautam and Singh (1977), Sharma (1979).

Number of branches per plant had direct effect of -0.0028 to 0.0732 while its highest indirect ffect was observed via number of pods per plant. Highest indirect effect via number of pods has also been reported by Gautam and Singh (1977); Amaranath (1986).

Number of clusters per plant ranged from -0.0172 to 0.3206 in their direct effect on seed yield. Positive direct effect of number of clusters per plant on seed yield was also observed by Yap and Lee (1975); Veeraswamy and Rathnaswamy (1973) and Yao *et al*. (1988). The indirect effect of this trait was highest via number of pods per plant compared to other characters.

The direct effect of number of pods per plant on seed yield was highest compared to other traits in different environments. Its indirect effect was highest via plant height. Similar direct effects were reported by Sharma (1979); Sharma *et al*. (1983); Kaw and Menon (1973); Veeraswamy and Rathnaswamy (1973); Malhotra *et al*. (1972) and Gautam and Singh (1977).

Hundred seed weight had a direct effect ranging from 0.3327 (second environment) to 0.6577 (third environment), on seed yield. Similar direct effects were also reported by Veeraswamy and Rathnaswamy (1975); Gautam and Singh (1977); Ma (1983); Zhou (1983); Choulwar and Borikar (1987) and Yao *et al*. (1988).

The direct and indirect effect of different traits on seed yield varied widely (from negative to positive) in different environments. This indicates that the direct and indirect effects can be altered or changed by the environments.

5.4. PERFORMANCE OF GENOTYPES IN DIFFERENT ENVIRONMENTS

The data obtained from twentyfour diverse genotypes of soybean for each of the eight characters were analysed individually to find out the performance of genotypes in all the six environments.

The mean performance of the genotypes in each environment for different characters are given in the Table 4.5 to 4.12. Such of the five genotypes as found to be best performing for each character in each of the environments are given in Table 4.13. Further, genotypes stable over all the six environments are also given in Table 4.13.

As indicated by the environmental means sixth environment found to be more favourable for early flowering (34.19 days) followed by second (39.48 days), third (40.84 days), first (43.50 days), fourth (46.26 days) and fifth environment (57.51 days). Monetta and KB-78 genotypes were found to be flowering early in all the environments. List of genotypes suitable to different environments for early flowering are given in Table 4.13.

Days to maturity was found to be very less in the third environment as indicated by environmental means of 99.33 days. On the contrary first environment took maximum number of days to maturity (115.12). Among the genotypes KB-78 and Monetta were found to be less durated in all the environments under study. UGM-21 was found to be medium durated (90-105 days) all over the environments. KHSb-2 was found to be late in most of the environments where it took 105-120 days. Whereas in the fourth and fifth environments it was found to be very late (more than 120 days), similarly the variety Hardee was found to be late (110-120 days) in all the environments except in the fourth environment where it took more than 120 days for its maturity. Other genotypes varied in the maturity period and are listed in Table 4.6, better genotypes suitable for different environments are also listed precisely in Table 4.13.

Fifth environment was found to be more favourable for higher plant height (51.90 cm) followed by sixth (47.93 cm), first (42.93 cm), fourth (37.90 cm), second (34.57 cm) and third environments (25.24 cm). Even though some of the genotypes exhibited uniform plant height over the environments, majority of the genotypes varied in their height in different environments (Table 4.7). Genotypes suitable for different environments for varying plant height are given in Table 4.13.

Environments had little influence on number of branches per plant as indicated by a narrow range of environmental means. However second environment was found to be more favourable for better expression of this character where it gave 3.16 branches per plant. This was followed by fourth (3.10), first (2.83), fifth (2.65), sixth (1.85) and third environments (0.97). Genotypes differed in their performances in different environments and they are given in Table 4.8. List of suitable genotypes for different environments are given in 4.13.

First environment (May) was found to be more favourable for higher number of clusters per plant (14.85) followed by second (13.96), fourth (12.97), fifth (11.72), sixth (10.31) and third environments (7.25). Among genotypes UGM-30, UGM-34, KHSb-2 and DS-2 were found to be high cluster bearers in most of the environments. However, genotypes will not be uniform over environments in respect of clusters bearing (Table 4.9). Some of the suitable genotypes for different environments under study, are listed in Table 4.13.

Varying environmental means (13.76 to 41.32) and environmental indices (-13.76 to 13.80) indicate the greater influence of environment on number of pods per plant. To get higher number of pods, first environment (May) was found to be more favourable as it gave 41.32 pods per plant. On the contrary third environment (September) was found to be less favourable for this character (13.76 pods per plant). Among the genotypes UGM-30, UGM-34, KHSb-2, Hardee and DS-2 were found to bear high number of pods per plant. But they found to vary from environment to environment (Table 4.10). List of genotypes in respect of high number of pods per plant for different environments are listed in Table 4.13.

With regard to hundred seed weight, environments have moderate influence, which was reflected by varying environmental means (12.35 to 17.10). First environment (May) was found to be more condusive for higher 100 seed weight (17.10 g), followed by sixth (16.42 g), second (13.96 g), third (13.09 g), fifth (12.46 g) and fourth environment (12.35 g). Genotypes differred for their 100-seed weight in different environments (Table 4.11). Table 4.13 provides information on suitable genotypes for different environments to obtain higher 100-seed weight.

In respect of seed yield per plant MACS-189, UGM-21, PK-472, KB-38A, KB-60 and DS-2 genotypes were found to be uniform over the environments. With a mean yield of 7.51, 7.25, 7.45, 7.12, 9.37 and 7.25 g per plant respectively. Remaining eighteen genotypes varied in their yielding ability from environment to environment (Table 4.12) indicating the influence of environments on the expression of this character. Among the six environments, first environment (May) was found to be more favourable for higher seed yield per plant (13.51 g). List of genotypes which perform well only in specific environments are given in Table 4.13.

5.5. GENOTYPE X ENVIRONMENT INTERACTION

Genotype-envirnment interaction are of major importance to the plant breeders in developing improved varieties. This interaction is usually present and it reduces progress from selection (Comstock and Moll, 1963; Singh et al., 1974). Selection of stable genotypes that interact less with the environments in which they are to be grown, are known to reduce genotype x environment interaction to a considerable extent (Allard and Bradshaw, 1964). Genotypes which interact less with the environments are selected and it aids the breeder to greater extent in developing stable genotypes.

In the present investigation to identify and estimate genotype x environment interaction the statistical procedure given by Sundararaj et al. (1972) has been adopted. This revealed significant differences among the genotypes, environments as well as genotype x environment interaction for all the eight characters viz., days to 50 per cent flowering, days to maturity, plant height, number of branches per plant, number of clusters per plant, number of pods per plant, 100 seed weight and seed yield per plant (Table 4.14). Similar results were obtained in soybean for various characters by many workers. Khurana and Yadava (1982), Kaw and Menon (1978a), Kaw and Menon (1983b), Funnah and Mak (1980a). Genotype x environment (GE) interaction were also reported from other crops in cowpea. Mungomery et al. (1972), Malik et al. (1973) observed GE interaction in seed types whereas Paroda et al. (1974) noticed in fodder types. Ojamo and Adelana (1970) observed GE interaction in groundnut for its seed yield.

Malhotra and Singh noticed GE interaction for pod number and seed yield in Bengalgram. Khan and Erskine (1978) observed GE interaction in winged bean similarly Choudhary and Haque (1977) observed in greengram. In the present investigation, the significance of overall GxE interaction called for the determination of stability parameters for each of the genotypes.

The analysis of variance as per Eberhart and Russell (1966) revealed significant differences among the genotypes for all the characters (4.15). The additive enrivonmental variance was found to be of considerable magnitude as indicated by the significance of environment linear for all the characters. Similar observations were made by Talukdar and Kanwar (1986). Pooled deviations (non-linear) were significant for all the nine characters indicating that this portion which is unpredictable, formed major part of the GxE interaction. This is in agreement with the findings of Chauhan (1984) and Acharya et al. (1985). However GE-interaction (linear) and pooled deviation mean (squares) non-linear were found to be significant for the characters, days to 50 per cent flowering, plant height, seed yield per plant and 100-seed weight, indicating the contribution of both linear and non-linear components towards the

GE interaction variance of these characters. The more pronoucned linearity for days to 50 per cent flowering, plant height, seed yield per plant and hundred seed weight indicated that the variations among the genotypes could largely be explained by differences in regression slopes for these characters. This obviously indicated that the accurate prediction of the phenotypic performances of the genotypes can be reduced for these characters. But such predictions are not possible for days to maturity, number of branches per plant, number of clusters per plant and number of pods per plant due to the pronounced non-linearity. However results contradictory to this observation that, Konwar and Talukdar observed significant pooled deviation (non-linear) only for number of pods per plant, number of clusters per plant, number of seeds per pod, 100 seed weight and seed yield per plant but not for number of clusters per plant, and non-significant GE (linear) for number of seeds per pod and seed yield per plant. Such contradictions are not unexpected because, different workers had used different genotypes in varying environments. Thus, it can be inserted that there is no or simple relationship between the genotypes and the environments and therefore, it is rather difficult to predict the performance of the genotypes across the environments.

5.6. STABILITY FOR INDIVIDUAL CHARACTERS

Stability analysis was carried out by employing the linear regression model proposed by Eberhart and Russell (1966). Although there are a number of models available to characterise the genotypes for their GxE interaction, in effect the stability, this model is widely used for its simplicity and reliability. Many workers have employed this model (Naidu et al., 1980); Nagamine and Wada, 1982; Jamadagni et al., 1984; Snivanna, 1989; in paddy Konwar and Talukdar, 1986; Gopani et al., 1972; Lal et al., 1973; Khurana and Yadava, 1982 in soybean). In the present investigation, this analysis indicated that the genotypes differed significantly in their response to varying environments in respect of eight characters viz., day to 50 per cent flowering, days to maturity, plant height (cm), number of branches per plant, number of clusters per plant, number of pods per plant, 100-seed weight and seed yield per plant.

When once the GxE interaction was found significant, the next task was to identify the stable genotype which interact less with the environment and thus perform nearer to consistency across the environments. The model employed in this investigation considers three parameters viz., (i) mean ( ) - performance, (ii) regression coefficient (bi) - cultivar means are regressed against environmental index, i.e., a predictable response by a cultivar to either good or poor environments, and (iii) deviation from regression (S^2di) - a measure of genotype x environment interaction of unpredictable type.

An ideal stable genotype is defined as the one possessing high mean performance, with regression coefficient around unity (bi=1) and with least deviation from regression coefficient i.e., as close to zero as possible. The linear regression is regarded as the measure of response of a particular genotype. If regression coefficient (bi) is greater than unity the genotype is said to be highly sensitive to environmental changes but adopted to high yielding environments. If bi is equal to unity, it indicates average sensitivity to environmental changes and adaptability to all environments. If bi is less than unity (1.00), it indicates less sensitivity to environmental changes and if this is accompanied by a high mean value, then the genotype is said to be better adapted to widely differing conditions. If the mean is low, it can be interpreted that the genotype is poorly adopted to all environments.

Performances of highly sensitive, average sensitive and less sensitive genotypes cannot be predicted when we grow in different environments.

In the present study stability parameters such as mean (existing), regression coefficient (bi=1) and the deviation from regression coefficient S di (as close to zero as possible), suggested by Eberhart and Russell (1966) were considered to explain and discuss the stability of different genotypes for various characters under consideration.

5.6.1. Days to 50 per cent flowering

Among twentyfour genotypes, only three viz., Monetta, JS-81-714 and KB-74 were found to be stable for this character over six environments as indicated by regression coefficient (bi=1) and mean square deviation ($S^2di=0$) and it is shown in Table 4.16 and Figure 4.4. Monetta was earliest to flower (37.94 days) whereas JS-81-714 was of medium duration (39.94 days) and KB-74 was late to flower (45.00 days).

The genotypes DS-76-1-37-1, JS-79-277, DS-2, KB-38A, UGM-21, KB-32, MACS-124, MACS-125, MACS-189, PK-471, PK-472 and UGM-30 even though possessing high mean and unit regression they were significantly deviated from mean square deviation ($S^2di=0$). Hence they are classified under average sensitive genotypes. This indicates their suitability to all environments with unpredictable performances.

Five genotypes viz., Hardee, KB-60, MACS-13, KHSb-2 and UGM-34 were found to be highly sensitive to environment as indicated by their unit regression value exceeding unity. Since these genotypes are also possessing high mean value they can be adopted to high yielding environments.

The genotypes Bragg, KB-78, PK-416 and JS-81-303 in addition to low mean values they also possessed regression coefficient less than one. Thus these genotypes were classified under low sensitive to environmental variation. This indicates their poor adoptability to all environments under study.

The results obtained are in contrast to the results of Kaw and Menon (1978a) where they observed all genotypes as stable for this trait.

5.6.2. Days to maturity

The environments influenced much for the expression of this character as revealed by varied environmental indices and environmental means. The stability parameter, the regression coefficient was not significantly deviated from unity for all the genotypes except for UGM-21. Whereas, the deviation from regression was found to be significant for all the genotypes except for the same genotype UGM-21. Thus no genotype was found to be stable for this character (Table 4.17 and Fig.4.5).

Four genotypes viz., DS-2, KB-60, UGM-30 and UGM-34 were found to be highly sensitive to environment as indicated by their regression coefficient exceeding unity. Thus these genotypes are suitable to favourable environments. But as they were not stable their performance cannot be predicted early when grown in different environments.

Regression coefficient (bi) was found to be less than one for Bragg, JS-81-303 and UGM indicating their less sensitiveness to environment. Thus these genotypes were suitable to all environments but their performances will be very poor as indicated by the low mean. Their performances also cannot be easily predicted.

Seventeen genotypes with average and above average mean, did not significantly deviate from unit regression coefficient but they were deviated from mean square deviation (S di). Hence these genotypes were classified under average sensitive genotypes. They are suitable to all environments. However their performances cannot be easily predicted as were not stable. Similar results were obtained by Kaw and Menon (1978b). Among average sensitive genotypes Monetta (87.72) and KB-78 (90.89) were found to be earliest to mature, while the genotype KHSb-2 was of maximum duration with 124.33 days.

5.6.3. Plant height in cm

As per the stability parameters, seventeen genotypes were found to be stable for plant height in the present investigation (Table 4.18 and Fig.4.6). They are Hardee (36.97), Bragg (30.30), Monetta (26.21), KHSb-2 (53.33), MACS-13 (39.29), MACS-189 (38.13), UGM-21 (43.07), PK-416 (31.04), PK-471 (31.65), PK-472 (29.46), KB-32 (32.30), IB-38A (33.82), KB-74 (31.54), DS-2 (44.65), DS-76-1-37-1 (32.38), JS-79-277 (41.56) and JS-81-714 (31.92).

The genotypes UGM-30, UGM-34, MACS-124 and MACS-125 were found to be highly sensitive to environmental fluctuations (bi more than one) indicating their better suitability to highly favourable environments. Since they were not found to be stable their performance may not be predicted when they are grown in different environments.

Regression coefficient (bi) was found to be less than unity for KN-78 and JS-81-303 indicating their poor adaptability to all environments. But they were less sensitive to environment. Their performances also cannot be predicted. Similar results in other genotypes were observed by Gopani et al. (1972).

5.6.4. Number of branches per plant

For number of branches per plant ten genotypes were found to be not significantly deviated from regression coefficient (bi=1) and mean square deviation ($S^2di=0$) indicating their stability over six environments for this character (Table 4.19 and Fig.4.7).

Genotype KB-60 was highly sensitive to environmental fluctuations (bi more than one) with high mean performance (3.53) indicates its suitability to high yielding (more favourable) environment. As it was not stable its performance cannot be easily predicted when grown in different environments.

Low mean (1.46) coupled with regression coefficient (bi) less than one indicates KB-78 has got less sensitivity to environmental fluctuations. Thus it is adopted to all environments and its performance over the environments is unpredictable.

Even though UGM-30 and UGM-34 found to be less sensitive to environment their high mean performance indicates their better adoptability to widely differing conditions with unpredictable performances when grown in different environments.

Remaining genotypes included MACS-125, MACS-124, Bragg, PK-471, KB-74, DS-2, MACS-189, Hardee and KB-32 which were of average response to environmental variation indicating that they are suitable to all environments. When they are grown over environments their performances may not be easily predicted. Khurana and Yadava (1982) noticed the similar observations.

5.6.5. Number of clusters per plant

Stability parameters bi and S^{γ}di indicates eleven genotypes viz., PK-472, JS-81-714, JS-81-303, DS-76-1-37-1, KB-32, PK-471, KB-38A, MACS-189, UGM-21, DS-2 and MACS-124 to be stable for this character over six environments with the mean performance of 8.92, 9.32, 9.34, 10.21, 9.94, 10.07, 10.65, 11.32, 13.56, 14.06 and 11.88 clusters per plant respectively (Table 4.20 and Fig.4.8). It also indicates their performances can be predicted well over all the environments studied. Similar results were recorded by Konwar and Talukdar (1986) and Gopani et al. (1972).

The genotypes KB-60, KHSb-2 and UGM-30 were found to be highly sensitive to environmental fluctuation as indicated by regression coefficient (bi is more than one) and mean square deviation (S di=0). It indicates their suitability to more favourable environments with unpredictable performance when grown in different environments. On the contrary genotype Monetta and KB-78 were found very less sensitive to environment with poor mean performance, which indicates their poor adaptability over all the environments studied.

The regression coefficient (bi) was found to be equal to one for the following genotypes viz., Bragg, KB-74, MACS-125, JS-79-277, Hardee and UGM-34, indicates their average sensitivity to environmental fluctuations. But they can be suitable to all types of environments being studied. As they are not stable their performances cannot be easily predicted when grown over environments.

5.6.6. Number of pods per plant

Among the twenty four genotypes studied only seven (Table 4.21 and Fig.4.9) viz., MACS-185, UGM-21, PK-471, JS-81-303, KB-74, KB-38A and KB-32 observed to be stable for this character as indicated by regression coefficient (bi=1) and mean square deviation from regression (S di=0). Their mean pod number per plant being 29.69, 30.55, 25.99, 23.47, 21.42, 21.83 and 21.83 respectively. Konwar and Talukdar (1986) did not find any stable genotypes for this character in their study which was under different environments with different genotypes.

As per the stability parameters DS-76-1-37-1, MACS-13, MACS-125, JS-79-277, KB-60 and UGM-30 were found to be of average sensitivity to environments. Thus they were suitable to all the environments with unpredictable performance.

As the regression coefficient exceeded unity for Hardee, DS-2, KHSb-2 and UGM-34 were found to be highly sensitive to environmental fluctuations. But they are more suitable to favourable environments compared to their performances under less favourable environments. As these genotypes were not stable when they are grown in different environments, their performance may not be predicted very easily. On the contrary genotypes Monetta, KB-78, PK-416 and PK-472 were found to be less sensitive to environmental fluctuations (bi=less than one) indicating their poor adoptability to all environments with unpredictable performance.

5.6.7. 100-seed weight (g)

Among twenty four genotypes only two viz., UGM-21 and DS-76-1-37-1 were found to be stable for this character over six environments as indicated by regression coefficient (bi=1) and mean square deviation ($S^2di=0$) from regression (Table 4.22 and Fig.4.10).

The genotypes Monetta, KB-78, MACS-189, MACS-13, MACS-124, JS-81-303, MACS-125, KB-74, JS-79-277, JS-81-303, KHSb-2, PK-416 and KB-60 were found to be average sensitive to the environments (bi is equal to one). This indicates their suitability to all the environments. As they were not stable, their performances cannot be predicted when they are grown in different environments.

JS-81-714, KB-38A, PK-471, PK-472 and KB-32 genotypes were found to be highly sensitive to the environmental variations. But they are more suitable for favourable environments compared to less favourable ones. However their performances cannot be easily predicted.

Hardee, UGM-34, UGM-30 and DS-2 were found to be less sensitive to environmental variation (bi less than one). Among these, Hardee having higher mean, indicated its better adoptability to widely differing conditions in respect of this character. On the contrary DS-2, UGM-30 and UGM-34 by possessing lesser mean value exhibits their poor adoptability to all environments. However the performance of these genotypes when grown in different environments cannot be easily predicted.

Similar results were observed by Gopani et al. (1972) and Konwar and Talukdar (1986) in soybean.

5.6.8. Seed yield per plant (g)

As per the stability parameters, regression coefficient (bi) and mean square deviation from regression (S di) six among twenty four genotypes were found to be stable for this character over six environments (Table 4.23 and Fig.4.11). They were MACS-189, KB-38A, UGM-21, DS-2, PK-472 and KB-60. Among them KB-60 was found to be highest yielder (9.37 g) followed by MACS-189 (7.51 g), PK-472 (7.45 g), UGM-21 (7.25 g), DS-2 (7.25 g) and KB-38A (7.12 g). These genotypes were found to be suitable for all the environments with predictable seed yield per plant. Stable genotypes for seed yield per plant in soybean were also reported by Gopani <u>et</u> <u>al</u>. (1972), Konwar and Talukdar (1986).

Since the regression coefficient (bi) was equal to one in case of genotypes KB-32, PK-416, JS-81-303, MACS-124, JS-81-714, KB-74, MACS-13, MACS-125, UGM-34, KHSb-2 and UGM-30, they were found to be average sensitive to the environments, indicating their suitability to all the environments under study. As these genotypes were not stable and their performances cannot be easily predicted when they are grown in different environments. Among them UGM-30 was found to be highest seed yielder per plant (12.82 g) followed by KHSb-2 (12.5 g).

Three genotypes viz., Hardee, PK-471 and JS-79-277 were found to be highly sensitive to environmental fluctuations as indicated by stability parameters. $S^2di=0$ and bi with the value being more than one. Among these genotypes Hardee ranks first with a seed yield of 10.36 g per plant followed by JS-79-277

(9.41 g) and PK-471 (9.01 g). They can be considered to be well suited to more favourable environments like May sowing compared to less favourable environments like September sowing as in the case of this study. However, when they are grown in different environments their performance may not be predicted easily.

The genotypes KB-78, Monetta and Bragg were found to be less sensitive to environmental fluctuations as indicated by stability parameters $S^2di=0$ and bi less than one. Less mean performance of these genotypes indicates their poor adoptability to all environments.

It was evident from the statistical analysis that the genotypes differed significantly from environment to environment. However the response of genotypes to changing environment was not the same for all the characters. Environments differed among one another for all the characters indicating that there existed inherent differences among the environments.

First environment (May sowing) was conducive for majority of the characters followed by sixth (March sowing), second (July sowing), fourth (November sowing) and fifth environments (January sowing). While the third environment (September sowing) was not favourable for most of the characters. However for early flowering and early maturity second (July sowing) and third environments (September sowing) were found more favourable respectively. Genotype x environment interaction which was highly significant for all the characters, ruled out any possibility of isolating a particular character with low magnitude of interaction. This in turn has failed to facilitate using any of the characters studied as a criterion in the future selection programme.

The pooled deviations (Table 4.15) for all the characters were high and not approaching zero indicating that the predictions cannot be valid. Further this also suggested that the contribution of non-linear component was more than linear component towards he interaction effects.

No single genotype was stable for all the characters, as revealed by the stability parameters for each character and for each genotype (Table 4.16 to 4.23). However, some strains were found to be stable for some characters. This suggests that stability for yield in a variety can be achieved by stabilizing some characters, and stability for one character is independent of stability for another character.

In respect of seed yield per plant, the genotypes Hardee, KHSb-2, UGM-30, UGM-34, MACS-125, KB-60 and JS-79-277 would perform better in most of the environments.

The whole discussion can be summarised in the following way.

Number of clusters and pods per plant were strongly correlated with seed yield and also had highest direct effect in most of the environments studied.

Based on overall performance of genotypes in different environments, sowing in the month of May appeared most congenial for higher seed yield where number of pods per plant, clusters per plant, plant height and test weight contributed more towards seed yield. On the other hand sowing in the month of September found not favourable for most of the characters including seed yield. However the genotypes Hardee, UGM-30, KHSb-2, UGM-34, MACS-124 besides KB-60, MACS-189, UGM-21, PK-472 and KB-38A found to perform well in this environment also.

The genotypes viz., KB-60, MACS-189, UGM-21, PK-472, KB-38A besides KHSb-2 and UGM-30 are stable with general adoptability in all the environments studied.

For optimum seed yield, the genotype should mature around 118-124 days and should have a medium height (50-60 cm) with more number of branches. However, if the plants have less branches at least they must be tall with higher number of pods to achieve optimum seed yield. This information is likely to help in choosing genotypes with desirable ideotype to fit into different cropping systems.

FUTURE LINE OF WORK

1. As an expansion of present investigation, similar stability analysis needs to be carried out over locations. Thus suitable genotypes for different locations and environments can be effectively identified.

2. It seems to be worthwhile to further evaluate the genotypes against different stress conditions, so that, those which are better suited for such conditions can be used in future varietal improvement programmes.

SUMMARY

VI. SUMMARY

The present investigation was taken up with the prime objective of knowing genotype x environment interaction besides assessing genetic variability, association between different characters and relative contribution of different traits towards seed yield in soybean. To identify stable genotypes, twentyfour diverse genotypes tested in six environments (seasons) viz., E_1 (May, 1988); E_2 (July, 1988), E_3 (September, 1988); E_4 (November, 1988); E_5 (January, 1989) and E_6 (March, 1989). The results obtained are summarised in the text to follow.

The difference between genotypic coefficient of variability (GCV) and phenotypic coefficient of variability (PCV) for eight characteristics (viz., days to 50 per cent flowering, days to maturity, plant height, number of branches per plant, number of clusters per plant, number of pods per plant, 100-seed weight and seed yield per plant) studied in all the six environments was narrow. This speaks of the reliability of PCV as a measure of GCV. The heritability was high for days to 50 per cent flowering, days to maturity, plant height, number of clusters per plant, number of pods per plant and 100-seed weight. But the genetic advance was high for plant height and number of pods per plant. While it was low to moderate for remaining characters. This indicated that additive gene action is operating for plant height and number of pods per plant while for the other characters non-additive gene action seems to be operating. There is slight variation in GCV, PCV, heritability and genetic advance in different environments. The heritability for number of branches per plant is low to moderate. The variation in these genetic parameters with change in the environment points out that these parameters can also be altered by the environment.

There is a strong association between seed yield and days to 50 per cent flowering, days to maturity, plant height, number of branches per plant, number of clusters per plant and number of pods per plant irrespective of the environments. There is variation in the association of seed yield with 100-seed weight with change in the environment.

The direct effect of number of pods per plant on seed yield was highest, followed by 100-seed weight. The direct effect of other characters fluctuated between negative and positive values indicating the influence of environment on these traits. The indirect effect of most of these characters on seed yield was highest via number of pods per plant.

Number of clusters and pods per plant were strongly correlated with seed yield and also had highest direct effect, therefore these are the reliable traits on selection programme.

The two way analysis of variance revealed that the genotypes and environments differed significantly for all the characters under study. This also suggested the existence of significant genotype x environment (GE) interactions in respect of all the eight characters studied.

Analysis of overall performance of genotypes in different environments indicated sowing in the month of 'May' is congenial for most of the characters including seed yield. On the other hand sowing in the month of September is found not favourable for the better expression of characters under consideration.

The genotypes differed in their response to varying environments for majority of the characters as indicated by the stability analysis done as per the model proposed by Eberhart and Russell (1966). Environment (linear) was significant for all the characters, while genotype x environment (linear) was found significant only for days to 50 per cent flowering, plant height, seed yield per plant and 100-seed weight. Pooled deviation on the other hand was highly significant to all the characters indicating that unpredicatable portion formed the major part of the GxE interaction.

Stability parameters were computed for each character and for all genotypes adopting the methods outlined by Eberhart and Russell. None of the genotypes was stable for all the characters. Stability for one character was independent of the other characters.

The genotypes viz., KB-60, MACS-189, UGM-21, PK-472, KB-38A besides KHSb-2 and UGM-30 are stable with general adaptability in all the environments studied and hence they can be exploited in future breeding programme.

REFERENCES

VII. REFERENCES

Abrams,R., 1975, Status of research on pigeonpea in Puerto rico. Int.Workshop on grain legumes. ICRISAT, 141-147.

Acharya,S., Sharma,K.D. and Sahi,H.P.S., 1985, Unsuitability of micro-environment for assessing the stability for yield and its components in rice. Indian J.Agric.Sci., 55(2):139-141.

Akhanda,A.M., Prine,G.M., Green,V.E. and Hinson,K., 1981, Phenology and correlation of growth phases in late planted soybean in Florida, USA. Indian J.Agric.Sci., 51(4):214-20.

*Alam,S., Muresan,T. and Dencescu,S., 1983, Correlations between yield and agronomic characters in soybean [Glycine max (L.) Merrill] and the heritability of these characters. Agronomie., 26:37-48.

*Allard,R.W., 1961, Relationship between genetic diversity and consistency of performance in different environments. Crop Sci., 1:127-133.

Allard,R.W. and Bradshaw,A.D., 1964, Implications of genotype environmental interaction in applied plant breeding. Crop Sci., 4:503-508.

Amaranatha,K.C.N., 1986, Genetic variability, correlations and path analysis of some quantitative characters in soybean [Glycine max (L.) Merrill]. M.Sc. thesis submitted to University of Agricultural Sciences, Bangalore, Karnataka, India, pp.105.

Anand,A.C. and Torrie,J.H., 1963, Heritability of yield and other traits and interrelationships among traits in the F_3 and F_4 generations of three soybean crosses. Crop Sci., 3:508-511.

*Aristarkhova,M.L., 1976, Correlation of characters in soybean. Tr.Leningr.0-va estestvoispyt, 73(5):22-32.

Barbind,R.P., Reddy,V.G. and Ashmatoddin,M., 1981, Correlation and regression studies in soybean. J.Maharastra Agric.Univ., 6(2):128-130.

*Bartlett,M.S., 1937, Tests of homogenity of variance. Statist.Soc.Suppl., 4:137.

Bhatnagar,P.S., 1989, Project Co-ordinators report, AICRP on soybean. NRC Soybean (ICAR), Indore, page-ii.

Bliss,F.A., Barker,L.N., Franckowiak,J.D. and Hall,T.C., 1973, Genetic and environmental variation of seed yield, yield components and seed protein quality and quality of cowpea. Crop Sci., 13:656-660.

Brain Westcott, 1986, Some methods of analysing genotype environment interaction. Heredity, 56:243-253.

Breese,E.L., 1969, The measurement and significance of genotype-environment interactions in grasses. Heredity, 31:181-200.

Burton,G.W. and Devane,G.M., 1953, Estimating heritability in Fall fescue (Festuca cirunclinaceae) from replicated cional material. Agron.J., 45:478-481.

Chan,K.L., Lee,R.S. and Thseng,F.S., 1986, Genetic variation of soybean hybrid populations by natural selection in spring crop season at four locations and frequency distributions for certain agronomic characters in F-8 gene ratios. Journal of Agrl.Research of China, 35(3):263-279.

Chan,K.L., Lee,R.S. and Thseng,F.S., 1986, Genetic variation of soybean hybrid populations by natural selection in spring crop season at four locations and frequency distributions for certain agronomic characters in F-2 generations. Journal of Agrl.Research of China, 35(3): 263-279.

Chauhan,V.S., 1984, Stability of yield performance in some hill rice varieties. Crop Improv., 11(2):148-149.

Chen,M.L., 1978, Studies on the optimum regression analysis method for multi collinear data and its application to the relationship between growth and yield in soybean varieties. Memories of the College of Agriculture. National Taiwan University, **18**(1):78-87.

Chen,Y., 1988, Analysis of inheritance and correlation of leaf shape of hybrid progenies from cultivars of different leaf shape in soybean. Soybean Sci., **7**(1):13-18.

Choulwar,S.B. and Borikar,S.T., 1987, Path analysis in M-3 generation of cowpea. J.Maharastra Agril. Univ., 12(1):431.

Chowdhury,S.K. and Haque,M.N., 1977, Stability performance of some green gram varieties. Indian J.Agric.Sci., **47**:303-304.

*Comstock,R.L. and Moll,R.H., 1963, Genotype x environment interactions. Statistical Genetics and Plant Breeding (Ed.W.D.Hanson and H.F.Rabinson). National Academy of Science, National Research Council Publication, **982**:164-196.

*Dai,O.H., 1981, Preliminary studies on the variation and inheritance of the main quantitative characters in local varieties of summer sown soybean in southern Anhui. Zhonggho Youliao., **2**:18-23, China.

Dewey,D.R. and Lu,K.H., 1957, A correlation and path coefficient analysis of components of created wheat grass seed production. Agron.J., **51**: 515-518.

*Diazcarrasco,H. and Leon Gonzalez,J.P., 1985, Phenotypic correlations in soybean and their importance in selection for yield. Ciencias de la Agricultura, **24**:99-103.

Dixit,P.N. and Patil,V.P., 1984, Path analysis studies in soybean. J.of Maharastra Agril.University, **9**(3):267-269.

Eberhart,S.A. and Russell,W.A., 1966, Stability parameters for comparing varieties. Crop Sci., **6**:36-40.

*Ecochard,R., 1986, Inheritance of measurable selection criteria in soybean. Paris France CFTTOM, 129-135.

Finlay,K.W. and Wilkinson,G.N., 1963, The analysis of adoption in plant breeding programme. Aust.J. agric.Res., **14**:742-754.

Fisher,R.A. and Mackenzie,W.A., 1923, Studies in crop variation II. The manurial response of different potato varieties. J.Agric.Sci., Cambridge, **13**:311-320.

*Fisher,R.A. and Yates,F., 1963, "Statistical tables for Biological, Agricultural and Medical Research". Oliver and Boyd, Edinburgh.

*Fontes,L.G., Almeida Filho,J.De, Reis,M.S., Sediyama,T. and Sediyama,C.S., 1980, Oil and crude protein contents of the seeds and correlations with some agronomic features of soybean varieties and lines. Revista Ceres., **27**(149):17-22.

Freeman,G.H., 1973, Statistical methods for the analysis of genotype environment interaction. Heredity, **27**:15-23.

Frey,K.J., 1964, Adaptation reaction of oat strains selected under stress and non-stress environmental conditions. Crop Sci., **14**:55-58.

*Fundora Mayor,Z. and Gonalez Bayon,R., 1985, Correlations and path coefficients in three varieties of soybean in the spring. Ciencias de la Agricultura, **24**:129-130.

Funnah,S.M. and Mak,C., 1978, Varietal evaluation and correlation studies of an exotic population of soybean. Malaysian appl.biol., **7**(2):131-137.

Funnah,S.A. and Mak,C., 1980, Genotype x environmental interactions on grain yield and other characters of soybeans. Experimental Agriculture, **16**(3):269-273.

Funnah,S.M. and Mak,C., 1980a, Genotype x environment interactions on grain yield and other characters of soybeans. Expl.Agric., **16**:269-273.

Funnah,S.M. and Mak,C., 1980b, Yield stability studies in soybeans (Glycine max). Expl.Agric., **16**:387-392.

Gautam,P.L., Garg,D.K., Pal,S., Malik,S.K. and Manglik,V.P., 1986, Genotype x environment interactions and crop improvement, A review in: Genetics and crop improvement (Eds.P.K.Gupta and J.R.Bahi), Rastogi and Company, Subash Bazar, Meerut, India.

Gautam,P.L. and Singh,H.B., 1977, Analysis of character association in soybean crop improvement. Crop imp., **4**(2):184-190.

Gopani,D.D. and Kabaria,M.M., 1970, Correlations of yield with agronomic characters and their heritability in soybeans. Ind.J.Agric.Sci., **40**:847-853.

Gopani,D.D., Kabaria,M.M. and Joshi,S.N., 1972, Stability parameters for comparing varieties of soybean [Glycine max (L.) Merrill]. Indian J.of Agric. Sci., **42**:400-404.

Goulden,C., 1959, Methods of statistical methods. Asia Publishing House, Calcutta.

*Gupta,V.P., Ramanujum,S. and Kaul,A.K., 1974, Stability analysis in respect of protein, sulphur and protein value index of seed and its implication in adaptation of chickpea [Cicer arietinum (L.)]. Genetika, Yugoslavia, **6**:247-261.

Gyusova,M. and Ilcheva,E., 1987, Height in soybean plants as an index of agronomic and meteorological conditions for seed yield development. Vasil Kalarav., **27**(4):11-125.

Hanson,G.H., Robinson,H.F. and Comstock,R.E., 1956, Biometrical studies of yield in segregating populations of Korean Lespedeza. Agron.J., **48**:267-282.

Hays,H.K., Immer,F.R. and Smith,D.C., 1965, Methods of plant breeding. McGraw Hill Book Co., New York.

Hill,J., 1975, Genotype x environment interaction a challenge for Plant Breeding. J.Agric.Sci. Camb., **85**:477-493.

Hwang,Y.H. and Kim,D.V., 1986, Efficiency of selection environment in early generation selection of hybrid populations of soybean for full and late season cropping. Res.rep.rural devop.Adms. Crops, Korea republic, **28**(2):154-171.

Jamadagni,B.M., Sawant,P.S., Patil,S.L. and Chauhan,S.A., 1984, Stability for grain yield in very early duration rice genotypes. J.Maharashtra Agric. Univ., **9**(1):116-117.

Johannsen,W., 1909, Elements der Exakten Erblic-kkeitslehre, Ist ed., 515pp, Jena:Gustav Fischer.

Johnson,R.W., Robinson,H.F. and Comstock,R.E., 1955, Estimates of genetic and environmental variability in soybeans. Agron.J., **47**:314-318.

Johnson,R.W., Robinson,H.F. and Comstock,R.E., 1955, Genotypic and phenotypic correlations in soybeans and their implications in selection. Agron.J., **47**:477-483.

*Johanssen,W.L., 1909, Elements des exatetes exblich Ketitslehire Jena: Gustun Fisher.

Joppa,L.P., Lebsock,K.L. and Busch,R.H., 1971, Yield stability of selected spring wheat cultivars (Triticum aestivum L. em. Thello) in the Uniform regional nurseries, 1959-1968. Crop Sci., **11**:238-241.

Kaw,R.N. and Madhava Menon,P., 1973, Heritability estimates and path coefficient analysis for agronomic characters in soybean [Glycine max (L.) Merrill]. Madras Agric.J., **60**:1512-1516.

Kaw,R.N. and Menon,D.M., 1978a, Genotype x environment interaction in Glycine max (L.) Merrill. Varietal tests. Madras Agricultural Journal, **65**(11):720-724.

Kaw,R.N. and Menon,P.M., 1978b, Evaluation of soybean genotypes at Coimbatore. Madras Agricultural Journal, **65**(12):779-786.

Khan,T.N. and Erskine,W., 1978, The adaptation of winged bean [Psophocarpus tetragonolobus (L.) DC] in Papua New guinea. Aust.J.Agric.Res., **29**:281-289.

Khurana,S.R. and Yadava,T.P., 1982, Stability and adoption in soybean. Indian J.Agric.Sci., **52**(5):292-296.

Knight,R., 1970, The measurement and interpretation of genotype environment interactions. Euphytica, **19**:225-235.

Konwar,B.K. and Talukdar,P., 1984, Environmental influence on the genetic parameters in soybean. J.of Research, Assam Agril.University, **5**(2):135-142.

Konwar,B.K. and Talukdar,P., 1986, Stability analysis of yield and its components in soybean. Crop Improv., **13**(1):172-175.

Lakshminarayana Rao,N.A., 1974, Analysis of genetic variability and formulation of selection indices for yield in soybean. Mysore J.agric. Sci., **8**:156.

Lal,M.S., Mehta,S.K., Deodhar,A.D. and Sharma,Y.K., 1973, Protein and oil content, their correlations and phenotypic stability in soybean as influenced by different environments in Madhya Pradesh. Indian J.Agric.Sci., **43**(1):14-17.

Lal,M.S. and Fazel Haque,M.D., 1971, Path analysis of yield components in soybeans. Ind.J.Genet., **31**:357-362.

Lewis,D., 1954, Genotype x environment interaction - A relationship between heterosis, phenotypic stability and variability. Heredity, **8**:333-356.

Liu,D.T., Zhou,Y.F. and Chen,H.F., 1985, Genotypic correlations and path analysis of quantitative characters of local spring soybeans varieties in China. J.Fujian Agril.Collg., **14**(1):37-42.

Lush,J.L., 1940, Inter-size correlation regression of offspring on dams as a method of estimating heritability of characters. Proc.Amer.Soc., Animal Production, **33**:293-301.

Luthra,O.P. and Singh,R.K., 1974, A comparison of different stability models in wheat. Theor. Appl.Genet., **45**:143-147.

Ma,Y.G., 1983, Correlation between yield and its components and path coefficient analysis in F_2 soybean hybrids. Hereditas, China, 5(4):16-19.

Malhotra,R.S., 1973, Genetic variability and discriminant function in soybean. Madras Agric.J., **60**(4):225-228.

Malhotra,R.S. and Singh,K.B., 1973, Genetic variability and genotype x environment interaction in Bengal gram. Indian J.Agric.Sci., **43**:914-917.

Malhotra,R.S., Singh,K.B. and Dhaliwal,H.S., 1972, Correlations and path coefficient analysis in soybean [Glycine max (L.) Merrill.]. Ind.J. Agric.Sci., **42**:26-29.

Malhotra,R.S., Singh,K.S. and Singh,J.K., 1974, Genetic variability and genotype x environment interaction in Lentil. J.Res., PAU, **10**:17-21.

*Malik,J.S., Paroda,R.S. and Arora,N.D., 1973, Genotypes-environment interactions for green fodder yield in cowpeas. Z.Pflzucht., **69**:333-339.

Malik,S.S. and Singh,B.B., 1987, Genetic variability and heritability in interspecific crosses of soybean. Indian J.of Agric.Sci., **57**(2): 122-124.

*Miku and Damaskin,D.P., 1982, Methods of determining coefficient of heritability in soybean. Referativnyi Zhurnal, 36-45.

*Mungomery,V.E., Byth,L.E. and Williams,R.J., 1972, Environmental effects and varietal performance of cowpea and mung bean accessions in South-eastern Queensland. Aust.J.Expt.Agric.Anim. Husb., **12**:523-527.

*Nagamine,T. and Wada,M., 1982, Adaptability of rice varieties to late direct sowing in well drained fields. Japanese J.Crop Sci., **51**(2):190-195.

Naidu,B.S., Joshi,M.S., Badraiah, Khan,T.A. and Jayakumar, 1980, IET-2490 and IET-2730 have high grain yield stability. Curr.Res., UAS, Bangalore, **9**(9):148-149.

Ojoma,O.A. and Adelana,B.O., 1970, Variety x environment interactions in groundnut variety tests in Western Nigeria. J.Agric.Sci., Camb., **75**:419-420.

Paroda,R.S., Karwasru,R.L. and Yadav,H.R., 1974, Precition of phenotypic performance in fodder cowpeas. Indian J.Genet., **34A**:1148-1156.

Perkins,J.M. and Jinks,J.L., 1968, Environmental and genotype x environmental components of variability. III. Multiple lines and crosses. Heredity, **23**:339-356.

Pfeffer,T.W. and Pilcher,D., 1987, Effect of early and late flowering on agronomic traits of soybean at different planting dates. Crop Sci., **27**(1):108-112.

Prakash,R., Haque,F. and Prasad,J., 1966, Preliminary studies on variability and correlation in soybean. J.Agric.Res., **1**:15-19.

Pushpendra and Ram,H.M., 1987, Genetic components of variation for certain yield contributing traits in soybean. Indian J.Agric.Sci., **57**(4):221-224.

Rajashekaran,S., Premsekar,S. and Hanumantha Rao,H.K., 1980, Selection and evaluation of the relative influence of the morphological characters and yield components on yield of soybean. Madras Agric.J., **67**(2):71-76.

Rashid,M.H. and Islam,M.A., 1982, Coefficient of genetic variability, heritability and correlation of agronomic characters in soybean. Madras Agric. J., **69**(7):479-481.

Rohewal,S.S., 1970, Stability of some superior soybean varieties. Indian J.Genet., **30**:650-653.

Rohewal,S.S. and Koppar,M.N., 1973, Association analysis in soybean. Ind.J.Genet., **33**:96-100.

Saini,M.L., Jhorar,B.S. and Solanki,K.R., 1977, Genotype x environment interactions for seed yield in cluster bean. Indian J.Agric.Sci., **47**:345-347.

Schultz,W.M. and Bernard,R.L., 1976, Genotype x environment interactions in the regional testing of soybean strains. Crop Sci., **7**:125-130.

Sharma,C.D., 1988, The Pulzzling pulses scenario. Agric. Situ., India, **43**:783-784.

Sharma,S.K., 1979, Note on path coefficient analysis in the F populations of soybean grown at two locations. Ind.J.Agric.Sci., **49**(10):820-821.

Sharma,S.K., Rana,N.D. and Mehta,H., 1986, Genetic variability interrelationships and path coefficient analysis in a collection of small seeded soybean. Egyptian Journal of Genetics and Cytology, **15**(2):273-283.

Sharma,S.M., Rao,S.K. and Goswami,U., 1983, Genetic variation, correlation and regression analysis and their implications in selection of exotic soybean. Mysore J.agric.Sci., **17**(1):26-30.

Shih,C.Y., 1948, correlation between vegetative characters and yield of soybean. Plant br.Abstr., **18**:172-174.

Shivanna,S., 1989, Stability analysis of yield and yield components in medium late maturing genotypes of Rice (*Oryza sativa* L.). M.Sc. thesis submitted to University of Agricultural Sciences, Bangalore, Karnataka, India, pp.140.

*Sichkar,V.I., Knyazev,A.V. and Datyka,V.F., 1987, Breeding soybean for increased symbiotic nitrogen fixation. Vaskhnil., **33**:16-22.

Singh,D.V. and Swarup,R., 1988, Trends in production, productivity and Acerage of pulses in Himachal Pradesh. Agric.Situ., India, **43**:283-287.

Singh Laxman, Sharma,D., Baghel,S.S., Tomar,G.S. and Mishra,P.K., 1974, Estimation of genetic and environmental variability in Bengal gram. SABRAO J., **6**:207-211.

Sprague,G.F. and Federet,W.T., 1951, A comparision of variance components in corn yield trials. II. Error, year x variety, location x variety and variey components. Agronomy, J., **43**:535-541.

Srivastava,R.L., Sahal,R.N., Saxena,J.K. and Singh,L.B., 1976, Path analysis of yield components in soybean. Indian J.Agric.Sci., **10**(3):171-173.

Strohm,J.L., 1966, the inheritance of height, maturity, seed weight and yield and their associations in four soybean crosses. Diss.Abstr., **27**:1738-1739.

osses.D

Sundararaj,N., Nagaraju,S., Venkataramu,M.N. and Jagannath,M.K., 1972, Design and analysis of field experiments. University of Agricultural Sciences, Bangalore, Karnataka, pp.424.

Tai George,C.C., 1971, Genotypic stability analysis and its application to potato regional trails. Crop Sci., **11**:184-190.

Tong,Y., 1986, correlation and path analysis for the main quantitative characters of soybean. Ningxia Agril.Sci.Tech., **6**(3):31-34.

Veeraswamy,R. and Rathanaswamy,R., 1975, Character association analysis in soybean. Madras Agric. J., **62**(9):534-536.

Veeraswamy,R., Rathanaswamy,R. and Palaniswamy,C.A., 1973, Biometric studies of yield and yield components in the segregating populations of Glycine max (L.) Merrill. Madras Agric.J., **60**:1517-1521.

Verma,M.M. and Vrik,D.S., 1983, Regression analysis for varietal adaptation. Crop Improv., **10**(2):67-78.

Viswanatha,S.R., 1989, "Highlights of research accomplishments in soybean and an approach to its development in Karnataka" In: Souvenir of Sopa Convention held on 7th April, 1987. Pub: Soybean Processors Association of India, Indore, pp.34-36.

Weber and Moorthy,B.R., 1952, Heritable and non-heritable relationship and variability of oil content and agronomic characteristics in the F-2 generation of soybean crosses. Agron.J., **44**:202-209.

Whigham,D.K., Minor,H.C. and Garmer,S.G., 1978, Effects of environmental and management on soybean performance in the tropics. Agron.J., **70**:587-592.

Wright,S., 1921, Correlation and causation. J.Agric. Res., **20**:557-585.

Yao,T.Z., 1988, Correlative heritability analysis of main agronomy characters of North-east spring soybean variety. Acta Agricultura, **10**(3):23-27.

Yao,T.Z., Wang,Z. and Kang,B., 1987, Study on heritability and correlation of quantitative characters of soybean variety. Acta Agricultura Univ.Filinensis, **9**(2):31-37.

Yap,T.C. and Lee,L.F., 1975, Performance and path coefficient analysis of soybean under local conditions. Malaysian Agric.Res., **4**(2):97-102.

Yao,T.H., 1988, Correlative heritability analysis of main agronomy characters of Northeast spring soybean variety. Acta Agricultura, **10**(3):23-27.

Yates,F. and Cochran,W.G., 1938, The analysis of groups of experiments. J.Agric.Sci.Cambridge, **28**:556-580.

Zhou,F.S., 1983, Path analysis of the major agronomic characters in parental cultivars of soybean. Hereditas, China, **5**(2):7-9.

***Original not seen.**