STUDIES ON GENETIC MANIPULATION OF CANOPY AND REPRODUCTIVE ATTRIBUTES IN GROUNDNUT (*Arachis hypogaea* L.)

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CERTIFICATE

Mr. G.V.S. Nagabhushanam has satisfactorily prosecuted the course of research and the thesis entitled "**STUDIES ON GENETIC MANIPULATION OF CANOPY AND REPRODUCTIVE ATTRIBUTES IN GROUNDNUT (*Arachis hypogaea* L.)**" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

Date : 01-5-1989

(DR. M.V.R. PRASAD)
Chairman

CERTIFICATE

This is to certify that the thesis entitled "**STUDIES ON GENETIC MANIPULATION OF CANOPY AND REPRODUCTIVE ATTRIBUTES IN GROUNDNUT** (*Arachis hypogaea* L.)" submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Agriculture of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide, research work carried out by Mr. **G.V.S. Nagabhushanam** under my guidance and supervision. The subject of the thesis has been approved by the Students Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma or has been published. The published part has been fully acknowledged by the author of the thesis.

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LIST OF ABBREVIATIONS

SDW	Seedling Dry Weight
DF	Days to Flower
CC	Canopy Circumference
CD	Canopy Diameter
LA	Leaf Area
LDW	Leaf Dry Weight
SDW	Shoot Dry Weight
RDW	Root Dry Weight
TDM	Total Dry Matter at 60 Days
NN 0-5	Nodule Number at 0-5 cm
NN 5-10	Nodule Number at 5-10 cm
NN 10-15	Nodule Number at 10-15 cm
NN >15	Nodule Number at more than 15 cm
TNDN	Total Nodule Number
NDW	Nodule Dry Weight
PH	Plant Height
NP	Number of Primaries
NS	Number of Secondaries
NMP	Number of Mature Pods
NIMP	Number of Immature Pods
NMK	Number of Mature Kernels
NIMK	Number of Immature Kernels
IMKWT	Immature Kernel Weight
MKWT	Mature Kernel Weight

Contd......

NAP	Number of Areal Pegs
NTOTP	Number of Total Pegs
TDMH	Total Dry Matter at Harvest
100 KWT	100-Kernel Weight
SH %	Shelling Per cent
Oil %	Oil Per cent
RP %	Recovery Percentage
HI	Harvest Index

NOTE : In the entire text

** indicate significance at 1% level.

* indicate significance at 5% level.

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Date : 1 -5-1989. **(G.V.S. NAGABHUSHANAM)**

DECLARATION

I, G.V.S. **NAGABHUSHANAM**, hereby declare that the thesis entitled "STUDIES ON GENETIC MANIPULATION OF CANOPY AND REPRODUCTIVE ATTRIBUTES IN GROUNDNUT(*Arachis hypogaea* L.)" is result of the original research work done by me. I, further, declare that the thesis or any part thereof has not been published earlier elsewhere in any manner.

Date : 1-5-1989

(G.V.S. **NAGABHUSHANAM**)

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ABSTRACT

The investigations on genetic manipulation of the canopy and reproductive characters in groundnut (*Arachis hypogaea* L.) have lead to the characterisation of groundnut genotypes based on canopy development falling in the categories of 1 to 4. The first being the most compact canopy type and the fourth being the most spreading canopy type with intermediate canopy classes possessing higher degrees of yield stability falling in categories two and three. The attributes such as canopy diameter, nodule number and mass per plant at 60 days were found to be relatively more stable, exhibiting strong positive correlation not only among themselves, but also with kernel yield and as such can be incorporated into the selection criteria for groundnut breeding.

The cross combinations involving canopy categories 2 and 3 not only demonstrated higher degrees of heterosis in F_1, but also resulted in larger degrees of variances for the canopy and reproductive attributes in the F_2 and hence were found to form an appropriate mating system with adequate levels of genetic divergence conducive for recovery of superior recombinants. The combining ability and heritability analysis revealed preponderant non-additive interactions and moderate to low heritability levels for canopy and reproductive attributes warranting an appropriate breeding strategy.

The mutational analysis has revealed (1) the simultaneous mutagen induced variances for the above mentioned canopy and reproductive attributes; (2) the differential genetic nature of sequential branching *Spanish* and *Valencia* and alternate branching *Virginia* genotypes warranting selection for the above characters in the M_2 generation in respect of the former and in M_3 in case of the later.

Some promising segregants for canopy and yield attributes including a partial aerial podding plant type and some interesting mutants for canopy and reproductive characters holding promise for groundnut breeding have been isolated from this investigation.

INTRODUCTION

INTRODUCTION

A "green revolution" in groundnut production was hinted by Smartt (1978) based on very impressive yield levels of 9.4 to 9.6 tons ha^{-1} achieved by a farmer Mr. B. Huntsman Williams during the year 1972-1973 and 1973-1974 in Rhodesia using the variety Makulu Red. The trend of groundnut production in India however, does not reflect such a rosy picture. Although groundnut occupies a pivotal place in the nation's edible oil economy on one hand and the agricultural economy of the semi-arid regions of the country on the other, the productivity levels of the groundnut in the monsoon season in our country are the lowest in the world (Annon, 1987). In spite of considerable work on the genetic improvement of groundnut in India and abroad, the yield levels of various improved varieties of groundnut under semi-arid conditions are far from satisfactory (Rao, 1976).

The tardy progress in groundnut breeding has been attributed to paucity of adequate degree of genetic diversity in the varietal forms of groundnut for certain important agronomic attributes (Gregory, et al., 1980) and lack of reliable selection criteria based on the combination of stable characters (Prasad, et al., 1984). Selection based on yield components such as pod number and weight in groundnut is inadequate, as these characters exhibit the considerable degree of interaction with environment due to development of sink in the soil (Madhavi, 1988 and Wynne and Coffelt 1980). Several workers including Coffelt and Hammons (1974); Singh et al. (1979); Yadava et al., (1984) and Kataria et al., (1984) have worked out correlations between seed and pod characters on one hand and yield on the other.

However, our knowledge regarding the inter-relationships between the canopy characters and yield components in groundnut still remains fragmentary except for few recent investigations (Prasad et al., 1984, Prasad, 1988; and Madhavi, 1988). The investigations of Duncan et al., (1978); Ashely (1984); and Prasad, (1988) clearly pointed out the relevance of developing selection criteria involving canopy characters. It may be observed that the specific genetic nature and physiological requirements of the sequential and alternate branching forms so far ignored, have to be taken into consideration in this respect.

A review of genetical and breeding research carried out till recently reveals that genetic problems arising out of the possible tetrosomic inheritance in groundnut (Arunachalam et al., 1984) and constraints limiting the incidence of wider degrees of variances for important agronomic characters and recovery of desirable recombinants, (Norden, 1980 and 1982) have largely remained unattended to.

While hybridization studies in this context could yield useful results, mutational analysis of sequential and alternate branching genotypes could throw additional light on our approaches to groundnut breeding.

The present investigation has therefore, been taken up to -

1. **understand the inter-relationship between canopy and reproductive attributes in groundnut, through the characterisation of the groundnut genotypes based on the canopy development;**
2. **develop comprehensive and efficient selection criteria based on stable character combinations to be used in the groundnut breeding;**

3. identify appropriate parental cross combinations which could lead to higher levels of variances in the segregating generations; and
4. study the pattern of mutagen induced variances in relation to canopy type for important agronomic attributes.

Realising the necessity and importance of a wider degree of genetic variability in the studies of this nature, a cross section of groundnut genotypes pertaining to all botanical categories together with recently developed induced mutants for certain canopy and reproductive characters (Prasad, 1988) together with an interspecific derivative developed at ICRISAT have been included in this study.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The primary objective of groundnut breeding is to increase the productivity of pod, kernel and oil per unit area per unit time and per unit input. Any crop improvement programme has to be dynamic and consistent to meet the changing trends in production and utilization. Hull and Carver (1938) in Florida aimed at evolving a high yielding variety with smooth, attractive appearance and sweet flavour of the Spanish type and non-sprouting tendency of runner type. The principal attributes sought in improved varieties of groundnut in the USA, according to Bailey (1968), were higher yield potential, uniform maturity of seeds, resistance to damage of microbial origin, adaptation to mechanical harvesting, superior flavour, texture and keeping quality, enhanced nutritional value of kernel and greater consumer appeal.

In India, where groundnut is cultivated mainly for its edible oil, the breeding objectives are oriented towards increased yield of pods, high shelling out turn, enhanced oil content besides early maturity and resistance to major pests and diseases (Dharampal Singh, 1952 and Seshadri, 1962). As the crop is extensively cultivated under rainfed conditions, breeding for stability in performance accompanied by resistance to drought gains importance. Hence incorporation of environmental stability and wide adaptability while retaining genetic diversity should be the key feature of the groundnut breeding programme (Hammons, 1976).

Single plant and mass selection procedure in heterogeneous populations dominated earlier varietal improvement programme. Varietal improvement can be done effectively by well planned hybridization programmes including back crossing and inter-specific hybridization (Gregory, 1965 and Norden, 1973). Induced autoploidy in a species like Arachis hypogaea with a high chromosome number did not seem to be promising (Raman and Kesavan, 1963). Induced mutagenesis has been shown to be a good means of obtaining useful genetic diversity in groundnut (Gregory, 1956a).

Since 1910 when Van der stock (cited from Hull, 1937) initiated breeding work on groundnut in Java adopting single plant selection, a number of workers in the groundnut growing countries have evolved a substantial number of varieties by selection. However, Umen (1933), based on breeding work conducted in the USSR since 1926, reported that pureline selection did not yield very favourable results and considered hybridization as essential. Hull and Carver (1936) in Florida found that the existing types did not combine the desirable characters like seed dormancy, erect plant type, large seed, dark green foliage, light tan seed with high or low oil content and stated that such types could only be produced by hybridization. Higgins (1938) found that hybridization gave rise to a great multiplicity of plant and nut types thereby offering scope for selection. Darlington (1948) indicated the scope for enriching the available variation in groundnut by crossing the cultivated tetraploid species with a diploid. Gregory et al. (1951), as a result of the breeding attempts made in North Carolina, concluded that hybridization was necessary for the success of practical groundnut breeding. Seshadri (1956) emphasised that improvement of quality in groundnut could be achieved only through hybridization. Norden (1973) indicated that the possibilities for groundnut improvement by introduction and selection without hybridization have been practically exhausted in the USA. According to him, success in breeding through hybridization depends on the availability of transferable genetic variation and will be more likely if the objectives are clearly defined, the correct parents are selected and the hybrid populations are managed properly. It is, therefore, that the available spanish/valencia and Virginia types should be carefully analysed for various attributes contributing to yield and related characters, resistance etc and extensive hybridization work between Spanish - Virginia crosses could be most rewarding. Handling of such crosses need not be confined to conventional hybridization and selection methods. An organized programme could take recourse to mass intermating of segregating progenies. Various mating systems could be conceived. Three-way and multiple crosses are likely to be more rewarding than single crosses. Some quantitative genetic work involving single, three-way and double crosses could provide useful guidelines and are strongly recommended (Rao, 1976).

Plant habit in groundnut deserves attention of plant physiologists and plant breeders. Most cultivated forms are excessively vegetative for the yields than return and there is wastage of energy in unproductive aerial pegging (Rao, 1976). Short stature could eliminate excess of aerial pegs. Determination of the optimum size of the photosynthetic system and its efficiency, a restructuring of the system in such a way that most of the flowers produced have an opportunity to send gynophores into the soil is essential. Arresting of excessive vegetative growth would enable the plant to channel its energies towards pod development (Rao,1976). Mutation could be an effective tool in restructuring the vegetative frame of groundnut genotypes. Utilization of such mutant forms in the types of hybridization programmes discussed could enhance yield potential (Rao, 1976).

Over the past 30 years, the groundnut breeding research has been revolving around the exploitation of certain phenotypic attributes such as yield per se, number of seeds per pod and kernel weight (Rao, 1976). Groundnut has been termed as an "unpredictable legume" (Gregory et al., 1973) largely due to the difficulty encountered in assessing the yield, based on canopy growth and also lack of perceptible response of the crop to agronomic practices.

The main goal for the improvement of groundnut crop in developing countries is larger and more stable yield. Study on interrelationships between canopy characters, physiological attributes and yield components is very much necessitated in order to reach the goal (Rao, 1976). The improvement in the yield of cereals in developing countries has come in part from selection for a different morphological and physiological pattern of growth; also from selection for wider adaptation and more stable yields in adverse environments (Swaminathan, 1975). Hence the breeding objective from the physiological stand point should be to select the new cultivar for the expected length of the particular growing season to which it will be adopted and to use the largest possible proportion of the available growing season for pod filling (McCloud et al., 1980). Obraztsov (1983) also emphasized the need for the main parameters of morphological and physiological model for a variety, as one of the biological aspects in breeding.

A brief review on various findings related to canopy attributes in groundnut and other crops is presented below.

2.1. CANOPY ATTRIBUTES

As the growth and development of groundnut plant appears to be characterized by excessive vegetative growth for its pod yield, it has been suggested by Swaminathan and Jain (1973) that restructuring of morphological frame of the plant towards compaction, that most of the flowers produced have an opportunity to send gynophores into the soil would bring about a considerable enhancement in yield. Cahaner and Ashri (1974) reported that use of efficient selection criteria involving certain canopy attributes together with the yield components in groudnut breeding would be useful.

The investigations carried out by Prasad et al. (1984) indicated that genetic restructuring of peanut plant to combine compact canopy frame and higher pod yield was possible in the case of Virginia genotypes. The Spanish types, on the other hand, did not tolerate any reduction in vegetative growth which reflected in decreased pod production probably because they attained a critical balance for canopy attributes.

The relationship between seed yield and canopy rating in medium and late maturing groups of soybean was reported by Metz et al. (1984). He suggested that smaller leaflet size and more open canopies in these groups resulted in higher seed yield; possibly through more efficient light utilization within the canopy.

Dwivedi et al. (1986) compared the groundnut canopy orientations viz., South-North, East-West, radial and cross. They opined that the cross orientation favoured soil moisture storage and greater seed yields than the other three orientations.

Despite the release of number of cultivars of groundnut with different degrees of canopy development the specific guidelines and selection criteria for development of an optimum canopy structure, conducive for efficient photosynthesis and pod production are not available. Hence, the study of canopy attributes in relation to pod development seems to be one of the important aspects of groundnut improvement.

2.2. GENOTYPE - ENVIRONMENTAL INTERACTION

The primary objectives of applied breeding programs are to develop and identify genotypes that have consistent performance for the target environments. Usually, a series of genotypes are evaluated over a series of environments to determine their relative ranking. The relative importance of the differences in ranking of genotypes among environments is based on the analysis of variance to determine if the genotype by environment interaction (GE) is significantly different from zero. Environments included for testing often are partitioned into years, locations within years, management levels, soil types, climatic patterns, length of growing seasons, stress vs. nonstress and plant density levels. Because of the importance of identifying genotypes that have predictable performance for the target environments, extensive studies have been conducted to determine how important GE is for different crop species. In most instances, GE could be detected and breeders evaluate genotypes in several environments (Hallauer, 1988).

A class of methods, designated as stability analysis, has been developed within the past 20 years which summarize the relative performance of genotypes for a series of environments (Hallauer, 1988). The stability analysis permitted the calculation of parameters that characterized each genotypes performance for a series of environments. The relative stability of the genotypes, therefore, could be compared. The methods involve the regression of genotype means on the environment means, which has been referred to as joint regression analysis (Freeman, 1973). Several stability analyses have been suggested and they differ primarily in the definition of a stable genotype, methods used to measure the productivity of environments (environmental index), and the partitioning of the environment and GE sums of squares.

A stable genotype has been defined either as one that performed consistently over environments (b_1=0) or one that responded to improved environments (b_1=1). In other instances, the regression coefficient was used as a measure of response and the deviation mean square as a measure of stability. The parameter used to define stability of a genotype depends on the concept of stability and the intended use of the information. Another major problem associated with the method of stability analysis is defining the environmental index and assuming a linear relation between GE interaction effects and the environmental index. The earlier methods used the means of all genotypes as a measure of environmental index and regressed individual genotypes on the environmental index (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966). When varieties are compared over a series of environments, the relative rankings usually differ. This causes difficulty in demonstrating the significant superiority of any variety (Eberhart and Russell, 1966). The variation arising from the lack of correspondence between the genetic and non-genetic effects is known as the genotype-environment interaction. The failure of a genotype to give the same phenotypic performance when grown under different environments is the reflection of the genotype environment interaction.

The genetic factors are not independent of the non-genetic environmental effects. This interplay of genetic and non-genetic i.e., genotype-environment interaction, reduces the correlation between genotype and phenotype, which in turn reduces confidence in inferences from experimental data, relevant to both plant improvement and inheritance mechanisms. Allard and Bradshaw (1964), rightly observed that the nature of genotype-environment interactions are extremely complex. Genotype-environment interaction is usually present irrespective of the fact whether the genotypes are purelines, single cross or double cross hybrids, test crosses, S_1 lines, segregating populations or any other material with which the breeder may be working. In the past the principal analytical approach has been to estimate genotype-environment interaction, from the pooled analysis of variance (Immer et al., 1934; Salman, 1951; Horner and Frey, 1957; Sandison and Bartlett, 1958). These estimates were then used to identify those environmental factors which interacted more strongly with the genotypes so that subsequent experiments might be modified accordingly. This technique, however, could provide information only on the existence of genotype-environment interaction and failed to give any measurement of the interaction of individual genotypes with environment.

A more homeostatic genotype is the one for which the variance of phenotypic values evoked in different environments is less (Lewis, 1955). In other words, the phenotypic stability can be defined as ability of a genotype to produce a narrow range of phenotypes in different environments. Lewis (1955) measured the phenotypic stability in terms of a stability factor measured as

$$SF = \frac{\text{Mean performance in the highest yielding environment}}{\text{Mean performance in the lowest yielding environment}}$$

According to Lerner (1954), genetic homeostasis is the ability of a genotype to withstand environmental fluctuations. Variability in performance over a range of environments could therefore be used as a criterion for measure of phenotypic stability. Plaisted and Paterson (1959) described a procedure to characterize the stability of the performance of several varieties but their method becomes cumbersome when a large number of genotypes were tested.

Wricke (1962) developed a method to estimate the ecological valence or in short ecovalence of genotypes grown under several environments to measure the stability of performance. But Jowet (1972) reported that Wricke's method based on single parameter called ecovalences, was least informative.

Later on interest was centered on regression technique as an alternative method of analysing the genotype-environment interaction. One of the essential features in developing the technique was to quantify the environment on the basis of mean performance of test material. Originally suggested by Yates and Cochran (1938), it was modified by different workers for use in breeding experiment (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Perkins and Jinks, 1968; Breese, 1969 and Freeman and Perkins, 1971). The regression of genotype on environment provides two simple measures of the genotypic changes to environments, namely, regression coefficient and deviation from regression alone. For measuring the genotype x environment interaction through linear regression technique, Yates and Cochran (1938), Finlay and Wilkinson (1963), Eberhart and Russell

(1966) and Perkins and Jinks (1968) used the mean obtained by averaging all the cultivars for a particular character at each location as the environmental index. Freeman and Perkins (1971), Fripp (1972) and Hill (1975) proposed alternative procedures to provide an independent environment index. Mahajan and Rao (1982) observed that practically the independent and dependent environmental indices considered for measuring the genotype-environment interaction lead to the same conclusion and that mean of the genotypes could be used as the environment index, since it was readily available.

However, a better way to ascertain phenotypic stability was given by Finlay and Wilkinson (1963), who used two parameters namely, (1) the mean performance over all the environments and (2) regression of performance in different environments over the respective environmental means. On this model a regression value of $b < 1$ means the genotype has greater resistance to environmental changes and possesses above average stability, while $b > 1$ would mean below average stability. However, mean performance must also be considered, otherwise a variety which is lowest yielding in all environments may also show $b < 1$. Generally a variety having $b = 1$ and high mean yield would be considered as the most widely adapted while $b = 1$ and a low mean yield would indicate a poorly adapted genotype.

Even though different stability models are available, the model of Eberhart and Russell (1966) provides a means of partitioning the genotype-environment interaction of each variety into two parts i.e. (1) the variation due to the response of the variety to varying environmental indices and (2) the unexplainable deviation from the regression on the environmental index. According to this model the most stable variety is one having high mean, unit regression coefficient (b_1=1.0) and the deviation from regression as small as possible (s^2d=0).

The statistical design can further be extended to incorporate biometrical genetic analysis so as to account for the genotype-environmental interactions associated with additive, dominance and epistatic gene effects. Buco Alanis (1966) developed a model to measure the genotype-environmental interaction when only two homozygous parents were grown in a large number of environments. Buco-Alanis and Hill (1966) extended this model to include the F_1 between the homozygous parents, while Buco Alanis et al. (1969) extended it further to include F_2 and back cross.

The regression analysis of Eberhart and Russell (1966) has been widely used by many workers (Johnson et al. 1968; Baker, 1969; Breese, 1969; Jowet, 1972; Peter and Rai, 1976; Choudhary and Haque, 1977; Kaptain Rai et al. 1978; Bahl et al. 1980; Bijapur, 1980; Sharma et al. 1980; Yadav Ishwar Singh, 1980; Kandalkar and Sanghi, 1982; Bhatade and Bhale, 1983; Desai et al. 1983; Henry and Daulay, 1983a,b and Sanghi and Raj, 1983). It was also reported by different workers that as far as the ranking of genotypes with respect to their stability is concerned, it remains the same under different models (Luthra and Singh, 1974; Singh and Chaudhary, 1977 and Mahajan and Rao, 1982). Jowet (1972) and Singh and Chaudhary (1977) have suggested that Eberhart and Russell's (1966) model may be used for stability analysis as it is relatively simple.

The instability of the cultivated groundnut particularly for yield is one of the main problems facing the groundnut breeders. Well buffered cultivars, with small genotype x environment interactions, are usually desired. Stability of yield over seasons and throughout a wide geographical area are important attributes of a commercial peanut cultivar (Reddy, 1988).

Wessling (1966) studied the reaction of Spanish, Valencia, Virginia bunch and Virginia runner varieties and strains to wet and dry growing seasons in Brazil. He found that the Spanish, Valencia types grow best during the wet seasons, but they were unable to maintain their superiority over the other types during dry seasons. The Virginia bunch types were least affected by climatic conditions unless at extremes. He concluded that the runner types were divisable into two groups, one reacting similarly to the Spanish-Valencia types and the other to the Virginia - bunch types.

Chen and Wan (1968) measured the genotype x environment interaction in Taiwan using 13 groundnut cultivars grown at 10 locations for two years. Both cultivar x year and cultivar x location interactions were small for yield ; but the cultivar x year x location interaction was highly significant.

Ojomo and Adelana (1970) in a study of cultivar x enviornmental interaction with 16 cultivars grown at 3 locations for 3 years in Western Nigeria found significant in both cultivar x location and cultivar x year x location interactions.

Joshi et al. (1972) measured the stability of five bunch cultivars and a local standard at seven environments in Gujarat. Cultivars showed stability in all environments for yield. The local standard was low yielding in both good and poor environments, but one genotype released for cultivation as 'J11' performed consistently well in both poor and good environments.

Ojeda (1973) observed a significant sowing date x variety interaction in groundnut yield trials during 1967 season in Argentina. Wynne et al. (1973) in USA studied six groundnut lines representing the three botanical groups under two-long-day and two short-day photoperiodic treatments. They found the characters related to flowering and fruiting greatly different under short-day treatments than under long-day treatments.

In India, singh et al. (1975) tested eight promising spreading varieties of goundnut ('C66', 'C87', 'C112', 'C156', 'C173', 'M13', 'C148' and 'M145') in four environments of Punjab (Ludhiana, Jalandhar, Kapurthala and Samrala). Pooled analysis of variance for pod yield showed that the mean differences between the genotypes and genotype x environment interaction component were highly significant. Both the environment (linear) and genotype x environment (linear) components of variation for stability were highly significant. The differences in stability were mainly due to the linear regression. The 'M13' had average stability and high level of performance for pod yield and hence it was considered as an ideal variety in the material studied.

Sangha and Jaswal (1975) studied 12 groundnut varieties 'C87', 'C102', 'C112', 'C142', 'C143', 'C148', 'C162', 'C164', 'C172', 'M145' and 'PGNo.1' for two years (1968 and 1969) at Ludhiana, Samrala, Kapurthala and Jalandhar. The Performance of varieties in different years was quite uniform but was inconsistent at different locations. There was a little phenotypic stability in 'C148', others exhibited no stability or adaptability at all. The small and non-significant variety x year interaction indicated that the performance of different varieties in different years was very much similar and suggested that little would be gained by testing the varieties for more than two years.

Marenah and Anderson (1977) observed in a trial of six varieties during 1973-75 that 'NC15' gave the highest pod yields with or without fungicide application. 'Shulamit' and 'NC17' showed the highest increase in pod yields following fungicide applications. Sandhu and Khehra (1977b) evaluated the parental, F_1, F_2, F_3, BC1 and BC2 generations of 'C501' X 'AK12-24' and 'C501' X 'Ah6595' at two sites in 1972. A significant genotype x enviornment interaction was found for pod yield, 100-seed weight and length of primary and secondary branches but not for the number of mature pods and number of primary branches.

Nur and Gasim (1978) conducted four trials during 1969-73 with five varieties representing upright branch, spreading bunch and runner types which were sown on 1st june, 1st july and 1st August. Early sowing resulted in high pod yield but reduced shelling percentage. All the characters studied showed significant variety x sowing date interaction. 'MH383' was the highest yielding variety at each sowing date.

Tai and Hammons (1978) in Georgia, found large and significant cultivar x location x year interactions and small, year x cultivar and location x cultivar interactions for groundnuts grown in two year field trials, in respect of pod yield, percentage of sound matured kernels, extra large kernels and fancy-sized pods and 100 kernel weight.

Williams _et al_. (1978) reported from Rhodesia that data from 26 trials with three to four varieties indicating that varieties react differently to environment, some varieties being superior under cool-cloudy conditions and the others under warm, sunny conditions. The cultivars were sensitive to changes in the environment before the fruit filling than during the actual fruit filling phase.

Wynne and Isleib (1978) estimated genotype x environment interactions in nine *Virginia* cultivars in two separate studies for five years. A substantial cultivar x location x year second order interaction was observed for yield in both studies. Both cultivar x location and cultivar x year interactions were small when compared to the variation among cultivars. They concluded that no advantage could be gained by subdividing the production area into sub areas for breeding or testing purposes.

Wynne and Sullivan (1978) determined the influence of environment or seedling emergence for eight *Virginia* groundnut cultivars at five locations over a three year period. Both cultivar x year and cultivar x location x year interactions were significant.

Yadava and Kumar (1978a) studied eleven varieties in three environments for phenotypic stability of pod yield, shelling percentage, 100 seed weight and oil content. The magnitude of the linear component of the genotype x enviornment interaction was high for pod yield, 100 seed weight and oil content. Of the varieties studied, '28-206' was stable for yield but not for other characters.

Yadava and kumar (1978b) also used 17 genotypes grown in four envirnments to estimate genotype x environment interactions and stability parameters for 100 kernel weight, oil content and shelling percentage. The linear and non-linear portions of the genotype x environment interactions were significant for all the three traits. In all the environments 'Faizpur 1-5' had consistently high 100-kernel weight and oil content, and 'Ah 6279' had high shelling percentage. Genotype x environment interactions were significant for these characters. The stability parameters for the different traits were apparently governed by independent gentic systems.

Yadava and Kumar (1979) studied the genotype x environment interaction for pod yield and the number of days to maturity in 13 groundnut varieties grown in four different years. The linear portion of genotype x environment interaction was significant for both characters, but the non-linear portion was significant only for the number of days to maturity. 'Georgia 119-20' proved to be a high yielding variety suitable for all environments tested, and 'NC4X' an early maturing, high yielding variety suitable for less favourable environments.

Mercer - Quarshie (1980) from a study of 17 groundnut cultivars grown at four locations in 1971-72 and at three locations in 1972-73 reported that variety x year x location interaction effects were significant for all the five characters, Viz., Pod yield, number of pods per plant, seed yield, shelling outturn and 100-seed weight. The variety x year interaction was significant only for 100-seed weight, and the variety x location interaction was significant for seed yield and 100-seed weight. It was concluded that testing in several locations was more important than testing during several years.

Wynne and coffelt (1980) determined yield and percentage of sound matured kernels and of extra large kernels in a two years study for nine crosses with eight lines per cross in F_4 and F_5 generations at two locations. Cross populations and lines within crosses were significantly different for all traits. Cross populations interacted with the year - location environments for all traits, and lines within crosses interacted with the environment for all traits except yield.

Shorter and Norman (1983) have evaluated twelve cultivars for grain yield in two trials. The cultivar x location interaction was significant but the cultivar x harvest date within location interaction was not. Overall 29 environments, the cultivar x environment interaction was significant. In orthogonal sets of five localities and two years, the cultivar x year x location interactions were significant, and cultivar x year and cultivar x location interactions were not significant. Pattern analysis showed that cultivars of dissimilar genetic origin had different yield responses across environments. An environmental classification based on cultivar x environment interactions indicated that there were no temporal or closely related regional environment groups with similar cultivar x environment interactions. It was concluded that lower critical percentage differences between new and established cultivars in pre-release trials can be obtained by adding environments rather than replicates.

Wynne and Gregory (1981) in a review on genotype x environment interactions in groundnut opined that genotype x environment interactions vary with the material tested and the site chosen for testing.

Kumar _et_ _al_. (1984) studied pod yield and four yield related quality characters in 12 _Spanish_ bunch genotypes under three environments. In general genotype x environment interactions were significant for all the characters. For pod yield, non-linear components of interactions were significant whereas for four others linear components were significant. Non-linear components had higher values for all the traits except for pod yield and days to maturity.

kernel percentage, 100 kernel weight, but more flexible association with mature, immature and tender pods per plant and pods per unit weight.

2.3. NODULATION

Nodules on groundnut were found to be smaller than those on other food legumes; they were smooth, globose and often flattened horizontally along the main and lateral roots (Rajagopala Iyer, 1976). Schiffman and Lobel (1977) reported that nodules form in large numbers at the top of the tap root and that, number of nodules increased with increase in soil molybdenum, sulphur and phosphorous. The extent to which nodules formed depended on genotype, location and soil type (ICRISAT, 1977).

Ayala (1977) found that the nitrogenase activity and plant total nitrogen content were correlated with specific nitrate reductase activity of intact nodules. He concluded that the nitrate reductase activity of intact nodules seemed to be the most promising test for comparative evaluation of effectiveness of peanut Rhizobia.

Large differences in the ability to fix nitrogen, in the nitrogenase activity and in the number and weight of nodules, were observed amongst 48 lines examined by ICRISAT (1978). In a study by Ratner et al., (1979), nitrogenase activity was very low until 50 or 60 days after sowing but increased to a maximum during pod-filling. While comparing two seasons for nodule number and weight and nitrogenase activity, it was found that nodule number and nodule weight were high while nitrogenase activity was low, and the opposite occurred in the second season. However, maximum nitrogenase activity occurred about 90 days after planting in both seasons.

Wynne et al., (1979) found changes in nitrogenase activity, nodule number and nodule weights at different harvest dates during the season.

These characteristics were different for cultivars, and there was a cultivar x harvest date interaction. There was also interaction for nodule number and weight, and nitrogenase activity. Arunachalam et al., (1984) correlated nitrogenase activity and root nodule mass with a measure of relative performance based on 17 characters. They concluded that Virginia bunch and Virginia runner were the most promising groups in relation to nodulation.

Root system is traditionally the "poor relation" in crop physiological studies and it needs to be given more attention in groundnut (Ashley, 1984).

2.4. HETEROSIS

Heterosis is the increased or decreased vigour of F_1 hybrid over its better parent or the mid-parental value (Rai, 1979). In plant breeding programmes conventionally heterosis is referred to denote the expression of increased vigour of the hybrid over the better parent, which is termed as heterobeltiosis (Fonesca and Patterson, 1968).

The evidence that heterosis in peanuts, like heterosis in other crop species such as wheat (Fonesca and Patterson, 1968; Sun et al., 1972; Widner and Lebsock, 1973), alfalfa (Sriwatana-pongse and Wilsie, 1968), cotton (Marani, 1963, 1968), corn (Moll et al., 1962) and tobacco (Matzinger and Wernsman, 1968), is related to genetic diversity. Heterosis in peanut is generally observed in crosses between the subspecific groups. These results imply that gene action differs in crosses made within and crosses made between botanical varieties.

Heterosis or inbreeding depression usually indicates that nonadditive gene action is important (Wynne and Coffelt, 1982). Several investigators have reported estimates of heterosis for peanuts. The manifestation of heterosis in different economic traits of groundnut was first observed by Stokes and Hull (1930) in 11 groundnut crosses. Marked heterosis for vegetative traits and pod yield were obtained for several crosses by Higgins (1940) when he crossed 16 cultivars in diallel. Individual plant yields were highest for *Spanish* x *Virginia* crosses. Katayama and Nagatomo (1963) noticed marked heterosis in some of the hybrids studied by them.

Syakudo and Kawabata (1963) found appreciable heterosis for top weight in *Virginia* x *Spanish* and *Valencia* x *Virginia* F_1 hybrids in their study involving 2 *Virginia*, 1 *Spanish* and 2 *Valencia* cultivars. Such vigour did not appear in F_1 plants between varieties within each type or in *Spanish* x *Valencia* crosses. Pod length of F_1 was intermediate between that of the parents.

Lin (1966) found significant hybrid vigour for length of main stem and branches for F_2 plants grown in Taiwan from the cross of a *Spanish* type by Florispan Runner (a *Virginia* cultivar). The superiority of the F_1 hybrids over their better parents for yield as well as for the number of branches and leaflet length was shown by Hassan and Srivastava (1966) using crosses among 3 cultivars differing in maturity and growth habit. They observed greater heterosis for vegetative traits between *Virginia* x *Valencia* cultivars.

Parker *et al*. (1970) noted that F_1 crosses of *Valencia* x *Virginia* gave greater heterosis than did crosses of *Virginia* x *Spanish* or *Valencia* x *Spanish* for several seedling characters measured in a controlled environment for a diallel crosses of 6 peanut lines collected from 3 centres of diversity in South America. Wynne *et al*. (1970), using the same parents as Parker *et al*. (1970), reported that F_1 hybrids from *Virginia* x *Valençia* parents gave greater heterosis than other crosses for vegetative plant characters. Crosses of *Valençia* x *Spanish* gave greatest heterosis for yield and fruit characters. The highest yielding cross, however, resulted from a cross of *Virginia* x *Spanish* parents.

Coffelt and Hammons (1971) recorded 661 pods weighing 1.96 pounds from one F_1 hybrid plant and 1,156 matured seeds from another F_1 plant. On an average more than 700 seeds were obtained per F_1 plant. Hammons (1973a) reported heterotic responses for fruit yield for F_1 hybrids resulting from crosses made between the subspecific peanut groups.

Wynne *et al*. (1975) observed significant heterosis over the mid-parent in 2 crosses sown with drill, while in space-planted test, 4 crosses were equal to or higher than the mid-parent. Their studies indicated genotype x environment interaction in the expression of heterosis.

Five cultivars representing *Virginia* and *Spanish* types in all possible hybrid combinations were evaluated in Senegal by Garet (1976). Heterosis was found in certain crosses for pod and seed size, pod and seed number per plant and shelling out turn. In all cases where heterosis was observed, the cross was made between *Virginia* and *Spanish* parents.

Raju (1978) recorded heterosis ranging from 20-37% over the superior parent with respect to 3 important yield components viz., mature pods (20.05%), 2-seeded pod (20.8%) and pod yield per plant (37.02%). Raju *et al*. (1979) in their studies on F_1 hybrids of 5 X 5 diallel set (excluding reciprocals) for 7 characters observed greater heterosis for number of mature pods, number of 2-seeded pods, pod yield and 100-kernel weight in a

Virginia x *Spanish* cross and a moderate heterosis for these characters in *Virginia* x *Virginia* cross and concluded that Indian x exotic crosses were the best for the expression of heterosis.

Arunachalam *et al*. (1980) classified parents of 2 diallel crosses as high or low based on their general combining abilities as computed for 15 characters. High x low crosses produced greater heterosis than high x high or low x low crosses. In the first 15 x 15 diallel set positive heterosis for 9 characters including pod yield was recorded whereas they could record positive heterosis for as many as 13 characters including pod yield in another 10 x 10 complete diallel set.

Isleib and Wynne (1980) crossed 28 diverse lines collected from South America, Africa and China with elite *Virginia* breeding line and grew the F_1 and F_2 generations in 2 North Carolina locations. Positive heterosis was observed for number, size and yield of pods. Parents of subsp. *fastigiata* generally had greater heterotic responses than parents from subsp. *hypogaea*, *fastigiata* parents from the Peruvian centre of diversity gave the maximum responses.

Muralidharan and Raman (1980) recorded positive heterosis for days to flowering, number of 2-seeded pods and pod yield per plant in the hybrids derived by crossing some bunch groundnut varieties with *Arachis monticola*, a wild species. The data from diallel cross of 10 diverse groundnut lines made in 1944 was analysed by Gregory *et al*. (1980). They found hybrid vigour for F_1 hybrids between subspecies. Most F_2 hybrid means were equal to mid-parental values although some F_2 means were exceptionally high or low.

Sridharan and Marappan (1980) reported positive heterosis over the better parent in all the hybrids for number of mature pods and pod yield per plant. The range of heterosis for number of mature pods and pod yield was from 6.22% to 38.40% and from 4.20% to 70.30% respectively. Hybrid vigour for fruit yield, seed yield and 100 kernel weight was observed by Layrisse *et al*. (1980) in F_2 progenies of a diallel cross of 10 lines. The parents belonged to 2 each of the 5 centres of genetic diversity in South America.

Durga Prasad (1981) studied 64 F_1's obtained from 8 x 8 line x tester design crosses. The parents were assigned high (H) and low (L) status based on the phenotypic values of a number of related component characters spanning the entire growth phase. Fortyfour crosses were found to be heterotic over better parent, out of which 23 crosses were between parents with high and low general combining ability (gca) followed by 13 crosses between parents both of which had high gca. The distribution of crosses heterotic over better parent showed that the top most rank was obtained by *Virginia* runner x *Spanish* bunch and *Spanish* bunch x *Valencia*. Maximum frequency of heterotic crosses was found in H X L followed by H X H crosses.

Arunachalam *et al*. (1982) studied 2 sets of diallel crosses involving 15 and 10 parents respectively at the seedling stage and at flowering and harvest for a total of 15 characters. Only 1 cross 'PI 259747 x PI 298115', showed heterosis for as many as 6 characters; 6 crosses in the first diallel showed heterosis for 4 or more characters as did 8 in the second. When the parents were assessed for gca overall the 15 characters the highest proportion of crosses showing heterosis occured in between high gca and low gca parents. This overall gca assessment agreed with an assessment based on the seedling characters in 47% of the crosses in the first diallel and in 90% of the crosses in the second diallel (64% of the total). Crosses within variety groups as well as those between them, had a high proportion of crosses showing heterosis.

Heterosis in 20 crosses was studied by Raju (1982). In general, heterosis was not observed with any spectacular frequency or magnitude especially for pod yield. Only 2 out of 20 crosses exhibited significant heterosis for pod yield which were infra specific and intra-subspecific. The study, therefore indicated that heterosis for economic yield may be obtained in both infra specific and intra-subspecific crosses, unlike most of the previous reports where yield heterosis was thought to be prevalent in inter-subspecific crosses only.

Isleib and Wynne (1983) crossed a total of 27 exotic cultivars, representing each of the 5 secondary centres of diversity in South America as well as Africa and China. Heterosis measured as a deviation of the F_1 performance from the mean parental value was observed for all traits. Heterosis upto 19 % above the better parent occurred for pod size and length. A significant portion (27 to 68%) of the variability in heterotic effects was attributable to differences among the parental groups, with generally higher levels expressed in inter-subspecific crosses. They also found a linear and increasing relationship of heterosis to divergence between parents for the traits which exhibited more dominance while, for the others a curvilinear relationship was observed.

The frequency and magnitude of heterosis in relation to genetic divergence among parents was examined by Arunachalam _et_ _al_. (1984) in 2 diallel cross experiments in groundnut. The frequency of heterotic crosses and the magnitude of heterosis for yield and its components were found to be higher in crosses between the parents in intermediate divergence classes than extreme ones. This study thus showed that there was an optimum level of genetic divergence between parents to obtain heterosis in F_1 generation.

Xiang et al. (1984) observed significant heterosis for pod weight per plant and seed weight per plant in an incomplete diallel cross of four Spanish and four Valencia type cultivars. Deshmukh et al. (1985) aslo suggested that genetic divergence of parents was most important for greater magnitude of heterosis.

Arunachalam and Bandyopadhyay (1986) postulated that the chances of high frequency and magnitude of heterosis were greater in crosses between parents with high genetic divergence.

Basu et al. (1986d) observed 34.7 to 57.3 per cent heterosis over the parental value for pod yield; low heterosis for 100-seed weight and shelling percentage. They studied (Basu et al. (1986d) the magnitude of heterosis for 11 vegetative and reproductive characters through a half-diallel involving 8 genotypes belonging to subspecies hypogaea and fastigiata. Spanish x Spanish recorded highly desirable negative heterosis for days to 50% flowering and high positive heterosis for number of mature pods and pod yield.

Prasad (1987) observed higher degrees of heterosis for pod number and pod yield in F_1's using TAP-5, aerial podding genotype as male parent in combination with other Spanish, Virginia and Valencia genotypes as female parents.

In a review on heterosis in groundnut Wynne and Gregory (1981) arrived at the following conclusion regarding the nature of gene action. Heterosis in groundnut is most often observed in crosses between the subspecific groups. The results suggest that gene action differs in crosses made within and those made between botanical varieties. Additive genetic variance appears to be of primary importance in crosses made between parents chosen from a single botanical variety, but both additive and non-additive genetic variance may be significant in crosses made between parents from different botanical varieties.

In groundnut, however, heterosis cannot be exploited for commercial production of hybrid varieties because of the natural restrictions found in the form of peculiar floral structure, inadequate pollen supply and difficulties in the transfer of pollen from one genotype to the other.

2.5. CORRELATION STUDIES

Yield is a complex character and depends upon the expression of a number of components known as yield components. Correlation studies indicate a magnitude of association between any pair of characters. A knowledge of the association of the yield components with each other and with the yield is helpful in the improvement of the complex character, yield, for which direct selection is not much effective (Reddy, 1988).

Rachie and Roberts (1975) suggest that groups of characters are associated and passed on to their progeny after crossing in peanuts. This makes it difficult to develop new cultivars with desired characteristics, especially if the parents are from different subspecific groups. Several studies have been conducted which contribute information on character interrelationships. Traits indicative of yield such as number and weight of pods per plant, number and weight of seed per plant, and pod and seed size were reported to be positively associated in peanut cultivars (Sun, 1932; Hayes, 1933; Maralihalli, 1933; Humphrey, 1942; Lin, 1954; Dorairaj, 1962; Jaswal and Gupta, 1966, 1967; Chandra Mohan et al., 1967; Badwal and Gupta, 1968; Gopani et al., 1970; Sangha and Sandhu, 1970; Coffelt and Hammons, 1973). Significant negative associations were observed between number of pods per plant and seed size measured as g per 100 seed. Inconsistent results have been found for pod weight per plant and g per 100 seed (Lin, 1954; Badwal and Gupta, 1968; Sangha and Sandhu, 1970; Dholaria et al. 1972; Coffelt and Hammons, 1973).

Moustafa and Sayid (1971) studied 12 yield components in the varieties with different habits. Yield was positively correlated with all the characters except in 1 variety ('Balodi 100') in which yield was not significantly correlated with main branch length. The characters most effective on yield were main branch and the number of pods per plant.

High contribution of number of branches to yield in the spreading group and number of pods in the bunch group was reported by Dholaria and Joshi (1972). Seed yield per plant was related to pod weight rather than seed size. The genotypic and phenotypic correlations were estimated in 30 spreading varieties by Khangura and Sandhu (1972). These studies indicated that pod yield had strong association with the number of primary and secondary branches, lateral spread, the number of mature pods and shelling percentage. Phadnis et al. (1973) found that pod yield was influenced to the maximum by the number of pods per plant and seed weight per plant.

Dholaria et al. (1973) studied 5 yield components in 20 varieties with spreading and bunch growth habits under high and low fertility levels. Pod yield was significantly and positively correlated with the number of pods, branches per plant and with seed weight per plant in varieties of both growth habits grown at both the fertility levels. Among all the yield components, highly negative correlation of the number of mature pods with 100 kernel weight and highly positive correlation with shelling percentage were observed by Badwal and Harbans Singh (1973). Mature pods in semi-spreading and erect groups, 100-kernel weight in spreading and erect groups, and shelling percentage in semi-spreading group showed significant positive correlation with pod yield.

Chandola et al. (1973) stated that the number of pods per plant, the number of primary branches and fresh weight of pods were positively correlated with grain yield in groundnut except the number of secondary branches. In 1973, Kushwaha and Tawar reported positive and non-significant correlation for height of main axis with pod yield; positive and significant correlation between the number of mature pods and pod yield; negative but non-significant association of percentage of oil with days to maturity and 100-pod weight. Sangha (1973b) reported positive correlation for the number of primaries with the number of secondaries (0.4401) and with mature pods (0.3259); a significant negative correlation of number of secondary branches with pod yield (-0.5767), significant positive correlation of this character with number of pods (0.5160), significant phenotypic and genotypic positive association of number of mature pods with pod yield and significant and positive correlation of pod yield with 100 kernel weight. A negative association of shelling percentage with bold seed in spreading and semi-spreading varieties and a positive association with smaller kernels in bunch varieties was observed by Varisai Mohammed et al. (1973).

The correlations among 5 agronomically important traits were studied by Samooro (1975). Pod number and seed number were positively correlated with seed maturity but negatively correlated with average pod size. They were not significantly correlated with shell thickness. Significant positive correlation was observed between average pod size and shell thickness. Sangha and Sandhu (1975) observed that 100-seed weight was highly and positively correlated with lateral spread but negatively correlated with the number of pods in a study involving 27 varieties.

Shany (1977) studied contents of protein and oil in mature seeds of 9 cultivars and 5 cross derivatives there was a highly significant positive correlation between protein content and the number of pods per plant and mean seed weight. The reciprocal was true for the above traits' correlation with oil content. The protein content and oil content were antagonistic but their sums were fairly similar in 8 cultivars (80.0-84.0) with one exception (76.5). The narrow range indicated that the improvement in the content of one of these components was at the expense of the other, since there seemed to be an upper limit for protein + oil. Kudupley (1977) studied the correlation between yield and several chemical constituents in 17 groundnut cultivars. Yield was found to be significant and positively correlated with seed protein and negatively with leaf nitrogen percentage. The correlation of yield were positive but non-significant with total carbohydrates of leaves, oil percentage and 100-seed weight.

Lakshmaiah (1978) in his extensive study, observed positive and significant correlation for height of main axis with the number of nodes on main axis and the number of primary branches; and significant negative correlation with the number of secondary branches, the number of nodes on secondary branches, the number of mature pods and yield. But in Rabi 1977 with the material, the author reported a positive and significant phenotypic and genotypic correlation of this character with the number of nodes on main axis and negative corelation with the number of secondary branches and number of mature pods. The number of nodes on main axis showed positive correlation with yield during kharif 1976 and negative association between them was seen in Rabi 1977. The number of primary branches showed a significant and positive correlation with the number of nodes on primaries and secondaries and the number of secondary branches in Kharif 1976 crop but in Rabi 1977 crop, the character showed a positive but non-significant association with pod yield. The number of nodes on primary branches showed positive and significant association with the number of secondary branches and number of nodes on secondaries during both the seasons. Similarly, number of secondary branches exhibited a positive and significant correlation with the number of nodes on secondaries and yield during both the seasons.

Rao (1978 and 1979) in a study of 34 bunch-type cultivars grown in kharif 1978 reported strong correlation (r greater than 0.8) between yield and 100 seed weight and height and days to flowering. In another study involving 200 cultivars of both indigenous and exotic origin, Rao (1979b) observed that peg number, first primary branch length, leaf breadth, pod number, flower number and plant height were positively and significantly correlated with yield. Patra (1980) in a study of 32 promising cross derivatives tested in comparison with 3 standard varieties estimated correlation coefficients for 7 yield components. The studies indicated that selection based on 3 components, shelling percentage, the number of mature pods and number of immature pods per plant proved to be more effective than selection based on yield alone.

Durga Prasad (1981) studied correlations in a set of 160 cultivars equally divided among *Spanish* Bunch (SB), *Valencia* (VL), *Virginia* Bunch (VB) and *Virginia* Runner (VR) subgroups. The number of estimable correlation coefficients was higher in VB and VR than in SB and VL. A study of the direction and magnitude of correlations among 17 component characters showed, in general, a major cancellation of desirable and undesirable ones. It was interesting to note that a comparison of the correlations of 7 above ground with 10 below ground characters showed a higher frequency of undesirable ones than desirable ones. Nagabhushanam (1981) reported a positive and significant association of the number of days to first flowering with height of main axis and pod yield and a positive and non-significant association with shelling outturn, number of mature pods and 100 - kernel weight. Height of main axis had a positive and significant association with number of nodes present on it, and a positive and non-significant association with number of primary branches. The number of nodes on main axis exhibited a positive and significant correlation with number of primary branches. The number of primary branches and secondary branches had positive and significant association between them and showed a positive and significant association with pod yield per plant, number of secondary branches, number of mature pods, 100-kernel weight and shelling percentage.

Yadava *et al*. (1981) found that pod yield was significantly and positively associated with pod number and the number of primary branches in a study with 26 strains. Ibrahim (1983) studied three varieties, one each of bunch, spreading bunch and runner habits, for 14 characters in 1979-80. In each, seed yield was correlated with the number of mature pods, flowers, pegs and branches. Considering all the three varieties together, the total number of pods was also correlated with seed yield. In a correlation study involving 15 cultivars, belonging to all the three habit groups, Lakshmaiah _et_ _al_. (1983) observed that the number of secondaries, nodes on primary and secondary branches, length of secondaries and mature pods possessed significant and positive correlation coefficients with yield. Wu (1983) in a study with six cultivars found that branches/plant and greenleaves/main stem were positively correlated with yield (number of pods). Phenotypic and genotypic correlations among pod yield, pod number, primary branches, days to first flowering, days to maturity, plant height, shelling percentage and 100-kernel weight were estimated by Yadava _et_ _al_. (1984) in a study with 16 bunch groundnut genotypes. In general, genotypic correlations were of higher magnitude as compared with their corresponding phenotypic correlations, pod yield was found to be positively and significantly associated with pod number, primary branches and 100-seed weight. Pod number possessed the significant positive correlation with primary branches, days to first flowering and plant height. Days to first flowering was also correlated with days to maturity and shelling percentage. Days to maturity exhibited significant positive association with plant height.

Kataria _et_ _al_. (1984) in a study involving 17 strains found that pod yield per plant correlated positively with 100-kernel weight and shelling percentage. Nigam _et_ _al_. (1984) tested 97 advanced selections for association among 16 vegetative and reproductive traits and observed significant positive association between the following attributes; (i) single mature seed weight and most of the vegetative traits, (ii) number and weight of pods and seeds per plant and the height of main axis, and

(iii) the number of nodes and pegs.

Tangteerawattana (1984) studied character association in 14 varieties in 2 (rainy and dry) seasons and observed positive relationships between the number of pods per plant, seeds per plant and the length of primaries and yield in the rainy season but the length of primaries showed greater association with yield in dry season. In a study of 20 varieties, Alam *et al*. (1985) found that pod yield per plant had a positive correlation with the number of pods per plant, days to maturity, the number of secondary branches and plant height.

Choudhari (1985) studied 29 bunch genotypes in two seasons for growth and yield attributes and found significantly positive relationship between total dry matter with pod yield. Deshmukh *et al*. (1986) in a study with 22 *Virginia* - bunch genotypes observed that phenotypic correlations, in general, were much lower than the genotypic correlations. At genotypic level, pod yield showed a significant positive association with number of mature pods per plant, 100 pod weight, 100 kernel weight and percentage of sound mature kernels but a negative association with days to 50% flowering and dry matter at harvest. Deshmukh *et al*., (1987) in a study with 28 *Virginia* runner varieties of groundnut found that number of secondary branches, number of mature pods per plant and 100-kernel weight showed significant positive correlation with pod yield.

2.5.1. F_1 generation :

Sandhu and Khehra (1977a) reported that pod yield was closely associated with the number of mature pods and number of secondaries in a cross involving 'C501' x AK 12-24', and in other cross 'C501' x 'Ah6595' pod yield was associated with the number of mature pods and number and length of both primary and secondary branches. They also recorded a non-significant correlation of oil percentage with almost all characters and concluded that indirect selection of this character through any other character is not possible, and further inferred that improvement of this character will not have any adverse effect on pod yield.

Mahesh kumar (1981) studied correlations in 28 F_1 hybrids and their parents (four established cultivars used as ovule - parents and seven cultivars with wider genetic base as pollen parents). Correlation studies among the parents revealed a positive and significant association of yield with the number of secondary branches (0.8236), number of mature pods (0.8831) and number of nodes on primary branches (0.9002), and significant and negative association with the height of main axis (-0.6155). Among F_1's, the association of yield with the number of nodes on primary branches (0.3914), number of nodes on main axis (0.4487) and number of mature pods (0.7962) was positive and significant.

Raju _et_ _al_. (1981) studied the correlation in both parents and F_1's of a five parent diallel. They found that the genotypic correlations were higher than phenotypic ones for most of the characters. The genotypic correlations showed that the number of mature pods was negatively associated with many characters except pod yield in the parent material. But in F_1's pod yield was significantly correlated with the number of primary branches, number of mature pods and 100-kernel weight. Unlike in the parents, the number of mature pods was also positively associated with all other characters except plant height.

Mohinder Singh _et_ _al_. (1984) in a study involving 35 F_1's and 12 parents reported that 100 kernel weight and pod width had positive and significant phenotypic correlations with pod yield.

Khanorkar et al. (1984) in a line x tester analysis found a strong positive correlation (0.92) between plant height and the number of immature pods.

2.5.2. F_2 Generation

Syakudo and Kawabata (1965) studied the F_2 progeny of crosses between Virginia, Spanish and Valencia botanical groups. They found a significant positive correlation between pod and kernel weights and suggested that the bringing together of various favourable characters in a variety may be successful.

Coffelt (1974a) studied correlations for 9 characters in 6 F_2 and parental populations. Highly significant correlations were observed for pod number with pod weight, seed number and seed weight; pod weight with seed number and seed weight; and seed number with seed weight.

Coffelt and Hammons (1974a) studied correlation coefficients in an F_2 population between 'Argentine' (Spanish type) and 'Early runner' (Virginia type). Highly significant positive correlations were found between number of pods and pod weight, number of seeds and seed weight. Selection for increases in any of the 4 characters, viz., number of pods, pod weight, number of seeds and seed weight should, therefore, result in a corresponding increase in the remaining 3 characters.

Gibori et al. (1978) in the F_2 population of a 9x9 diallel cross studied correlations between pod size, yield, days to first flower and weight of plant. Pod yield per plant was not highly correlated with the other 3 traits, suggesting selection for yield can not be accomplished by indirect selection.

Balkishan (1979) studied correlations in 5 cultivars, viz., 'Robut 33-1', 'Shulamit', 'TMV-10', 'J-11' and 'Gangapuri' and eight F_2 progenies developed by crossing them. Pod yield was positively and significantly correlated with the number of primary branches and mature pods in the parents and F_2 progenies. Pod yield also possessed significant and positive association with 100-kernel weight in the parents. The number of mature pods and number of primary branches alone possessed significant positive correlation with yield, suggesting that by selecting for the number of mature pods and primary branches, the pod yields could be improved.

Sangha et al. (1979) in the F_2 progenies of a cross 'M145xTifton 1108' reported that pod yield was positively and highly associated with the number of pods and 100-kernel weight. At genetic level, primary branches, secondary branches, the number of pods and 100-kernel weight were highly associated with each other.

Balaiah et al. (1980) observed that the yield was positively and significantly correlated with the number of primary and secondary branches and the number of mature pods in 105 semi-spreading F_2 segregates. Height of the main axis was not correlated with yield. Labana et al. (1980) in the segregating F_2 population from the cross, 'M145 x U2-47-3' recorded that the yield of pods was highly and positively correlated with the number of secondary branches, number of pods and 100-kernel weight. The height of the main shoot, the number of primary branches, secondary branches and pods were also highly correlated with one another.

2.6. COMBINING ABILITY STUDIES

The study of the g.c.a and s.c.a are essential in identifying superior parents and to study the heterotic effects in breeding programmes. The determination of general combining ability (gca) and specific combining ability (sca) gives an indication about the performance of the parents. General combining ability is associated with genes which are additive in effects and specific combinig ability is attributed primarily to deviations from the additive scheme caused by dominance and epistasis (Rojas and Sprague, 1952). Although methods for characterizing genetic variability in self-fertilizing species are available, little information has been obtained on the various types of gene action and their relative importance in the inheritance of important traits in peanuts.

2.6.1 F_1 GENERATION

Parker et al. (1970) estimated combining ability for 17 characters measured on F_1 hybrid seedlings generated from a diallel cross of 6 lines, 2 each from 3 centres of diversity in South America. In a controlled phytotron environment, estimates of GCA were found to be more important than SCA.

Wynne et al. (1970) estimated combining ability in the same set of hybrids used by Parker et al. under field conditions. Out of 17 characters studied, estimates of sca were significant for 16 and of gca for 8. In general vegetative plant characters (eg. plant height, leaf length) had higher estimates of gca and sca, and estimates of sca were greater for yield and most of the fruit characters. Of the seven characters for which gca was greater in magnitude than sca, five were vegetative characters.

Estimates of sca components were greater for yield of fruit, green weight of plant and for eight of the other ten fruit characters. The sca component was twelve times greater than gca component for yield of fruit.

Garet (1976) in senegal evaluated the F_1 hybrid progeny from a complete diallel of five cultivars. Estimates of gca were significant for pod and seed yields per plant, the number of pods and seeds per plant, 100 pod-weight, 100 seed weight, oil content and shelling out turn. Since gca effects were larger than sca estimates for all the traits except shelling outturn, it was concluded that the major part of the total genetic variability was additive for all characters except shelling out turn.

Sandhu and Khehra (1976) found that non-additive effects were more important than additive effects for pod yield per plant and number of mature pods per plant, whereas additive gene effects were more important for 100-kernel weight. In a diallel set involving widely divergent inbred erect cultivars studied by Gibori _et al_. (1978) dominance was found to be responsible for yield per plant and days to first flowering. Raju _et al_. (1979) observed that both gca and sca effects were significant for the 12 characters studied in a five parent diallel. The sca variance was greater in magnitude for all the characters indicating the predomiance of non-additive gene action. Crompton _et al_. (1979) analysed combining ability for seed calcium concentration and total adenosine phosphates the two traits associated with seed germination and seedling vigour in groundnut. The data suggested that seedling vigour of _Virginia_ type groundnut can be improved by selection for increased calcium concentration following either inter-or intra subspecific hybridization.

Isleib _et al_. (1980) measured nitrogen fixation by the parents and F_1

generation in a diallel cross of 10 cultivars, indicating sca was significant for nodule number per plant, nodule mass, specific nitrogenase activity, shoot weight and total nitrogen, indicating the predominance of non-additive gene action. Nigam et al. (1985) in a 6x6 diallel involving low and high nitrogenase activity lines also found non-additive genetic variance for this character.

Singh and Labana (1980) in a 6 parent diallel cross studied combining ability for nine vegetative and fruit characters. Except for leaflet breadth and kernel weight, additive gene effects were found to play a major role in the inheritance of different traits. Based on the results obtained, they suggested, biparental progeny approach for the improvement of pod yield and its components.

Sridharan and Marappan (1980) reported additive gene action for height of the mainstem, average number of secondaries, 100 kernel weight and pod yield whereas they reported the non-additive gene action for the number of primary branches. They further stated that good general combiners were not always found to be the best specific combiners.

Labana et al. (1981) studied three characters in a 10 parent half-diallel; sca variance was greater for pods per plant and pod yield per plant and gca for 100 seed weight. High gca effects were shown by 'M13' and 'Shulamit' for pod yield per plant and 100 seed weight and by 'NCAC527' and 'Shulamit' for pods per plant. In a line x tester analysis using six early maturing Spanish-bunch varieties as female parents and 3 rust-resistant Valencia strains as male parents, Khanorkar et al. (1984) found that the 18 F_1's differed significantly for characters like plant height, number of primary branches, mature and immature pods, rust infection and leaf protein except for days to 75% flowering. Variance due to sca was found to be greater than gca variance for all the characters indicating a predominant role of non-additive gene action.

Manoharan et al. (1985) in a line x tester analysis involving seven females and three males reported additive gene action for plant height, 100 pod weight, shelling percentage and pod yield and non-additive gene action for pod number and the number of secondaries.

Basu et al. (1986b) reported that among the sources of resistance to both rust and leaf spots, 'NCAC17133(RF)' was the highest specific combiner for the nodes on mainstem, underground pegs, mature pods per plant, pod weight, 100 kernel weight and shelling percentage, followed by 'PI259747'. Basu et al. (1986c) in a line x tester study found 'Chico' to be the best general combiner for days to 50% flowering and days to maturity, the most important attributes governing earliness. 'TMV2xChico' exhibited the highest desired negative heterosis for both the characters.

Basu et al. (1987) in an eight parent diallel reported preponderance of additive gene action for days to 50% flowering, days to maturity, mature pods, pod yield, 100-kernel weight and shelling percentage.

2.6.2. F_2 AND SUBSEQUENT GENERATIONS

Wynne et al. (1975) estimated the combining ability in the F_2 generation of a six parent diallel cross involving the parents of Valencia, Virginia and Spanish botanical types, in drilled and space-planted tests. Estimates of both gca and sca were significant for percentage of extra large kernels and sound matured kernels, kernels per kg, pod length and yield measured in the drilled test. The estimates of gca were significant for all characters measured in space-planted test, and of sca were significant for 5 of the 6 characters. Estimates of gca were of greater magnitude than sca for all the characters except percentage of sound mature kernels. Sandhu and Khehra (1976) studied means of six generations in two crosses. Three characters associated with yield were studied. Non-additive gene effects were found important for the number of mature pods and pod yield and additive gene effect for 100 kernel weight.

Orbay et al. (1977) studied genetic behaviour of pod length, pod weight and seed weight in some crosses of groundnut and concluded that seed weight was controlled by one or two major genes with few minor genes, and additive effects appreared to be important for this character. Sandhu and Khehra (1977a) studied the component variances of shelling percentage in two crosses at two sites and found that it was governed by predominance of non-additive component. Gibori et al. (1978) studied pod yield per plant, days to first flowering, pod size and plant weight by analysing F_2 data from a 9x9 diallel cross involving cultivars of Virginia, Valencia and Spanish types. They reported bidirectional dominance for pod yield per plant and days to first flowering while the allels giving small pods were dominant and the alleles for large plants showed dominance and over dominance. Estimates of genetic components of variance indicated that additive genetic effects were significant for all traits and more important than non-additive effects except plant weight.

Mohammed et al. (1978) studied F_2 and F_3 generations of two crosses at two locations for characters including yield, fruit size, fruit maturing index and seed maturity index. They found that additive effects were significant for all the characters and non-additive for yield and fruit size. Isleib et al. (1978) evaluated the progeny from a 6 parent half-diallel cross of diverse groundnut cultivars from F_1 through F5 generations for the presence of epistatic effects. Significant variability attributable to sca persisted over generations for yield and other seed characters. For all the characters measured, estimates of epistatic variance were larger than those of dominance variance. Cahaner _et_ _al_. (1979) while detecting the genetic interactions by analysing the F_2 generation of diallel crosses of groundnut found duplicate gene interactions for the weight of pods per plant.

Layrisse et al. (1980) studied the F_2 generations of 10x10 diallel for yield, oil and protein characters and found that the component of variation due to gca was larger than that of sca for the above traits.

Sandhu and Khehra (1980) studied two crosses, their F_1, F_2, F_3, BC_1 and BC_2 generations at two locations. The additive x additive effects and complementary epistasis were important and duplicate epistasis indicated that progress through selection would be slow. Godoy (1982) evaluated parental, F_1, F_2 and F_3 populations of four crosses for pod and seed size. Dominance and additive gene effects were observed for both pod and seed sizes.

Raju (1982) studied the twenty crosses in F_1 and F_2 generations. Sca effects were found to be more predominant than gca. The study indicated that most of the characters can not be improved simultaneously using the pedigree method of breeding. Groups of characters may be improved in different crosses and thus can be brought together in carefully planned crossing progammes among the segregating progenies of different crosses.

Sandhu and Khehra (1983) studied the parents and F_1, F_2, F_3, BC_1 and

BC_2 generations of the two crosses at two locations. Additive and dominance gene effects were significant for the control of leaflet length and gynophore number respectively. For leaflet length and width, additive x additive gene effects were positive and important.

2.7 PATH COEFFICIENT ANALYSIS

The path coefficient analysis provides an effective means of untangling direct and indirect cause of association and permits a critical examination of specific forces acting to produce a given correlation and measures the relative importance of each causal factor (Green, 1980). Path analysis is useful in findingout the direct and indirect causes of associations, it helps in examining the relative contribution of direct and indirect effects of independent variables on the dependent variables (Narsinghani et al. 1978). Correlation coefficients do not give a complete picture of the causal basis of association. Partitioning the correlation coefficient into components of direct and indirect and assessment of the relative importance of each causal factor affecting the pod yield are possible through the path-coefficient analysis. Studies on path-coefficient analysis in groundnut are briefly reviewed.

Khangura and Sandhu (1972) estimated the genetic parameters in 30 spreading varieties of groundnut. Path coefficient analysis showed that the length of primary branch was the most important character having direct effect on pod yield. They concluded that improvement in pod yield of spreading groundnut was possible through selection for length of primary branch and the number of mature pods.

Badwal and Harbans Singh (1973) studied effects of growth habits on correlation and path coefficients. Path coefficient analysis showed that the number of mature pods in semi spreading and erect types, 100 kernel weight in spreading types had significant direct effect on yield. In general, secondary branches and shelling percentage showed indirect effects towards the pod yield. It was observed that the individual contribution by various component traits to pod yield varied from one group to the other. Chandola et al. (1973) stated that the number of pods per plant, primary branches and green weight of pods had a positive direct effect on yield, but the number of secondary branches had a negative direct effect.

Sandhu and Khehra (1977a) reported that in semi-spreading x bunch and semi-spreading x semi-spreading crosses of groundnut, large direct contribution to pod yield was effected by the number of mature pods. Balkishan (1979) in a study with five cultivars and F_2 progenies of eight crosses involving them reported that the pod yield was mainly contributed by the number of mature pods and to certain extent by the number of 2 seeded pods.

Yadava et al. (1983) studied path analysis of six yield components in 26 groundnut cultivars. Number of days to flowering and height were found to affect pod yield directly. Lakshmaiah et al. (1983) studied fifteen cultivars of groundnut belonging to three habit groups in two seasons, observed that the number and length of secondary branches and number of mature pods exhibited positive and direct path values. Wu (1983) in a study observed that branches per plant had an important direct effect on yield.

Yadava et al. (1984) in a study of 16 bunch groundnut genotypes found that pod number 100 kernel weight, number of primary branches and days to maturity had high positive direct effect on yield. Plant height affected pod yield indirectly through days to maturity. Nigam et al. (1984) found that selection for increased mature seed yield per plant would be possible by selecting characters viz., the number of mature pods, pod weight, mature seed weight either individually or in combination. Mohinder Singh et al. (1984) indicated at genotypic level, that pod length, pod width and shelling percentage were the important yield attributing characters.

Deshmukh et al. (1986) observed a high positive direct effect of mature pods, 100 pod weight, 100 kernel weight and percentage of sound matured kernel on pod yield. The characters showing negative association with pod yield also showed negative direct effects for days to first flowering, days to 50% flowering and dry matter at harvest. Bhagat et al. (1986) studied 26 groundnut varieties belonging to four habit groups and found that only the mature pods maintained a strong positive direct effect with pod weight. The direct effects of primary branches, fresh plant weight, node number of last pod bearing peg, aerial pegs and shelling percentage were also substantial and positive.

2.8. MUTATION BREEDING

The idea of producing mutations artificially and using them for breeding was clearly stated as early as 1901 by De Vries. He wrote that, "The knowledge of the laws of mutations will probably lead to the artificial production of mutations at will and thus the creation of completely new properties in plants and animals".

Auerbach et al. (1947) reported the mutagenic effects of first chemical mutagen, mustard gas, an alkylatiing agent. Since then, a large number of chemical mutagens have been shown to cause hereditary changes in a variety of organisms. Their effect is so similar to that of radiation that they have been called 'Radiomimetic substances'.

2.8.1. MUTAGENIC EFFECTS OF SODIUM AZIDE (NaN_3)

Sodium azide is a well known respiratory inhibitor. It inhibits the action of catalase and peroxidase enzymes (Niknejad et al., 1972 and Nilan et al. 1973). This chemical was found to be a potent mutagen in inducing mutants in crop plants but much of the work is confined to barley and rice.

In barley sodium azide treatments at low pH (3.0) produced mutation frequencies which were comparable with those induced by strong alkylating agents. Niknejad <u>et</u> <u>al</u>. (1972) reported that the frequencies of chromosome aberrations induced by azide alone were negligible but a synergistic increase in aberrations occurred when azide treatments were used in combination with radiation treatments.

High frequency of chlorophyll mutations in barley variety steptoe, following seed treatment with 0.001 M NaN_3 after 2 hours of pre-soaking in M_1 generation were observed by Nilan and Sander (1974). The high efficiency of NaN_3 was attributed to the lesser degree of physiological damage.

Kleinhofs <u>et</u> <u>al</u>. (1974) reported that there are some merits for the practical use of NaN_3 in mutation breeding, especially the fact that NaN_3 does not induce chromosome aberrations, suggesting that mutants induced by this agent are due to the mutations at gene level.

High frequency of chlorophyll mutations were observed by Konzak <u>et</u> <u>al</u>. (1975) when NaN_3 was used alone and it had a synergistic effect on mutation yields following N-methyl-N' nitroso Urea (MNU). The mutagenic efficiency of azide was found to be high, of low 'physiological' damage. It induced high mutation yields with very little influence on M_1, seedling height, M_1 seed yield or emergence of M_2 seedlings.

Brunner (1977) reported that the most efficient azide treatment on the basis of biological damage in grain legumes was 10^{-4}M to 10^{-3} M at pH 3.0 to pH 4.0 from 2-4 hours at 20°C. In *Vicia faba* the highest mutation rates were obtained after 4 hours with $2x10^{-3}$ M azide. *Viridis* and morphological mutants were the most numerous followed by *aurea*, *Virido albina*, *albina* and *tigrina* mutants.

Dnyansagar and Thengane (1977) reported that NaN_3 induced chlorophyll mutations in barley with least chromosomal damage. The synergistic effect was observed for M1 parameters in NaN_3 post-treatments with ethyl methane sulphonate (EMS), while the yield of M_2 chlorophyll mutants remained nearly unaffected.

Sander and Muehlbauer (1977) reported that sodium azide was an effective mutagen in *Pisum* sps. when used at a concentration of 10^{-3} M and at pH 3.0. Leaf aberrations were observed on gamma irradiated plants but not on azide treated plants, an indication that azide did not cause chromosomal damage. NaN_3 was as effective in total yield of mutants, but produced fewer stunted and variously deformed plants than gamma-rays. The lack of leaf aberrations in *Pisum* from azide treated seeds is probably due to unique specificity of azide as a mutagen that produces intragenic mutations without concomitant chromosomal aberrations.

Kleinhofs *et al*. (1978) reported that azide treatment causes reduction in seed germination and M1 seedling growth and an increase in male sterility and recessive embryo lethals in barley as scored by the reduced number of M2 seedlings per spike. Azide treatment causes heritable pollen sterility and embryo lethality which must be attributed to gene changes since chromosomal breaks are negligable.

The occurrence of physiological mutants and presumed single locus mutants in barley and peas following NaN_3 treatment were observed by Kleinhofs et al. (1978). The data indicated that specific gene or function mutations occur with high frequency in azide-mutagenized barley and peas.

Sarma et al. (1979) observed that, following NaN_3 treatment in rice, mutation frequency as well as the biological damage showed a linear response to the increase in concentration of azide. Azide induced maximum mutations in rice seeds, pre-soaked in water for 4-12 hours. Mutation frequency gradually declined, however, with further increase in duration of soaking. Long soaking periods adversely affected the azide mutagenecity in rice.

Guimaraes and Ando (1980) observed greater mutagenic efficiency of NaN_3 when compared to gamma rays. Survival and plant height in the M_1 tended to decrease with increasing concentration. Grains pre-treated in distilled water had greately reduced fertility in the M_1 compared to those which had not been pre-treated. By increasing NaN_3 concentration, proportionate reduction in germination rate and seedling growth was observed by Hasegawa and Inoue (1980). Frequency of chlorophyll mutations was highest when sodium azide was applied during 'S' phase of the first, post dormancy mitotic cycle.

Afsar Awan et al. (1980) observed decreased seed germination, seedling height and increased seed sterility in M_1, when seeds were treated with NaN_3 at different concentrations. It also induced higher frequency of chlorophyll and viable mutations in M_2 generations.

Prasad *et al*. (1984) reported that treatment with NaN_3 at a concentration of 3 mM was found to be most efficient as well as effective for induction of desirable mutants in groundnut.

2.9 MUTATION STUDIES IN GROUNDNUT

Loesch (1964) studied the effect of mutated background genotype on mutant expression in peanuts. He stated that progress in breeding may be achieved through the use of induced mutations having small effects, even with backgrounds associated with deleterious mutants. Emery *et al*. (1964) reported that morphological mutant expression in peanuts is commonly associated with one to a few gene mutations.

The treatment of two semi-spreading varieties of groundnut, C501 and Asiriya with X-rays was reported by Rao (1979). Two bushy mutants (one short and one dwarf) and leaf mutants were obtained from C501. From Asiriya, mutants with spreading habit or with dwarf bunch habit were obtained. It is considered that the results support the hypothesis of a common ancester for bunch and *Virginia* types.

Patil and Mouli (1979) reported the induction of mutants affecting height, number and growth of branches, leaf size and colour, pod size and pod number by radiation treatment in groundnut. Although beneficial mutants for direct use were rare, more than 20 cultures having improving yield, oil content and kernel quality have been developed from inter crosses between the available mutants.

Sinha and Rahman (1979) reported that mutants BP1 and BP2 of *Arachis hypogaea* which have a compact habit, large kernels and large pods and show early and mid-early maturity respectively, were derived from the late maturing variety 41C, which has a spreading habit and kernels and pods of medium size, on treatment with gamma rays.

In the mutation experiments coducted by Mouli _et al_. (1979), cultures of _Arachis hypogaea_ combining sequential flowering, early maturity and large kernels were developed. Hybridization among induced mutants and re-radiation of selected cultures has reflected in the development of such useful types as TG13, TG16, TG18A, TG19A and LV3.

Alterations in plant height, leaf size, internodal length and pod yield following treatment with gamma-rays and EMS were reported by Habib _et al_. (1980). Differences in stem girth were also found as a result of EMS treatment.

The effect of mutagenic treatments on character association in the M_3 generation of two varieties of groundnut was reported by Ramanathan and Rathinam (1983). The possibility of selection for yield with improved plant architecture from mutagen treated population was indicated by the altered character association. They also reported that the spectrum chlorophyll mutations showed differential response of the two varieties to mutagenic treatments. Two mutants having semi-spreading growth habit possessed desirable features of short stature, higher pod and kernel yield, bold kernels and increased shelling percentage compared to that of control.

Ramanathan (1984) observed that the effect of EMS on seedling height was greater than gamma rays in AH7911 variety of groundnut while, the reverse was true in the case of variety TMV9.

Ramanathan (1984) also reported the occurrence of 40 mutant plants from single treatments of gamma irradiation at 30 krad and EMS at 40 mM in TMV-9 and a combination (20 Krad+40 mM) treatment in Ah 7911. Mutant plants in M_2 showed superior yield and morphological similarity to parents. When they were tested in M3 generation, five out of forty lines gave significantly higher yield than their respective parents, with mature pods contributing to higher yield.

Prasad <u>et</u> <u>al</u>. (1984) indicated that, genetic restructuring of peanut plant to combine compact canopy frame and higher pod yield is possible in the case of <u>Virginia</u> genotypes. The <u>Spanish</u> types did not tolerate reduction in vegetative growth which reflected in decreased pod production probably because they attained a critical genetic balance for canopy attributes. All the mutants of <u>Spanish</u> type with higher pod number showed enhanced branch number and dry weight of vegetative parts.

The improvement of the peanut variety 'Tatu' through induction of mutations using NaN_3 was initiated by Prasad <u>et</u> <u>al</u>. (1985). NaN_3 at 3mM was found to be the most efficient as well as effective for induction of desirable mutants. Among the ten productive mutants selected, three of them dwarf, Sd-Hp and V3 consistently maintained their supriority in yield at significant levels over a period of three seasons including conditions of low rainfall. The mutants Dwarf and Sd-Hp demonstrated improvement in pod number per plant, seed number per plant, shelling percentage and harvest index, in M_4 generation and superior yield levels.

The details regarding the origin and characteristics of the groudnut mutant variety 'Co-2' was reported by Sivaram <u>et</u> <u>al</u>. (1985). It was derived from <u>Arachis</u> <u>hypogaea</u> POL-1 as result of EMS treatment. Due to increased secondary branching and thus more pods per plant, it has a higher pod yield than POL-1 with a high shelling outturn. Compared to CO-1 and TMV-12, CO-2 has a higher 100 seed weight.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigations were carried out during rabi (1986-1987), kharif (1987), late kharif (1987) and rabi (1987-1988) seasons at Agriculture College Farm, Rajendranagar, Hyderabad 500 030. The farm is situated at an altitude of 542.6 meters above mean sea level at the intersection of 80.50^{o} North latitude and 77.50^{o} East longitude.

3.1 MATERIAL

The material for the present study consisted of 15 groundnut genotypes, viz, 32-2-5, Compact Mutant of M 13, TMV2NLM, MH2BC28, PGN 1, PGN 2, TMV2, MH 2, M 13, Robut 33-1, GAUG-1, ICG(C)8, NC Ac 2821, MK374 and NC Ac 17090. The details of the genotypes, their salient features are furnished in Table 1.

Three different experiments were conducted. The details of each experiment methodology followed, statistical treatment of the data are presented below.

3.2 METHODS

3.2.1 Experiment I

The experiment I included the evaluation of 14 groundnut genotypes in four seasons to characterize and to categorise the genotypes for canopy and reproductive characters and to study the stability of canopy characters in relation to reproductive attributes. However, the genotype NC Ac 17090 was usded in mutation experiment. The experiment was laid out in a randomised block design with four replications. Fourth replication was used for destructive sampling. Each replication consisted of 14 plots of size 3.5 m x 1.2 m representing 14 genotypes. A spacing of 30 cm x 10 cm was followed.

Table 1. Experimental material of the present study.

S.No.	Name of the genotype	Botanical group	Salient features
1.	MH 2	*Valencia*	Selection from Gujarat dwarf mutant. This variety was released in the year 1978 for Haryana. This is an extremely dwarf (compact) variety possessing one to four seeded pods with red testa. Developed at HAU, Hissar.
2.	32-2-5	*Virginia* bunch	Gamma ray induced mutant of *virginia* parent MK 374. Possesses a compact canopy and matures by a few days earlier than the parent. Developed at IARI Regional station, Hyderabad.
3.	Compact Mutant of M 13	*Virginia* bunch	EMS induced mutant of M 13 for more compact canopy and synchronous pod bearing. Earlier in maturity by 5-7 days as compared to the parent. Developed at IARI Regional station, Hyderabad.
4.	TMV 2 NLM Narrow Leaf Mutant of TMV 2	*Virginia* bunch	EMS induced mutant of TMV 2. It has narrow leaves, which starts expressing after first four to five normal leaves, alternate branching, vegetative main axis and higher root nodule number and mass. Late in maturity by 10-15 days as compared to the parent. Developed at IARI Regional station, Hyderabad.
5.	Robut 33-1	*Virginia* bunch	Selection from Robut 33 (Israel). Possesses medium spreading, clustered pod bearing, early maturity and wider adaptability. Developed at A.R.S., Kadiri of A.P.A.U., Hyderabad.
6.	ICG(C) 8	Virginia bunch	Also known as CS 16. High yielding line. It is an interspecific derivative of *Arachis hypogaea* x *Arachis cardenasii*, developed at ICRISAT. Resistant to rust and late leafspot.

Contd..

Table 1. Contd..

S.No.	Name of the genotype	Botanical group	Salient features
7.	M 13	Virginia runner	Selection from 'NC 13'. This variety was released in the year 1972. Possesses more spreading habit with large sized pods. Developed at PAU, Ludhiana.
8.	NC Ac 2821	Virginia runner	ICRISAT's number ICG 2704. It is also called as Holland Jumbo. Introduced from USA.
9.	MK 374	Virginia bunch	Introduction from Nigeria, released in 1978 as Kadiri-2. Developed at A.R.S., Kadiri of A.P.A.U., Hyderabad.
10.	TMV 2	Spanish	Mass selection from 'Gudhiatham bunch'. Variety was released in 1940. Widely adopted. Developed at A.R.S., Tindivanam.
11.	GAUG 1	Spanish	Cross derivative of 'AK 10' x 'AK 12-24'. Variety was released in the year 1973. Developed at Gujarat Agricultural University. Variety with medium compact in spread.
12.	PGN 1	Spanish	Cross derivative of Manfredi x Robut 33-1
13.	PGN 2	Spanish	Gamma ray induced mutant of GAUG 1 for more pronounced canopy development. Developed at IARI/RS, Hyderabad.
14.	MH 2 8C-28 Better Canopy Mutant of MH 2	Valencia	Induced mutant of MH 2 for denser and spreading canopy development. Developed at IARI Regional Station, Hyderabad. Possesses higher yield potential than MH 2.
15.	NC Ac 17090	Valencia	A land race from South America (Peru). It is a short duration variety (105 days) possessing resistance to rust and late leafspot. Source: ICRISAT.

3.2.2 Experiment II

During rabi 1986-1987, the 14 genotypes which were evaluated in experiment I were crossed in a diallel mating system without reciprocals.

3.2.2.1 Hybridization Programme

The crossing was started with the initiation of flowering. The flower buds were emasculated and a bright coloured soft nylon thread was tied as a ring around the emasculated bud for identification. Emasculations were done between 4.30 pm to 6.00 pm and the emasculated buds were pollinated the next morning before anthesis, between 6.00 am and 8.00 am (Kale and Mouli, 1984)

Emasculation was done for about 4 to 5 consecutive buds arising from each axil and the others arising later were removed carefully.

3.2.2.2 Experimental Layout

Studies in the F_1 and F_2 generations

The 91 F_1 hybrids along with 14 parents were grown during kharif 1987, in a randomised block design with two replications. The plot size was 3.5 m x 1.8 m. The inter and intra row spacing adopted were 60 cm x 15 cm respectively.

The F_2 generation of 91 crosses along with 14 parents were grown during rabi 1987-88 in a completely randomized block design with two replications. The plot size ws 3.5 x 2.4 m. The inter- and intra-row spacing adopted were same as in F_1.

A basal dose of P_2O_5 at the rate of 40 kg/ha was applied. Nitrogen was applied at the rate of 20 kg/ha in two split doses. The first dose was given 30 days after sowing as top dressing Gypsum was applied at the rate of 500 kg/ha as top dressing when the crop was in peak flowering.

All appropriate cultural operations and prophylactic measures against pests and diseases were undertaken to maintain good crop growth.

3.2.3 Experiment III

Studies on induced mutations

The experimental material comprising four varieties belonging to different botanical groups have been treated with a chemical mutagen, viz., Sodium azide (NaN_3), using citric acid-Sodium phosphate buffer at pH3 as described by Prasad et al. (1985).

3.2.3.1.2 Preparation of citric acid-sodium phosphate buffer solution:

Sodium dihydrogen orthophosphate (sodium phosphate monobasic) $NaH_2PO_42H_2O$ was used to prepare the buffer solution. 0.1 M solution of phosphate buffer was prepared by dissolving 15.601 g of sodium dihydrogen orthophosphate $NaH_2PO_42H_2O$ (Mol wt - 156.01 g) in 1000 ml of distilled water. Similarly citric acid solution of 0.1 M was prepared by dissolving 21.01 g in 1000 ml. Equal quantities of 0.1 M solutions of citric acid and sodium dihydrogen orthophosphate were mixed and the pH of the 0.1 M citric acid-sodium phosphate buffer solution adjusted to pH3 by the addition of 0.1 M citric acid solution with the help of pH meter.

3.2.3.1.3 PREPARATION OF MUTAGENIC SOLUTION

reparation of sodium azide (SA) solution

A quantity of 0.195 g of sodium azide was dissolved in 1000 ml of 0.1 M citric acid-sodium phosphate buffer solution to obtain 3 mM sodium azide (Mol wt 65.01) at pH 3.0. pH of the buffer solution was tested with the aid of pH meter before treating the material.

Method of Seed treatment

Table 2. Details of mutagenic treatment in the four varieties of groundnut are presented in the table given below:

S.No.	Variety	Chemical	Concentrations
1	GAUG-1	-	Control
2	"	SA	3mM
3	NCAC 17090	-	Control
4	"	SA	3mM
5	Robut 33-1	-	Control
6	"	SA	3mM
7	M 13	-	Control
8	"	SA	3mM

Pre-treatment: Presoaking in water for 23 hours. Duration of treatment-3 hours.

In all the varieties, 300 well developed dry and well filled seeds were presoaked in water for 23 hours. Freshly prepared solution of sodium azide was used at the rate of 1 ml/seed and all the treatments were carried out at room temparature ($24 \pm 1^{o}C$). Seeds soaked in buffer solution were maintained as control.

Intermittent shaking was done to ensure uniform and equal contact of the mutagenic solution with all the seeds.

After completion of the mutagenic treatment the seeds were thoroughly washed in running tap water for 30 minutes to remove the excess amount of mutagen. The seeds were then sown immediately with the appropriate control. The seeds were sown on ridges by hand dibbling with a spacing of 60 cm between the rows and 15 cm between the seeds within a row in M_1 generation.

All the seeds harvested from M_1 plants were sown in M_2. Seeds from mutants selected based on their canopy and yield attributes were advanced to M_3 generation.

All cultural operations and plant protection measures were followed similarly as in the case of Experiment I and Experiment II.

3.3 OBSERVATIONS RECORDED

Four plants at random were selected from each plot of the fourth replication. The selected plants were dugout keeping the root system intact and brought to the laboratory in paper bags. The roots were washed thoroughly to remove soil particles. These plants were used for destructive analysis.

Five plants at random in each plot from the four replications were selected and tagged at 60 days after emergence (DAE) for further data recording.

3.3.1 EXPERIMENT I

Seedling dry weight (SDW) (on dry matter basis):

Seedling weight in g at 21 days after emergence (DAE) was considered for seedling dry weight.

Days to flower (DF) : Days from the date of sowing to the date of first flowering.

Canopy circumference (CC) : Canopy circumference was measured in cm with the help of a measuring tape by placing around the plant spread at 60 DAE.

Canopy diameter (CD) : Canopy diameter at 60 DAE was measured in cm in two different directions at ground level and the mean was taken into consideration.

Leaf area (LA) : Leaf area of fresh leaves were measured in cm^2 with the help of leaf area meter (LI-3000, Lincoln, Nebraska, U.S.A) at 60 days after emergence.

Leaf dry weight (LDW) : Leaves were dried in hot air oven and were weighed in g in an electronic balance at 60 DAE.

Shoot dry weight (SDW) : Shoot dry weight in g was weighed at 60 DAE in an electronic balance.

Root dry weight (RDW) : Root dry weight in g was taken at 60 DAE in an electronic balance.

Total dry matter at 60 DAE (TDM) : Plant dry weight in g including root dry weight also.

Nodule number at 0-5 cm (NN 0-5): Number of nodules was counted at 0-5 cm root length at 60 DAE

Nodule number at 5-10 cm (NN 5-10): Nodule number was counted at 5-10 cm root length at 60 DAE

Nodule number at 10-15 cm (NN 10-15): Nodules were counted at 10-15 cm root length at 60 DAE

Nodule number at >15 cm (NN > 15): Nodules were counted at more than 15 cm root length.

Total nodule number (TNDN): Total root nodules were counted at 60 days after emergence

Nodule dry weight (NDW): Root nodule dry weight was recorded in g at 60 days after emergence.

Plant height (PH) : The height of the plant at maturity was measured in cm from the first cotyledonary node to the tip of the main axis.

Number of primaries (NP) : Number of branches originating from the main axis (n+1) were counted at the time of harvest.

Number of secondaries (NS) : The total number of branches originating on primary branches (n+2) per plant were counted at the time of harvest

Number of mature pods (NMP) : Well developed pods were counted at harvest.

Number of immature pods (NIMP) : Number of undeveloped and shrivelled pods were counted at harvest.

Number of mature kernels (NMK): Well developed kernels were counted after shelling of air dried pods.

Number of immature kernels (NIMK): Number of undeveloped and shrivelled kernels were taken

Immature kernel weight (IMKWT): Weight of immature kernels in grams.

Mature kernel weight (MKWT): Weight of mature kernels in grams.

Number of aerial pegs (NAP): The total number of aerial pegs which did not have access to penetrate into the soil.

Number of total pegs (NTOTP): Sum of mature, immature pods and number of aerial pegs.

Total dry matter at harvest (TDMH): Plant dry weight in g at harvest including root system also.

100 kernel weight (100 KWT): Weight of 100 kernels in g.

Shelling per cent (SH %): The ratio of kernel weight to pod weight expressed in percentage

Oil per cent (Oil %): Oil per cent in uncrushed seed was determined by using Nuclear Magnetic Resonance (NMR) spectrometer at Directorate of Oilseeds Research (D.O.R), Rajendranagar.

Recovery percentage (RP %): It is the ratio of number of mature pods to the total number of pods including number of aerial pegs expressed as per cent (Arunachalam et al., 1984).

Harvest index (HI): Harvest index was expressed as the ratio of kernel yield to total dry matter.

3.3.2 Experiment II

Due to the limited number of F_1 plants destructive sampling was not done.

The following observations were recorded as described in Experiment I

Days to flower

Canopy circumference

Canopy diameter

Plant height

Number of primaries

Number of secondaries

Number of mature pods

Number of immature pods

Mature pod weight

Number of mature kernels

Number of immature kernels

Immature kernel weight

Number of aerial pegs

Leaf area at harvest

Leaf dry weight at harvest

Shoot dry weight at harvest

Root dry weight at harvest

Nodule number at 0-5 cm

Nodule number at 5-10 cm

Nodule number at 10-15 cm

Nodule number > 15 cm

Total nodule number

Nodule dry weight at harvest

100 kernel weight

Shelling per cent

Recovery percentage

Harvest index and

Mature kernel weight

The above characters were used for calculation of means and Heterosis studies.

The following characters were used for estimating the combining ability in F_1 and F_2 generations. Days to flower

Canopy circumference

Canopy diameter

Plant height

Number of primaries

Number of secondaries

Number of mature pods

Number of immature pods

Mature pod weight

Number of mature kernels

Number of immature kernels

Immature kernel weight

Number of aerial pegs

Leaf area at harvest

Leaf dry weight at harvest

Shoot dry weight at harvest

Root dry weight at harvest

Nodule number at 0-5 cm

Nodule number at 5-10 cm

Nodule number at 10-15 cm

Nodule number > 15 cm

Total nodule number

Nodule dry weight at harvest

100 kernel weight

Shelling per cent

Recovery percentage

Harvest index

Mature kernel weight

3.3.3 Experiment III

The following characters were used for calculation of means and variances in M_1, M_2 and M_3 generations.

Canopy circumference

Canopy diameter

Plant height

Number of primaries

Number of secondaries

Number of mature pods

Mature pod weight

Number of mature kernels and

Mature kernel weight

3.4 CATEGORISATION OF GENOTYPES FOR CANOPY DEVELOPMENT

Based on the mean performance of the genotypes for canopy circumference, canopy diameter and total dry matter at 60 days the groundnut genotypes were categorised under the scores 1, 2, 3 and 4. Different scales were adopted for rating the canopy in different seasons, viz., kharif 1987, late kharif 1987, rabi 1986-87 and rabi 1987-88 due to considerable genotype x environment interaction in respect of canopy circumference, canopy diameter and total dry matter at 60 days as per the work of Metz _et al_., (1984) on canopy rating in soybean. The different scales for different seasons are as follows (Table 3).

3.5 STABILITY ANALYSIS

Following the methodology of Eberhart and Russell (1966), three parameters viz., (1) overall mean of each genotype over the range of environments (2) the regression of each genotype on the environmental index and (3) a function of the squared deviation from this regression were estimated. The model proposed by Eberhart and Russell (1966) is as follows:

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

where,

i varies from 1 to 14

j varies from 1 to 4

Table 3. Scale for canopy categorisation in different seasons.

Rabi 1986-87			Kharif 1987			Late Kharif 1987			Rabi 1987-88				
Canopy circumference (cm)	Canopy diameter (cm)	Total dry matter (g)	Canopy circumference (cm)	Canopy diameter (cm)	Total dry matter (g)	Canopy circumference (cm)	Canopy diameter (cm)	Total dry matter (g)	Canopy circumference (cm)	Canopy diameter (cm)	Total dry matter (g)	Score	Category
< 50	< 20	< 10	< 100	< 40	< 10	< 55	< 21	< 6	< 100	< 40	< 10	1	COMPACT
51-109	20-31	11-15	135-145	41-46	11-16	55-95	22-31	7-12	140-160	41-50	11-15	2	MEDIUM COMPACT
110-130	32-40	16-20	146-155	47-52	17-22	96-136	32-41	13-18	161-180	51-60	16-20	3	MEDIUM SPREADING
> 131	> 41	> 21	> 156	> 53	> 22	> 136	> 41	> 18	> 181	> 60	> 21	4	SPREADING

Y_{ij} = mean of i-th genotype in j-th environment

u = mean of all genotypes over all the environments.

β_i = regression coefficient of i-th genotype on the environmental index.

which measures the response of this genotype to varying environments.

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

$_{ij}$ = the deviation from regression of the i-th genotype at j-th environment.

Analysis of Variance for Stability

The analysis of variance as proposed by Eberhart and Russell (1966) is given below.

Analysis of Variance to estimate stability parameters as proposed by Eberhart and Russell (1966).

Source	d.f.	S.S.	M.S.
Total (treatment combining)	ge-1	$\sum_i\sum_j Y_{ij}^2$-CF	
Genotype (cultivar)	g-1	1/e $\sum_i Y_{i.}^2$-CF	MS_1
Environment + (Genotype x Environment)	g(e-1)	$\sum_i\sum_j Y_{ij}^2-\sum Y_{i.}^2/e$	
Environment (linear)	1	$1/g(\sum_j Y_{.j} I_j)^2/\sum I_j^2$	
Genotype x Environment (linear)	g-1	$[(\sum_j Y_{ij} I_j)^2/\sum_j I_j^2]$- Environment (linear)S.S.	MS_2
Pooled deviations	g(e-2)	$\sum_i\sum_j \delta^2_{ij}$	MS_3

Deviations due to genotype.....I	e-2	$[\sum_j Y^{2}_{ij}-(Y_{I.})^2]$	MS_3-I
; :		$(\sum_j YI_jI_j)^2/\sum_j I^2{}_j=$	
; :		$=\Sigma_j\sigma^2 I_j$	
genotype....g	e-2	$\sum_j Y^2{}_{gj}-(Y^2{}_i)/e$ - $(\sum_j Y_{gj}I_j)^2/\sum_j I^2{}_j$ = $=\delta^2{}_{gi}$	MS_3-g
Pooled error	e(r-1)(g-1)		

- -

g = genotype (cultivar); e = environment; r = replication.

Estimation of Stability parameters

The regression coefficient (bi) and mean square deviations (s^2d) from linear regression were estimated as follows.

a) Regression coefficient

$$b_i=\sum_j Y_{ij}I_j/\sum_j I^2{}_j$$

where,

$\sum_j Y_{ij}I_j$ = the sum of products of environmental index (I_j) with corresponding mean of that genotype at each environment (Y_{ij})

$\sum_j I^2{}_j$ = the sum of squares of the environmental index I_j

b) Mean Square deviations(S^2d) from linear regression

$$S^2d=[\sum_j\hat{\delta}^2{}_{ij}/(e-2)]-s^2e/r$$

where,

$\sum_j\hat{\delta}^2{}_{ij}=\sum_j Y^2{}_{ij}-Y^2{}_i/g-(\sum_j Y_{ij}I_j)^2/\sum_j I^2{}_j$
= variance due to deviation from regression for a genotype

$\sum_j Y^2{}_{ij}-Y^2{}_i/g$ = variance due to dependent variable and

$(\sum_j Y_{ij}I_j)^2/(\sum_j I^2{}_j)$ = variance due to regression

S^2e/r = the estimate of pooled error

e = number of environments; r = number of replications

The various computational steps involved in the estimations are as follows:

Computation of environmental index (I_j):

$I_j = \sum_j Y_{ij}/g - \sum_{ij}\sum Y_{ij}/ge$

= Total of all the genotypes at the j-th environment/number of genotypes - grand total/total number of observations.

Computation of regression coefficient (b_i) for each genotype:

a) for each value of regression coefficient, $\sum_j I^2_j$ is common.

b) $\sum_j Y_{ij}I_j$ for each genotype is the sum of products of environmental index (I_j) with the corresponding mean ($\bar{X}$) of that genotype in each environment.

These values may be obtained in the following manner.

$(\bar{X})(I_j) = (\sum_j Y_{ij}I_j) = (S)$

where,

$(\bar{X})$ = matrix of means

(I_j) = vector for environmental index, and

(S) = vector for sum of products,

i.e. $\sum_j Y_{ij}I_j$

Computation of S^2d:

In a regression analysis, it is possible to partition the variance of the dependent variable (Y) into two parts, the one which explains the linearity between dependent and independent variables (Variance due to regression) and the other which explains the variance due to deviations from linearity.

$\sigma^2 Y = \sigma^2$ regression + σ^2 deviation from the regression.

The variance of mean over different locations with regard to individual genotype may be obtained in the following way:

$$\sigma^2_{gi} = \sum_j Y^2_{ij} - (Y^2_{i}/g)$$

The variance due to deviations from regression $(\sum_j \delta^2_{ij})$ for a genotype being

$$\sum_j \delta^2_{ij} = [(\sum_j Y^2_{ij}) - Y^2_{i}/g] -$$
$$(\sum_j Y_{ij} I_j)^2)/\sum_j I^2_j$$

where

$\sum_j Y^2_{ij} - Y^2_{i}/g$ = the variance due to dependent variable

and $(\sum_j Y_{ij} I_j)^2/(\sum_j I^2_j)$ = the variance due to regression because,

$$(\sum_j Y_{ij} I^2_j)/\sum_j I^2_j =$$
$$(\sum_j Y_{ij} I_j)(\sum_j Y_{ij} I_j)/\sum_j I^2_j = b_i \sum_j Y_{ij} I_j$$

From $\sum_j \delta^2_{ij}$ values, the stability parameters S^2d for each variety is computed as follows:

$$S^{-2}d = [\sum_j \delta^2_{ij}/(e-2)] - (S^2 e/r)$$

Mean Square deviation =

(Deviation from regression/d.f. for environment)-(pooled error/No. of replications)

The variance due to genotypes, environments and the pooled error were the same as those calculated in the pooled analysis of the data, except that the total sum of squares was mainly partitioned into three main components namely (1) sum of squares due to genotypes, (2) sum of squares due to environments + (geotype x environment) and (3) pooled error. Again SS due to GxE was further partitioned into two parts i.e. (a) SS due to GxE (linear) which is in fact SS due to regression and (b) SS due to deviations from linearity of response (i.e. SS due to deviations).

i) SS due to environment + (GxE) = $\sum_{ij}\sum Y^2_{ij} - (\sum_{i} Y^2_{i}/e)$

ii) SS due to environment (linear) = $(1/g)[\sum_{j} Y_j I_j)^2/\sum_{j} I^2_j]$

iii) SS due to genotype x environment (linear) =

$\sum_{j}[(\sum_{j} Y_{ij} I_j)^2/(\sum_{j} I^2_j)]$-SS environment (linear)

where

$(\sum_{j} Y_{ij} I_j)^2/\sum_{j} I^2_j) = b_i \sum_{j} Y_{ij} I_j$ for each variety.

<u>Tests of significance</u>

The following tests of significance were carried out.

(1) To test the significance of the differences among genotype means i.e., $Ho = u_1 = u_2 \ldots u_{14}$ the "F" test used was,

$$F = \frac{\text{Mean square due to genotype}}{\text{Mean square due to pooled deviation.}} = MS_1/MS_3$$

2) To ascertain that the genotypes did not differ due to regression on environmental index i.e., $Ho = b_1 = b_2 = b_3 \ldots b_{14}$, the 'F' test used was:

$$F = \frac{\text{MS due to genotype x environment (linear)}}{\text{MS due to pooled deviation}}$$

$$= MS_2/MS_3$$

3) Individual deviation from linear regression was tested as follows:

$F = [(\sum_{j} \delta^2_{ij})/(e-2)]/\text{pooled error}$

$p = 0.05$ at $(g-2)$ d.f.

4) The hypothesis that any regression coefficient does not differ from unity or from zero was tested by the appropriate 't' test i.e.

for (b-0) $(b-0)/(S\ b_i)$ = 't' ($P = <0.05$ for (e-2) d.f.)

for (1-b) $\frac{1-b}{SEb_i}$ = 't' ($P = <0.05$ for (e-2) d.f.)

$$SE\ b_i = \sqrt{\sum_j \delta^2 ij/(e-2) / \sum_j I^2{}_j}$$

Stability parameters

A genotype with unit regression coefficient (b-1) and the deviation not significantly differing from zero ($s^2d = 0$) was taken to be stable genotype with unit response. Mean and standard error of 'b' are

Mean of b = b = $\sum_i b_i/g$

SE b = $\sqrt{\text{M.S. due to pooled deviation} / \sum_j I^2{}_j}$

Population mean (u) and standard error were calculated as

$$\text{Population mean (u)} = \frac{\text{Grand Total}}{\text{Number of observations}}$$

$$\text{SE (mean)} = \sqrt{\frac{\text{MS due to pooled deviation}}{\text{No. fo environments} - 1}}$$

3.6 PHENOTYPIC AND GENOTYPIC CORRELATIONS

The genotypic and phenotypic correlation coefficients were calculated for pooled data and also partitioning Virginia and Spanish groups in pooled data, by working out the variance components for each pair of characters using the formulae suggested by Falconer (1985).

i) Phenotypic correlation

$r(x_i x_j)P = Cov(x_i x_j)P/\sqrt{V(x_i)P \times V(x_j)P}$

ii)Genotypic correlation

$r(x_i x_j)G = Cov(x_i x_j)G/\sqrt{V(x_i)G \times V(x_j)G}$

where

$r(x_i x_j)$ = Correlation between i^{th} and j^{th} characters.

$Cov(x_i x_j)$ = Covariance between i^{th} and j^{th} characters.

$V(x_i)$ and $V(x_j)$ = Variance for the i^{th} and j^{th} characters.

Genotypic and phenotypic variances were calculated as follows:

$$\text{Genotypic variance} = \frac{\text{Treatment MS} - \text{Error MS}}{\text{Number of replications}}$$

$$\text{Phenotypic variance} = \sigma^2 G + \sigma^2 E$$

The values of genotypic correlations exceeding unity should be considered as unity only (of same size).

To test the significance of the correlation coefficients at phenotypic level, the estimated values were compared with the table values of correlation coefficients (Fisher and Yates, 1967) at 5 per cent and 1 per cent level of significance with (n-2) degrees of freedom.

3.7 PATH COEFFICIENT ANALYSIS

The direct and indirect effects, at phenotypic level for parents evaluated in experiment I were estimated taking kernel weight per plant as dependent variable and considering limited number of independent variables, using path coefficient analysis suggested by Wright (1921) and elaborated by Dewey and Lu (1959). The following equations were formed and solved simultaneously by estimating the various direct and indirect effects.

$$r_{1y}=P_{1y}+r_{12}P_{2y}+r_{13}P_{3y}\cdots r_{112}P_{12y}$$

$$r_{2y} = r_{21}P_{1y} + r_{22}P_{2y} \cdots r_{212}P_{12y}$$

..

..

$r_{12y} = r_{12}P_{12y} + \cdots + r_{121}P_{1y}$

Experiment II

3.8 ESTIMATION OF MEANS AND VARIANCES

Means and variances were calculated for quantitative characters in 91 F_2 progenies and mean values for 14 parents which are involved in diallel genetic design. Following formulae were used.

$$\text{Mean } (\bar{X}) = A + \left[\frac{\Sigma fd}{\Sigma f} \times c\right]$$

$$\text{Variance } (\sigma^2) = \frac{1}{N} \left[\Sigma fd^2 - \frac{(\Sigma fd)^2}{N}\right] \times C^2$$

where

A = assumed mean;

f = frequency

d = (X-A)/C, where 'x' is the mid value of the class interval

N = Total number of observations

C = Length of the class interval

3.9 SELECTION CRITERIA

In order to group the means and variances of different characters in 91 cross combinations of F_2 generation, 10% selection criteria have been adopted for the following traits viz., canopy circumference and diameter at 60 days, number of primaries and secondaries, number of mature pods and its weight, number of mature kernels and its weight, total nodule number and its dry weight at harvest, leaf area at harvest, total dry matter at harvest, shelling per cent, 100-kernel weight and harvest index.

By adopting 10% selection criteria, the 91 F_2's for above characters were grouped into high variance with high mean, high variance with medium mean, high variance with low mean, medium variance with high mean, medium variance with medium mean, medium variance with low mean, low variance with medium mean and low variance with low mean.

3.10 ESTIMATION OF HETEROSIS

The magnitude of heterosis was worked out based on better parent value. The heterosis was estimated as per cent increase or decrease of F_1 over the better parent for 30 characters, as given below.

Based on better parent (Heterosis) = $$\frac{\bar{F}_1 - \overline{\overline{BP}}}{\overline{\overline{BP}}} \times 100$$

Significance of heterosis was tested using the formula suggested by Arunachalam et al. (1980).

$$t = \frac{\bar{F}_1 - \overline{\overline{BP}}}{\sqrt{2\ \mathrm{EMS}(F_1)/r}}$$

where F_1 = Mean of hybrid

BP = Mean of better parent

r = Number of replications.

3.11 ANALYSIS OF VARIANCE

Analysis of variance of the randomized block design for F_1 (parents + F_1s) and F_2s (parents + F_2s) were carried out separately as per Panse and Sukhatme model (1961) and is given below.

Source	df	MSS	Calculated F
Replications	(r-1)	Mr	Mr/E
Treatments	(t-1)	Mt	Mt/E
Error	(r-1)(t-1)	E	

where r = number of replications

t = number of treatments

The sum of squares of each character were tested against the corresponding error degrees of freedom using 'F' test.

The sum of squares due to treatments in F_1 were partitioned into sum of squares due to parents, F_1s and parents vs F_1s.

3.12 COMBINING ABILITY ANALYSIS

The combining ability analysis was carried out according to Method-2 and Model I of Griffing(1956b). The fixed effect model (Model I) was considered to be more appropriate in the present investigation, since the study was restricted to the parents and single crosses only. The mathematical model used is as follows:

$$X_{ij} = u + g_i + g_j + s_{ij} + 1/b \sum_k e_{ijk}$$

$i,j = 1,2...P$ (parents)

$k = 1,2...b$ (replications)

where u = population mean common to all parents

g_i and g_j = General combining ability effects of i^{th} and j^{th} parents.

s_{ij} = specific combining ability effect of i^{th} and j^{th} parents.

e_{ijk} = Environmental effect associated with the ijk -th individual observation.

The restrictions $\Sigma g_i = 0$ and $\Sigma(S_{ij} + S_{ii}) = 0$ (for each) are imposed on the combining ability elements. For combining ability estimates the degrees of freedom for genotypes was further divided into gca and sca as indicated below.

Source	df	Sum of squares	Mean squares	Estimated mean squares
gca	(p-1)		$\sigma^2+(P+2)(1/P-1)$	Σg_i^2
sca	P(P-1)/2		$\sigma^2+2/P(P-1)$	$\Sigma_i < \Sigma_j S^2_{ij}$
Error	m		Me'	σ^2

The above partitioning was as per the following formulae.

$$\text{Correction factor} = 2X^2_{..} /P(P+1) = \frac{(\text{Grand Total})^2}{\text{Total number of plots}}$$

Sum of squares for combining ability:

$$S_g = 1/(P+2) \left\{\sum_i (X_{i.} + X_{ii})^2 - 4/pX^2_{..} \right\}$$

$$S_s = \sum_{i<j}\sum X^2_{ij} - \frac{1}{(P+2)} \Sigma(X_{i.} + X_{ii})^2 + 2/(P+1)(P+2)\, X^2_{..}$$

$$= \text{Cross SS} - \text{gca SS} = \Sigma\Sigma\, X^2_{ij} - CF - S_g$$

By solving the expected mean suqres, the variance components of gca and sca were calculated.

Thus gca = Mg - Me'/(P+2)/(P-1) and

sca = Ms - Me'/2/P(P-1)

effects	variance
$\hat{u} = 2/P(P+1)X_{..}$	$Var(\hat{u}) = 2/P(P+1)\ \hat{\sigma}^2$

where,

p = number of parents entering the diallel cross

X_i = Female array total of the common parent

X_j = Male array total of the common parent

$X..$ = Overall total of the diallel table.

The error mean square Me' was obtained as, $Me' = \sigma^2e/bc = \sigma^2$ where $\sigma^2{}_e$ is the sampling error from the analysis of variance of the randomized complete block and bc is the total number of observations for each treatment over all the blocks. Tests of significance were made using Me' as the error estimate.

<u>Estimate of general and specific combining ability effects</u>:

General combining ability effects of the parents (g_i) and the specific combining ability (s_{ij}) effects of the crosses were calculated as per the following formulae.

$$\text{Mean } (\hat{u}) = 2/P(P+1)X\,..$$

$$\hat{g}_i = \{ (1/P+2\ (X_{i.} + X_{ii}) - 2/P\ X..) \}$$

where,

$\Sigma g_i = 0$ is the restriction followed

$$\hat{s}_{ij} = x_ij - \frac{1}{P+2} (X_{i.} + X_{ii} + X_{j.} + X_{jj}) + 2/(P+1)(P+2)\ X..$$

with the restriction $\Sigma(s_{ij} + s_{ii}) = 0$. SE of the difference between effects of two crosses having one parent common was estimated as follows:

$$SE(a) = (\hat{S}_{ij} - \hat{S}_{ik}) = \sqrt{(2(P+1)/(P+2))\hat{\sigma}^2}\ (i \neq j,\ k;\ j \neq k)$$

SE of difference between effects of two crosses having no parent in common was calculated as follows:

$$SE(b) = (\hat{s}_{ij} - \hat{s}_{kl}) = \sqrt{(2P\hat{\sigma}^2/(P+2))}\ (i \neq j,\ k,l;\ j \neq k,l;\ k \neq l)$$

The variance of effects were estimated as follows:

$$\mathrm{Var}(\hat{u}) = \frac{2}{P(P+1)} \hat{\sigma}^2$$

$$\mathrm{Var}(\hat{g}_i) = \frac{P-1}{P(P+2)} \hat{\sigma}^2$$

$$\mathrm{Var}(X_{ij}) = \hat{\sigma}^2 = Me'; \ \mathrm{Var}(X_{ij}-X_{kl}) = 2\hat{\sigma}^2$$

$$\mathrm{Var}(\hat{s}_{ij}) = \frac{P^2 + P + 2}{(P+1)(P+2)} \hat{\sigma}^2 \quad (i \neq j),$$

$$\mathrm{Var}(\hat{g}_i - \hat{g}_j) = \frac{2}{P+2} \hat{\sigma}^2 \quad (i \neq j),$$

$$\mathrm{Var}(\hat{s}_{ii} - \hat{s}_{jj}) = \frac{2(P-2)\hat{\sigma}^2}{P+2} \quad (i \neq j),$$

$$\mathrm{Var}(\hat{s}_{ij} - \hat{s}_{ik}) = \frac{2(P+1)}{(P+2)} \hat{\sigma}^2 \quad (i \neq j, k; \ j \neq k)$$

$$\mathrm{Var}(\hat{s}_{ij} - \hat{s}_{kl}) = \frac{2P}{P+2} \hat{\sigma}^2 \quad (i \neq j,k,l; \ j \neq k,l, \ k \neq l)$$

By taking square roots of the variances, the corresponding standard errors required for testing were obtained.

gca and sca components were estimated as per the following formulae

$$\hat{\sigma}^2 g = \frac{2}{(n+2)} (Mg - Ms)$$

$$\hat{\sigma}^2 s = Ms - Me'$$

The gca and sca variances associated with each parent were computed using the following formulae.

$$\hat{\sigma}^2 g_i = (\hat{g}_i)^2 = \left[(P-1)/(2P)^2 \ \sigma^2 e\right] \text{ and}$$

$$\hat{\sigma}^2 s_i = 1/(P-2) \ \hat{s}_{ij} = (1/(2P)^2)(P^2 - 2P+2)^2 \ \sigma^2 e)$$

3.13 HERITABILITY (H) : Heritability in narrow sense (n) was estimated by using the formula given by Gardner (1963).

(i) Heritability in narrow sense (n) = $\sigma^2 gca/\sigma^2 gca+\sigma^2 sca+\sigma^2 e$

where $\sigma^2 gca$ = additive variance (component due to gca)

$\sigma^2 sca$ = non-additive variance (component due to sca)

$\sigma^2 e$ = error component of variance.

3.14 ESTIMATION OF MEANS AND VARIANCES IN EXPERIMENT III

In the present study the estimation of means and variances for various canopy and reproductive attributes were calculated in M_1, M_2 and M_3 generations as in the case of Experiment II.

Estimation of mutation frequency in M_2 generation

Estimation of chlorophyll mutation frequencies: Chlorophyll mutation frequencies were estimated per treatment on the basis of both M_2 families and M_2 plants.

Chlorophyll mutation frequency (in M_2 family basis)

$$= \frac{\text{Number of } M_2 \text{ families segregating for chlorophyll mutants}}{\text{Number of } M_2 \text{ families scored}} \times 100$$

$$\text{Chlorophyll mutation frequency (on } M_2 \text{ plants basis)} = \frac{\text{no. of chlorophyll mutants recorded}}{\text{no. of } M_2 \text{ plants scored}} \times 100$$

Estimation of viable mutation frequencies:

Viable mutations in M_2 were also estimated per treatment based on M_2 family basis and M_2 plant basis.

Viable mutation frequency (on M_2 family basis) =

$$\frac{\text{Number of } M_2 \text{ families segregating for viable mutants}}{\text{Number of } M_2 \text{ families scored}} \times 100$$

Viable mutation frequency (on M_2 plants basis)

$$= \frac{\text{Number of viable mutants recovered}}{\text{Number of } M_2 \text{ plants scored}} \times 100$$

Estimation of mutagenic effectiveness and efficiency

Mutagenic effectiveness is the ratio between the percentage of M_2 families segregating for mutations and the product of time of mutagenic treatment and the concentration of mutagen.

$$\text{Mutagenic effectiveness} = \frac{Me}{tc}$$

where

Me = percentage of M_2 families segregating for mutants

tc = duration of mutagenic treatment (t) x concentration of the mutagen (c)

Mutagenic efficiency is the proportion of M_2 families segregating in relation to the percentage sterility induced by the mutagen.

$$\text{Mutagenic efficiency} = \frac{Me}{S}$$

where,

S = percentage seed sterility in M_1 generation (where seed sterility was estimated as percentage reduction of seed number in relation to control).

In the present study, modified formulae of Konzak *et al*. (1965) as adopted by Prasad (1972) were used for calculating the above.

DISCUSSION

DISCUSSION

5.1 CHARACTERISATION OF GROUNDNUT GENOTYPES FOR PLANT CANOPY

Groundnut (Arachis hypogaea L.) is different from the other grain legumes, in the sense it has aerial flowering and subterranean podding. In view of the positive geotropism of gynophores which develop into sink in the soil, it becomes difficult for the plant breeder to exercise selection based on the above ground characters which apparently do not seem to indicate the reproductive efficiency. Therefore, groundnut has been termed an 'unpredictable legume' (Gregory et al., 1973). While correlations have been developed among seed and pod characters on one hand, and yield of groundnuts on the other (Coffelt and Hammons, 1974; Tripathy, 1974; Singh et al., 1979; Yadava et al., 1984 and Kataria et al., 1984), our knowledge of inter-relationship between canopy characters and yield components of groundnut remains fragmentary.

In order to minimise interplant competition at the recommended spacing, canopy characters have to be identified, which indicate the role of physiological characters above ground as associated with sink size and development (Metz et al., 1984).

In the present investigation an effort was made to categorise the canopy employing scores 1 to 4. The factors believed to influence canopy rating are canopy circumference canopy diameter and total dry matter at 60 days (Metz et al., 1984). Based on the above considerations a rating of 1 indicated a compact canopy, 2 a medium compact canopy, 3 a medium spreading and 4 a spreading canopy.

Due to environmental differences among the seasons viz., kharif 1987, late kharif 1987, rabi 1986-1987 and rabi 1987-1988, considerable genotype x environment interaction was observed in respect of canopy circumference, canopy diameter and total dry matter at 60 days of each genotype, despite which the relative differences among the distinct canopy ratings were maintained in all the seasons. As per the canopy categorisation adopted in present study, MH 2 (Valencia) alone falls under canopy category of 1. While MH2BC28 (Valencia), PGN1 (Spanish), PGN2 (Spanish), TMV2 (Spanish) and GAUG-1 (Spanish) come under canopy category 2, the genotypes 32-2-5 (Virginia bunch), Compact Mutant of M13 (Virginia bunch), TMV2NLM (Virginia bunch), Robut 33-1 (Virginia bunch), ICG(C) 8 (Virginia bunch) and MK 374 (Virginia bunch) come under canopy category 3, the genotypes M13 (Virginia runner) and NC Ac 2821 (Virginia runner) were observed to form the canopy category 4.

An examination of each of the canopy categories from 1 to 4, revealed that the most compact category was restricted to sequential branching forms, while the most vegetative canopy form were essentially the alternate branching Virginia types and both these extreme categories were not characterised by high stability for kernel yields. The canopy category 2, however, consisted of sequential branching Spanish and Valencia forms. The canopy type 3, on the other hand, revealed alternate branching Virginia types.

In other words, the canopy compaction in groundnut from canopy types 4 to 1 marked a shift from Virginia forms to sequential branching types and vice-versa, with the attainment of the highest levels of stability for kernel yield in canopy categories 2 and 3, consisting of both Virginia and sequential branching Spanish and Valencia types. These observations draw support from the findings of Prasad et al. (1984), based on the induced mutations that higher productivity levels in terms of kernel yield could be achieved by genetic manipulation of canopy characters leading to canopy enhancement in sequential branching Spanish and Valencia types i.e., from canopy category 1 to 2 and canopy compaction in alternate branching Virginia types (i.e., from canopy type 4 to 3).

An evaluation of all the varieties for overall stability for pod and kernel yield has revealed that the most stable genotypes out of all the botanical types viz., PGN1, MH2BC28 and TMV2NLM pertained to canopy categories 2 and 3, there by indicating that an appropriate balanced combination of canopy and stability of kernel yield could be achieved only in these two (i.e, 2 and 3) canopy categories.

Although it was observed that the canopy categories 2 and 3 consisted exclusively of sequential and alternate branching forms respectively, an evaluation of a wider degree of variability might lead to inclusion of certain alternate branching varieties such as G 201 in canopy category 2 and some valencia forms in canopy category 3 (Vanisree, 1989).

The work on categorisation and characterisation of groundnut genotypes based on canopy attributes is almost non-existent. It may be pointed out that this was probably the first attempt to categorise and characterise the diverse groundnut genotypes based on the canopy attributes such as canopy circumference, canopy diameter and dry weight at 60 days. The traditional classification of groundnut based on branching and flowering patterns and pod and seed attributes (Gregory, et al., 1980; Bunting, 1955; Hayes, 1933) was taxonomic in nature and embraces all categories of canopy growth under each sub-species viz., fastigiata and hypogaea. The present study on the other hand, is an effort to identify the groundnut genotypes irrespective of their taxonomic position, on the basis of the canopy growth so as to relate it to agronomic potential and to workout appropriate parental combinations based on canopy types for use in groundnut breeding. A similar exercise carried out by Metz et al. (1984) in soybean was useful in relating maturity pattern to canopy development and choosing the appropriate parents for hybridization programmes.

The study suffers from a limitation of very few genotypes in canopy category 1 and 4. This situation could not be improved upon due to non-availability of seed material in large quantities of such other genotypes. It may also be stated that the extreme compact genotypes pertaining 1 are very few. Secondly, with regard to canopy category 4, the number could not be enhanced due to non-availability of good quality seed in large quantities of other genotypes which could fall in this category. Also, inview of already included large number of varieties it was not possible to enhance the number as that would have lead to difficulties in handling the parental and hybrid populations.

5.2 STABLE CHARACTER COMBINATIONS FOR SELECTION CRITERIA

Finley and Wilkinson (1963), Eberhart and Russell (1966) and Wricke (1960, 1962 and 1965) have described techniques for partitioning the genotype x environment interaction into meaningful parameters for describing crop yield stability.

Valid interpretations of quantitative inheritance, as well as predictions of future performance in a peanut breeding program depend on accurate assessment of genotypic values (Moll and Stuber, 1974). Unfortunately, genetic effects are not independent of non-genetic environmental effects. The interaction of genotype and environment reduces the correlation between genotype and phenotype which reduces confidence in the data relative to plant improvement and inheritance of quantitative traits. Genotype x environment interactions will often produce an upward bias in genetic variance estimates, causing expected response to selection to be greater than realized response.

Because of limited resources, peanut breeders have generally been interested in developing cultivars that are stable, that is the genotypes which show a minimum of interaction with the environment (Moll and Stuber, 1974). Several researchers have used regression techniques to characterize the responses of genotypes under varying environmental conditions, although many of the regression analyses used to measure phenotypic stability, do not meet rigorous statistical requirements (Moll and Stuber, 1974). However, they have proven to be useful indicators of stability.

Several research workers such as Wynne and Coffelt (1980), Shorter and Norman (1983), Wynne and Gregory (1981), Kumar et al., (1984), Reddy et al., (1984) and Norden et al. (1986) etc., measured the stability of genotypes for yield by using the analysis suggested by Eberhart and Russell (1966).

Despite the fact that such investigations have added useful results, the groundnut breeders by and large, have been selecting superior yielding genotypes based on number of pods per plant and pod and kernel weight per plant (Norden et al., 1986, Yadava et al., 1984). Since it is fairly established that the characters viz., pod number and pod weight per plant in groundnut were subjected to a larger degree of interaction with environment due to subterranean pod development mechanism of groundnut (Wynne and Coffelt, 1980; Chen and Wan, 1968; Coffelt, 1983, Madhavi, 1988, Sandhu and Khehra, 1977 and Sangha and Jaswal, 1975), selection based on such an unstable character combination may not be fruitful. This is amply reflected in the yield performance of most of the currently available groundnut varieties which have not exhibited any spectacular differences in productivity (Rao, 1976 and Duncan *et al*., 1978) most probably because they were selected based on the above characters. Therefore, it would be more appropriate to work out criteria of selection involving a combination of more stable characters, positively correlated to yield in addition to pod number and pod weight for genetic improvement of groundnut. This approach sounds more logical since in a homeostatic genotype, the component characters shift in a compensating manner in changing environment in order to give a consistent performance of the final character (Grafius, 1956).

Therefore in this present investigation an effort has been made to work out stability of a wide range of characters such as seedling dry weight, days to flower, canopy circumference, canopy diameter, leaf area at 60 days, leaf dry weight, shoot dry weight and root dry weight at 60 days, nodule number at 0-5 cm, 5-10 cm and 10-15 cm at 60 days, total nodule number and nodule dry weight at 60 days, plant height, number of primaries and secondaries, number of mature and immature pods, mature and immature pod weight, number of mature and immature kernels and their weights, number of aerial and total pegs, total dry matter at 60 days and at harvest, 100 kernel weight, shelling per cent, oil per cent, harvest index and recovery percentage. Such an attempt has already been carried out in wheat (Habibuddin, 1987). Based on the variances, characters could be classified as to their stability by way of percentage of genotypes to the total number taken into consideration possessing non-significant variances for the particular character and also taking into consideration, the contribution of non-linear component. It could be observed that the characters such as plant height, number of primaries, number of secondaries, canopy diameter, nodule number and nodule dry weight at 60 days, leaf dry weight, shoot dry weight and root dry weight at 60 days and total dry matter at 60 days and oil per cent are less subjected to the interactions with the environment in view of low pooled deviations as compared to pod number and pod weight commonly employed as selection criteria for high yielding genotypes. Although some workers have reported that pod yield and pod number per plant were stable in certain varieties (Yadava and Kumar, 1978 and Sangha and Jaswal 1975), a general review of literature supports the observations made in the present study that pod number and pod weight had shown a larger degree of environmental interactions (Wynne and Gregory 1981, Kumar et al., 1984 and Norden et al., 1986). In view of overwhelming confirmation of these observations it appears more appropriate to employ some of the above mentioned characters showing low pooled deviation as criteria of selection depending upon feasibility in addition to pod number and pod weight as suggested by Grafius (1956) and others to employ selection criteria consisting of a combination of most stable characters rather than depending upon certain unstable yield components alone.

Of all the above characters showing low pooled deviation thereby tending towards being most stable as compared to pod number and weight, the attribute of oil per cent cannot be considered as selection criteria in view of its non-feasibility and its strong negative correlation with kernel yield, as shown in the present investigation. The attribute of plant height may not be an appropriate choice considering the lack of its relevance, as it shows no strong positive relationship with kernel yield. Out of the remaining characters showing low pooled deviation, the root dry weight, nodule number and nodule dry weight at 60 days may not be practically feasible in the field. The rest of the characters perticularly number of primaries especially in *spanish* and *valencia* genotypes, number of secondaries in *virginia* genotypes, canopy diameter, leaf dry weight, shoot dry weight and total dry matter at 60 days have exhibited a strong positive phenotypic correlation and considerable degree of genotypic correlation with kernel yield.

These results are in agreement with the findings of Madhavi (1988), who reported the feasibility of employing initial canopy growth and total dry matter at 60 days, as criteria of selection in addition to yield components. In view of the practical difficulty of estimating leaf dry weight, shoot dry weight and total dry matter at 60 days in large segregating populations the canopy diameter at 60 days, number of primary branches in *spanish* and *valencia* genotypes and number of secondaries in *virginia* genotypes can be profitably employed as components of selection criteria in addition to the pod number and pod weight which have shown higher degree of instability over the seasons. Based on the environmental index, the expression of the pod number was more favourable only in the post-rainy season but not in monsoon season (Raju, 1982).

On the other hand, the expression of the characters such as canopy diameter and total dry matter at 60 days, number of primaries and secondaries were more favourable irrespective of the seasonal conditions.

5.3 STABILITY OF THE GENOTYPES FOR YIELD AND OTHER CHARACTERS

One of the major problems plaguing groundnut production and productivity has been the lack of the yield stability in respect of the groundnut varieties recommended for cultivation (Patra and Mohanty, 1987;

Table 44. STABILITY OF GROUNDNUT GENOTYPES FOR VARIOUS CHARACTERS

Character	Botanical Category	Low envionmental Standard deviation	Unit regression and deviation from regression	Common stable genotype
Seedling dry weight	*Virginia*	TMV2NLM,32-2-5,M 13,ROBUT 33-1	TMV2NLM,ICG(C)8.	TMV2NLM
	Fastigiata	PGN1, PGN2	GAUG1	NIL
	Combined	TMV2NLM, 32-2-5 & PGN1	TMV2NLM,TMV2,MH2BC28	TMV2NLM
Days to flower	*Virginia*	M13, Com.Mut. M13, ICG(C)8	Com.Mut.M13,TMV2NLM,M13	M13,Com.Mut.M13
	Fastigiata	GAUG1, PGN2	PGN1, PGN2, TMV2, MH2	PGN2
	Combined	GAUG1, PGN2, TMV2	Com.Mut.M13, M13, MH2, MH2BC28	NIL
Canopy circumference at 60 days	*Virginia*	MK374, M13, NC Ac 2821	32-2-5, MK374, NC Ac 2821	MK374, NC Ac 2821
	Fastigiata	MH2, PGN1, PGN2, TMV2	GAUG1	NIL
	Combined	MH2, MK374, M13, NC Ac 2821	32-2-5, PGN1	NIL
Canopy diameter at 60 days	*Virginia*	MK374, ROBUT33-1, M13	32-2-5, Com.Mut.M13, MK374 & NC Ac 2821	MK374
	Fastigiata	MH2, PGN2	PGN1, PGN2, TMV2, GAUG1	PGN2
	Combined	MH2, MK374, ROBUT33-1, M13	32-2-5, MK374, NC Ac 2821, PGN1	MK374
Leaf area at 60 days	*Virginia*	NC Ac 2821, M13	Com.Mut.M13,MK374,R33-1,NC Ac2821	NC Ac 2821
	Fastigiata	MH2, PGN1	PGN1, PGN2, MH2BC28, GAUG1	PGN1
	Combined	MH2, PGN1, NC Ac 2821, M13	Com.Mut.M13, R33-1, PGN1, PGN2, MH2 & GAUG1	PGN1, MH2
Leaf dry weight at 60 days	*Virginia*	NC Ac2821, Com.Mut.M13, M13	Com.Mut.M13	Com.Mut.M13
	Fastigiata	MH2, PGN1, GAUG1	PGN1, MH2, GAUG1	MH2, PGN1, GAUG1
	Combined	MH2, NC Ac 2821, PGN1,GAUG1	Com.Mut.M13, PGN1, MH2	MH2, PGN1
Shoot dry weight at 60 days	*Virginia*	Com.Mut.M13, 32-2-5, R33-1	Com.Mut.M13, MK374, R33-1	Com.Mut.M13, R33-1
	Fastigiata	MH2, PGN2, GAUG1	PGN2, MH2, GAUG1	PGN2, MH2, GAUG1
	Combined	MH2, PGN2, GAUG1, Com.Mut.M13	Com.Mut.M13, PGN2, MH2	MH2, PGN2, Com.Mut.M13
Root dry weight at 60 days	*Virginia*	32-2-5, ICG(C)8, NC Ac 2821	Com.Mut.M13, R33-1, NC Ac 2821	NC Ac 2821
	Fastigiata	MH2BC28, PGN1, TMV2	PGN2, TMV2, MH2BC28, GAUG1	MH2BC28, TMV2
	Combined	MH2BC28, PGN1, NC Ac 2821	TMV2NLM, NC Ac 2821, PGN1,TMV2 & MH2BC28	MH2BC28, PGN1 & NC Ac 2821

Contd....

Table 44. Contd....

Character	Botanical Category	Low envionmental Standard deviation	Unit regression and deviation from regression	Common stable genotype
Nodule number at 0-5 cm	_Virginia_	R33-1, TMV2NLM	MK374, R33-1, NC Ac 2821	Robut 33-1
	Fastigiata	MH2BC28, MH2	PGN2, MH2, GAUG1	MH2
	Combined	R33-1, MH2BC28, MH2, TMV2NLM	MK374,R 33-1,NC Ac2821,MH2,GAUG1	Robut 33-1, MH2
Nodule number at 5-10 cm	_Virginia_	R 33-1, 32-2-5, MK374	32-2-5, TMV2NLM, MK374	32-2-5, MK374
	Fastigiata	PGN2, TMV2	PGN1, PGN2, TMV2, MH2, GAUG1	PGN2, TMV2
	Combined	PGN2, TMV2, R33-1	32-2-5, TMV2NLM, MK374,PGN1,PGN2, TMV2 & GAUG1	PGN2, TMV2
Nodule number at 10-15 cm	_Virginia_	TMV2NLM, ICG(C)8, MK374	Com.Mut.M13, TMV2NLM, MK374,R33-1, ICG(C)8 & NC Ac 2821	TMV2NLM, MK374
	Fastigiata	PGN2, TMV2	PGN1, PGN2, TMV2, MH2, MH2BC28	PGN2, TMV2
	Combined	PGN2, TMV2, TMV2NLM, MH2BC28	Com.Mut.M13,TMV2NLM,MK374,ICG(C)8, NC Ac 2821,PGN1,PGN2,TMV2,MH2 & MH2BC28	PGN2, TMV2, TMV2NLM & MH2BC28
Total nodule number	_Virginia_	R33-1,Com.Mut.M13	32-2-5,Com.Mut.M13,MK374,R33-1	R33-1,Com.Mut.M13
	Fastigiata	MH2,MH2BC28	PGN1,PGN2,MH2,MH2BC28,GAUG1	MH2,MH2BC28
	Combined	R33-1,MH2,MH2BC28,	32-2-5,Com.Mut.M13,MK374,M13, R33-1,PGN1,PGN2,MH2	R33-1,MH2
Nodule dry weight	_Virginia_	32-2-5, MK374, NC Ac 2821	32-2-5, TMV2NLM, MK374, M13 & NC Ac 2821	32-2-5, MK374 & NC Ac 2821
	Fastigiata	MH2, TMV2	PGN2, TMV2, MH2	MH2, TMV2
	Combined	MH2,TMV2,32-2-5,MK374,NC Ac 2821, PGN1,PGN2,MH2BC28	11 Varieties Edcept (M13,R33-1, ICG(C)8)	MH2,TMV2,32-2-5,MK374 NC Ac 2821,PGN1,PGN2 & MH2BC28
Plant height	_Virginia_	M13,ICG(C)8,MK374	TMV2NLM, NC Ac 2821	NIL
	Fastigiata	MH2, PGN1	PGN1, GAUG1	PGN1
	Combined	MH2, M13, ICG(C)8	ICG(C)8, NC Ac 2821, PGN1, GAUG1	ICG(C) 8
Number of Primaries	_Virginia_	R33-1, NC Ac 2821, ICG(C) 8	32-2-5, Com.Mut.M13, TMV2NLM	NIL
	Fastigiata	MH2, GAUG1	PGN1, TMV2, MH2BC28, GAUG1	GAUG1
	Combined	MH2, GAUG1, PGN1, TMV2	R33-1, NC Ac 2821	NIL

Contd...

Table 44. Contd...

Character	Botanical Category	Low envionmental Standard deviation	Unit regression and deviation from regression	Common stable genotype
Number of secondaries	Virginia	NC Ac 2821, R33-1, Com.Mut.M13	32-2-5, Com.Mut.M13, R33-1 & NC Ac 2821	NC Ac 2821, R33-1 & Com.Mut.M13,MH2,TMV2
	Fastigiata	MH2,TMV2	TMV2, MH2, MH2BC28, GAUG1	MH2, TMV2
	Combined	MH2,TMV2,NC Ac 2821,MH2BC28	Com.Mut.M13,R33-1,NC Ac 2821, PGN1,PGN2,TMV2,MH2,MH2BC28 & GAUG1	MH2, TMV2, NC Ac 2821 & MH2BC28
Number of mature pods	Virginia	M13, NC Ac 2821, 32-2-5	32-2-5,Com.Mut.M13,TMV2NLM,M13	M13, 32-2-5
	Fastigiata	MH2, GAUG1, TMV 2	PGN 1, PGN 2, MH 2	MH 2
	Combined	M 13, MH 2, NC Ac 2821, 32-2-5	TMV 2 NLM, M 13, PGN 1, MH 2	MH 2, M 13
Number of immature pods	Virginia	Robut 33-1, NC Ac 2821, M 13	Com.Mut. M13, MK374, M13, Robut 33-1, NC Ac 2821	Robut 33-1, NC Ac 2821 M 13
	Fastigiata	MH 2, PGN 2, PGN 1	PGN 1, PGN 2, TMV 2, MH2, GAUG1	MH 2, PGN 2, PGN 1
	Combined	MH 2, PGN 2, PGN 1, TMV 2	NC Ac 2821, PGN 1, MH2BC28	PGN 1
Mature pod weight	Virginia	32-2-5, NC Ac 2821, Robut 33-1	32-2-5, Com.Mut.M13, TMV2NLM,M13	32-2-5
	Fastigiata	MH 2, GAUG 1, TMV 2, PGN 2	PGN 2	PGN 2
	Combined	MH 2, GAUG 1, TMV 2, PGN 2	32-2-5, TMV2NLM, PGN 1, MH2BC28	Nil
Immature pod weight	Virginia	Robut 33-1, NC Ac 2821, TMV2NLM	32-2-5, MK 374, M 13	Nil
	Fastigiata	MH 2, TMV 2, PGN 2	PGN 2, TMV 2, MH 2, GAUG 1	MH 2, TMV 2, PGN 2
	Combined	MH 2, TMV 2, PGN 2, PGN 1	32-2-5, Robut 33-1, NC Ac 2821	Nil
Number of mature kernels	Virginia	M 13, NC Ac 2821	32-2-5,Com.Mut. M13,TMV2NLM,M13	M 13
	Fastigiata	MH 2, GAUG 1, TMV 2	PGN 1, TMV 2, GAUG 1	GAUG 1, TMV 2
	Combined	MH 2, GAUG 1, TMV 2, M 13	32-2-5, TMV 2NLM, M 13, Robut 33-1, PGN 1, TMV 2	TMV 2, M 13
Number of immature kernels	Virginia	TMV2NLM, Robut 33-1, M 13	Com. Mut. M 13, MK 374	Nil
	Fastgiata	MH 2, PGN 1, TMV 2	PGN 2, TMV 2	TMV 2
	Combined	MH 2, TMV2NLM, Robut 33-1, PGN 1 TMV 2, MH 2	Com. Mut. M 13, TMV2NLM, PGN 1,	MH 2, TMV2NLM, PGN 1

Contd...

Table 44. Contd...

Character	Botanical Category	Low envionmental Standard deviation	Unit regression and deviation from regression	Common stable genotype
Mature Kernel weight	*Virginia*	NC Ac 2821, Robut 33-1, 32-2-5, Com. Mut. M 13	32-2-5, TMV2NLM, M 13	32-2-5
	Fastigiata	MH 2, GAUG 1, TMV 2	TMV 2	TMV 2
	Combined	MH 2, GAUG 1, TMV 2, MH2BC28	32-2-5, TMV2NLM, Robut 33-1, PGN 1, TMV 2, MH2BC28	TMV 2, MH2BC28
Immature kernel weight	*Virginia*	TMV2NLM, Robut 33-1, 32-2-5, Com.Mut. M13	32-2-5, Com.Mut. M 13, TMV2NLM, ICG(C) 8	TMV2NLM, Com.Mut. M 13, 32-2-5
	Fastigiata	MH 2, PGN 1, TMV 2	PGN 1, PGN 2, TMV 2	PGN 1, TMV 2
	Combined	MH 2, TMV2NLM, Robut 33-1, PGN 1	Com.Mut. M 13, TMV2NLM, PGN 1, TMV 2, MH 2	MH 2, TMV2NLM, PGN 1
Number of aerial pegs	*Virginia*	Robut 33-1, NC Ac 2821, MH2BC28, PGN 1, TMV 2	32-2-5, TMV2NLM, MK 374, M 13, Robut 33-1, NC Ac 2821	Robut 33-1, NC Ac 2821
	Fastigiata	MH2BC28, PGN 1, TMV 2, MH 2	PGN 1, TMV 2, MH 2, MH2BC 28, GAUG 1	MH2BC28, PGN 1, TMV 2, MH 2
	Combined	MH2BC28, PGN 1, TMV 2, MH 2	32-2-5, MK 374, M 13, Robut 33-1, PGN 1, TMV 2, MH2BC28, GAUG 1	MH2BC28, PGN 1, TMV 2
Number of total pegs	*Virginia*	Robut 33-1, NC Ac 2821, M 13	32-2-5, Com.Mut. M13, TMV2NLM, MK 374, M 13, Robut 33-1	Robut 33-1, M 13
	Fastigiata	MH 2, TMV 2	PGN 1, TMV 2, MH 2, MH2BC28	MH 2, TMV 2
	Combined	MH 2, TMV 2, MH2BC28	M 13, Robut 33-1, PGN 1, PGN 2, TMV 2, MH2BC28	TMV 2, MH2BC28
Total dry matter at harvest	*Virginia*	ICG(C) 8, MK 374, NC Ac 2821, Robut 33-1	32-2-5, Com.Mut. M13, TMV2NLM, M 13	Nil
	Fastigiata	MH 2, TMV 2, PGN 1	TMV 2	TMV 2
	Combined	MH 2, TMV 2, PGN 1, MH2BC28	PGN 1	PGN 1
100 kernel weight	*Virginia*	Com.Mut. M13,MK 374,M13,NC Ac 2821	M 13	Nil
	Fastigiata	MH 2, MH2BC28, TMV 2	PGN 1, PGN 2, MH2BC28	MH2BC28
	Combined	Com.Mut. M13, MH 2, MH2BC28, TMV 2	Robut 33-1	Nil

Contd...

Table 44. Contd....

Character	Botanical Category	Low envionmental Standard deviation	Unit regression and deviation from regression	Common stable genotype
Shelling per cent	*Virginia*	Robut 33-1, ICG(C) 8, NC Ac 2821	TMV2NLM, M 13, Robut 33-1	Robut 33-1
	Fastigiata	TMV 2, MH2BC28, PGN 1	PGN 1, TMV 2, MH2BC28	TMV 2, MH2BC28, PGN 1
	COmbined	TMV 2, MH2BC28, PGN 1, Robut 33-1	M 13, Robut 33-1, NC Ac 2821, PGN 2, TMV 2, MH2BC28	TMV 2, MH2BC28, Robut 33-1
Oil per cent	*Virginia*	MK 374, TMV2NLM, Com.Mut. M 13	Com.Mut. M 13, TMV2NLM, ICG(C) 8	TMV2NLM, Com. Mut. M13
	Fastigiata	PGN 1, MH 2	PGN 1, TMV 2, MH2BC28	PGN 1
	Combined	PGN 1, MK 374, TMV2NLM	TMV2NLM, RObut 33-1, ICG(C) 8, NC Ac 2821, PGN 1, GAUG 1	PGN 1, TMV2NLM
Harvest index	*Virginia*	MK 374, ICG(C) 8, Com.Mut. M13	TMV2NLM,M13,Robut 33-1,ICG(C) 8	ICG(C) 8
	Fastigiata	GAUG 1, PGN 1, TMV 2	TMV 2, GAUG 1	TMV 2, GAUG 1
	Combined	GAUG 1, PGN 1, TMV 2, MH 2	Com.Mut. M13,TMV2NLM,M13, PGN 1	PGN 1
Recovery percentage	*Virginia*	M 13, ICG(C) 8, Robut 33-1, Com.Mut. M 13	32-2-5, Com.Mut. M13, TMV2NLM, M 13, ICG(C) 8, NC Ac 2821	M 13, ICG(C) 8 Com.Mut. M 13
	Fastigiata	GAUG 1, PGN 1, PGN 2	PGN 1, TMV 2, GAUG 1	GAUG 1, PGN 1
	Combined	M 13, ICG(C) 8, Robut 33-1, Com.Mut. M 13	Robut 33-1	Robut 33-1
Total dry matter at 60 days	*Virginia*	TMV2NLM, NC Ac 2821, Com.Mut. M13	Com.Mut. M13, TMV2NLM, MK 374	TMV2NLM, Com.Mut. M 13
	Fastigiata	MH 2, GAUG 1, PGN 2	PGN 2, MH 2, MH2BC28, GAUG 1	MH 2, GAUG 1, PGN 2
	Combined	MH 2, TMV2NLM, NC Ac 2821, GAUG 1	Com.Mut. M13, TMV2NLM, MK 374, PGN 2, MH 2, MH2BC28, GAUG 1	MH 2, TMV2NLM, GAUG 1

Singh et al., 1975; Rao, 1976 and Yadava and Kumar, 1978). The work carried out by Eberhart and Russell (1966) has been extensively employed in various crops to identify stable genotypes.

An analysis of the stability pattern of all the genotypes comprising virginia, spanish and valencia genotypes falling into the various canopy categories has revealed that the genotypes PGN1, TMV2NLM and MH2BC28 exhibited a greater degree of stability than the rest. Out of these three varieties, two strains viz., PGN1 and MH2BC28 pertaining to sequential branching types com under the canopy category two, while TMV2NLM a virginia genotype pertains to a canopy category 3. It could be seen that two genotypes, viz., TMV2NLM and MH2BC28 are induced mutants for canopy development of the parental varieties TMV2 pertaining to canopy category 2 (Prasad 1988) and MH2 pertaining to canopy category 1. It is interesting to note that the above two mutant types representing a shift towards enhanced canopy development from the sequential branching parental systems exhibited much higher degree of stability for yield than the parents themselves.

When the virginia varieties alone considered for stability of yield the strains viz., M13, Compact Mutant of M13 and 32-2-5 showed higher degree of stability.

Out of these three stable virginia genotypes two strains viz., Compact Mutant of M13 and 32-2-5 pertain to canopy category 3. Both the genotypes were induced mutants, for relatively compact canopy development from the respective parental varieties viz., M13 and MK 374. It could be observed that 32-2-5 has exhibited distinctly higher degree of stability as well as low environmental standard deviation than its parent MK 374. In respect of

Compact Mutant of M13, the environmental standard deviation was of much lower order than its more spreading parent M13, despite its stability for pod yield. Therefore the Compact Mutant of M13 could be considered more stable than its parent for yield.

Considering the sequential branching varieties separately, it could be observed that the genotype PGN 2 exhibited stability for pod yield. Among the wide range of sequential genotypes it could be seen that the variety MH2 pertaining to canopy category 1, did not figure for yield stability. The only stable genotype identified PGN 2 pertaining to canopy category 2, is an induced mutant for enhanced canopy development (HP 21) of the variety GAUG-1 (Prasad et al., 1984), which did not show any degree of yield stability.

From the foregoing it is evident that the most stable genotype from the yield point of view largely pertained to the canopy categories 2 and 3.

A critical analysis of the above results clarifies that the genetic manipulation of canopy towards its enhanced development in respect of sequential branching types falling in the canopy categories of 1 and 2 on one hand, and towards canopy compaction in the case of alternate branching virginia types on the other (pertaining to canopy categories 4 and 3) could bring in stability for pod yield. The observations of Swarnlata, et al., (1984) regarding stability of induced mutants of virginia and spanish groundnut varieties are in confirmity with the findings of present investigation. The mechanism behind this phenomenon could be that the enhancement of canopy development of sequential branching systems might bring in appropriate genetic balance between canopy and yield components ensuring the stability of the canopy sustenance at the time of pod development. In respect of *virginia* genotypes characterised by unproductive canopy growth at post-flowering stage and pod formation, a canopy compaction through genetic manipulation might cut down this excessive wastage of energy thereby ensuring adequate supply of assimilates to developing pods. These interpretations are in confirmity with the observations of Ashley (1984), Duncan *et al*. (1978) and Prasad (1988).

These observations also confirm the interpretations of the results pertaining to the characterisation and categorisation of canopy of the genotypes from 1 to 4, arrived at in the present study.

The model for stability provided by Eberhart and Russell (1966) has been widely employed to work out the stability of the various crop genotypes for yield only. However, such an analysis in respect of a number of important characters having a definite bearing on the productivity in groundnut is not common. The identification of various genotypes that are stable for certain important characters is of paramount importance, as it helps in identifying parents for appropriate characters for use in hybridization programmes.

Such a study carried out by Seth *et al*. (1987), in respect of cotton has helped in identifying parents and hybrids stable for hallow length, ginning out-turn, seed and lint indices. Studies carried out by Yadava and Kumar (1978) on similar lines was useful in identifying genotypes of groundnut stable for 100-kernel weight, oil content and shelling percentage.

In the present investigation, an attempt was made to identify stable genotypes of groundnut for 33 characters based on environmental standard deviation, unit regression and deviation from regression as presented in

Table 44.

It could also be observed from the Table 44 that the stable genotypes showing low environmental standard deviation, unit regression (b = 1) and deviation from regression ($S^2d = 0$) for each of botanical types as well as overall the varieties put together, have been identified. This information will be of utmost use in the choice of the parents exhibiting stability for desired characters. It may be stated this is first and foremost attempt of this kind in groundnut.

5.4 CORRELATIONS AND PATH COEFFICIENT ANALYSIS

A task of selecting high yielding genotypes of groundnut is not a straight forward mechanism adopted in the case of aerial bearing crops such as wide range of cereals and pulses (Rao, 1976). In view of the peculiar subterranean pod bearing habit, the selection based on pod number and pod weight exhibiting a wide degree of interaction with the environment may not be fruitful (Wynne and Gregory, 1981, Kumar et al., 1984 and Norden et al., 1986). While correlations have been developed between yield on one hand, and seed and pod characters on the other (Coffelt and Hammons, 1974; Yadava, et al., 1984; and Kataria, et al., 1984), our understanding of the inter-relationship between the yield on one hand and wide range of canopy characters on the other is fragmentary. The results of the present study also indicated that the pod yield in groundnut may not be a stable character and as such there was a need to look for a combination of more stable characters positively correlated with the kernel yield to put the groundnut breeding on a sound footing.

Correlation studies among wide range of characters carried out in the parents, F_1 and F_2 generations had revealed that among the canopy attributes, canopy circumference, canopy diameter, leaf area and total dry matter production at 60 days were significantly and positively correlated with kernel yield in both alternate and sequential branching forms. According to the investigations carried out by Reddy *et al*. (1984) in crosses involving *Valencia* x *Spanish* and *Valencia* x *Virginia* plant spread accounted for more variation in the yield, there-by indicating the relationship between a character such as canopy diameter and yield. It may be stated that this study together with the investigations of Madhavi (1988) is a first attempt, to relate the above mentioned perceptible canopy attributes with the kernel yield. The above relationship has been found to hold good both at phenotypic and genotypic level. These findings are in confirmity with the observations of Madhavi (1988), who reported a strong positive relationship between the above attributes and kernel yield. Considering the other canopy attributes such as number of primaries and secondary branches, it has been observed that the primary branch number in the case of sequential branching type exhibited a strong positive correlation with kernel yield at both phenotypic and genotypic levels. In the case of alternate branching *Virginia* types, the number of primary and secondary branches showed a positive but non-significant correlation with kernel yield. As the data in respect of branch number was recorded at the time of harvest, when a number of unproductive branches could have been produced in *Virginia* genotypes thereby leading to the above results as observed by Ashley (1984). The canopy development in the initial stages upto 60 days is of immense significance in realising higher yield levels in both the types of groundnut. In fact one of the major limitations encountered in realisation of higher yield levels was the inadequacy of leaf area index in the initial stages of groundnut plant as suggested by

Ashley (1984) and Madhavi (1988). While the Spanish and Valencia genotypes do not produce extra branches at the time of pod development, the Virginia genotypes in general show an excessive and unproductive vegetative branches in the post-flowering stage thereby draining out the assimilates so crucially needed by the developing pods. This could be the reason for the above observation. Therefore, it is expected that the branch number at 60 days of crop growth might exhibit a significant positive correlation with kernel yield in the case of Virginia varieties as observed in sequential branching forms also. This is supported by Dholaria and Joshi (1972); Dholaria et al. (1973); Chandola et al., (1973); Sangha (1973); Lakshmaiah (1978); Rao (1976); Nagabhushanam et al. (1981); Yadava et al., (1981); Ibrahim (1983); Wu (1983); Alam et al., (1985) and Deshmukh et al. (1987).

Considering the seedling characters, it could be noted that seedling dry weight was observed to be strongly positively correlated with sequential branching forms but this attribute however exhibited a positive but non-significant correlation in Virginia genotypes.

The study of the root nodulation and its relation with kernel yield indicated that total nodule number and nodule dry weight per plant exhibited a strong positive significant phenotypic correlation with kernel yield in all the varieties, thereby bringing out the role of nodulation in the recovery of kernel yield. However, when the nodulation at different zones of root system was related to kernel yield, it was observed that nodule number at two different zones viz., 0-5 cm and 5-10 cm exhibited significant positive correlation in Virginia genotypes and positive but nonsignificant correlation with kernel yield in sequential branching varieties, probably because of relatively a less number of genotypes studied in that group. Studies of Wynne et al., (1980) have also demonstrated the positive role of root nodules in groundnut physiology, in view of strong positive relationship between nodule number and nodule mass with nitrogenase activity on one hand, total nitrogen content of the plant on the other. High heritability values have also been reported for nodule number and nodule mass (Wynne et al., 1980) thereby indicating that this trait could be selected for with advantage. The studies carried out by Arunachalam et al., (1980) have also brought out the strong positive association between kernel yield and nodule mass. On the whole, the total nodule number and nodule mass appeared to have a definite significant positive association with kernel yield in both sequential and alternate branching forms irrespective of the relationship between kernel yield and nodule number at different zones.

From the results of the present study as well as investigations of Arunachalam et al., (1980), it appears that the total nodule number and nodule mass per plant at 60 days could be taken as a reliable indication of the yield potential of the genotype. The present experiments have also indicated that the above parameters showing positive association with yield, such as canopy circumference and diameter, leaf area, total dry matter, nodule number and nodule mass at 60 days, number of primaries number of secondaries and seedling dry weight showing positive association with kernel yield, were strongly positively correlated among themselves thereby warranting to work out selection criteria involving these attributes. Considering the practical difficulties in estimating the leaf area, total dry matter, nodule number and nodule dry weight at 60 days in a large segregating populations of breeding material, due weightage may be given to study of canopy diameter at 60 days, which is also a measure of all the above canopy attributes together with number of primary branches in

Spanish and Valencia types and number of secondaries in Virginia forms.

The studies carried out by Anuradha (1987) based on the variance in different M_1 generations of Valencia groundnuts and Madhavi (1988) have also brought out that the canopy spread, dry matter and pod yield per plant showed a strong positive inter-relationship and as such, canopy spread could be employed as one of the criteria of selection in addition to pod yield per plant.

A study of the various reproductive attributes indicated that the number of mature pods, mature pod weight and number of mature kernels per plant and 100 kernel weight have exhibited a strong positive correlation not only with kernel yield but also with the above mentioned canopy attributes as well as nodule number and nodule dry weight. The observations of existence of strong positive correlation between the above mentioned reproductive attributes and kernel yield draws strong support from wide range of investigations (Dorairaj, 1962; Jaswal and Gupta, 1966, 1967; Mahapatra, 1966; Sangha and Sandhu, 1970; Coffelt and Hammons, 1973; Khangura and Sandhu, 1972; Nagabhushanam, 1981; Kataria et al., 1984, Deshmukh et al., 1986 and 1987). The observation of strong positive assoiciation between canopy attributes on one hand and reproductive attributes on the other is largely confined to the present investigation, since the earlier workers did not consider the canopy diameter, the leaf area and total dry matter at 60 days, while carrying out correlation studies. However, the positive correlation between the primaries and secondary branches on one hand and kernel yield on the other, was reported by Khangura and Sandhu (1972), Dholaria et al. (1973); Chandola et al. (1973); Sangha, (1973); Lakshmaiah et al. (1978); Nagabhushanam (1981), Yadava et al. (1981); Ibrahim (1983), Wu (1983), Yadava et al. (1984); Nigam et al. (1984); Alam et al. (1985) and Deshmukh et al. (1987).

The attribute of harvest index was observed to have a negative correlation not only with kernel yield per plant but also with the above mentioned canopy attributes as reported by Hiremath et al. (1984) and Madhavi (1988). Therefore, breeding programme to combine harvest index with kernel yield has to be chalked out carefully based on indirect selection involving certain attributes conducive for higher harvest index as well as higher yields such as induction of some degree of early maturity which does not necessarily exhibit negative correlation with yield as well as harvest index (Ashley, 1984 and Yadava et al., 1984).

Path coefficient analysis suggested by Dewey and Lu (1959) has been a valuable tool in working out the direct and indirect influences of wide range of associated characters on dependent variable i.e. yield per plant. However, wide range of investigations such as those of Khangura and Sandhu (1972), Sandhu and Khehra (1977), Badwal and Harban Singh (1973), Yadava et al. (1984). Lakshmaiah et al. (1983) and Deshmukh et al., (1987) did not come up with any novel information other than the established conventional trends such as direct influence of number of mature pods on pod yield. These investigations suffered from limitations due to exclusion of the canopy attributes. The present investigation which is first of its kind to include the canopy attributes viz., canopy diameter, leaf area and total dry matter together with nodule number and nodule mass at 60 days, mature pod number, mature pod weight, mature kernel number and 100 kernel weight in the path coefficient analysis involving the parents, F_1 and F_2 generations revealed the new trends which could be employed with profit in groundnut breeding. Unlike the previous investigations in groundnut, the study has brought out that the canopy characters such as canopy diameter and number of secondaries have exhibited positive direct effect on kernel yield together with mature pod weight, mature kernel number and 100 kernel weight. It has also been shown that canopy diameter exerts an indirect effect through mature pod weight, number of mature kernels, 100-kernel weight, total nodule number and number of secondaries on kernel yield. Although several earlier investigations as well as present investigation had shown that mature pod weight could be relied upon in view of its direct effect on kernel yield, the high degree of interactions of these attributes with environmental factors render them unstable to be used as sole criteria of selection. Therefore as clarified in the present study, it would be advisable to enlarge the selection criteria including most stable attributes such as canopy diameter at 60 days and number of branches at 60 days which have exhibited a greater degree of stability, in addition to their strong positive correlation with pod number and pod yield.

The above suggestion draws its strength not only from path coefficient analysis but also from the correlation studies as well as the stability analysis.

5.5 HETEROSIS:

Heterosis in F_1 generation expressed in terms of superiority over the better parent is of direct influence not only for developing hybrids in cross pollinated crops, but is also important in self-pollinated crops, as such heterotic crosses may help the breeder to select appropriate parents which may lead to the isolation of desirable transgressive segregants in advanced generations (Arunachalam *et al*., 1984). It has also been reported that levels of heterosis in crosses involving different groundnut varieties was not very high (Arunachalam et al., 1982 and Raju 1982). According to the available evidence, heterosis in groundnut like heterosis in other crop species such as wheat (Fonesca and Patterson, 1968; Sun et al., 1972; Widner and Lebsock, 1973), alfalfa (Sriwatanapongise and Wilsie, 1968); cotton (Marani, 1963, 1968), corn (Moll et al., 1962), and tobacco (Matzinger and Wernsman, 1968) is related to genetic diversity. According to Wynne and Gregory (1981), heterosis in peanuts is most often observed in crosses between sub-specific groups, viz., Virginia x Spanish and Virginia x Valencia. However, Arunachalam et al. (1984); and Madhavi (1988) reported occurrence of heterosis in F_1 generation involving Spanish x Valencia combination. It may be observed that in most of the investigations carried out so far on heterosis in groundnut, there was no systematic attempt to select the parental types based on canopy development. Such a basis for selection of the parents would be important, since the canopy development could account for the variations in yield components as has been suggested by Reddy et al., (1984), Ashley (1984) and Duncan et al, (1978). The results of the present investigation on the genotypic and phenotypic correlations as well as path coefficient analysis clearly pointed out the direct influence of canopy diameter, leaf area and total dry matter at 60 days not only on kernel yield and yield components, but also on nodule number and nodule dry weight which in turn was also found to influence the kernel yield.

An analysis of heterosis, in F_1 generation of the matings involving different combinations of parents characterised for canopy development has revealed that negative heterosis for canopy diameter at 60 days was observed in the crosses involving canopy combinations 2 x 4, 1 x 4, and 3 x 4, while significantly high level of positive heterosis for these characters in the case of canopy combinations 2x3, 3x2 and one cross viz., M 13 x NC Ac 2821 involving 4x4 combination. Rest of the canopy cross combinations have not shown any perceptible levels of heterosis for canopy diameter at 60 days. Very few investigations have been carried out in estimating heterosis for canopy diameter in hybrids, involving different canopy combinations. Syakudo and Kawabata (1963) found appreciable heterosis for shoot weight for Virginia x Spanish and Valencia x Virginia F_1 hybrids. They observed the absence of heterosis in the crosses between cultivars within each botanical varieties but not in Spanish x Valencia crosses. Wynne et al., (1970) reported that the F_1 hybrids from Virginia x Valencia parents gave greater heterosis than other crosses for vegetative plant characters. In the present investigation a similar trend could be observed as the hybrids obtained from 2x3 and 3x2 combinations pertained to the crosses of Virginia x Spanish and Virginia x Valencia types. Madhavi (1988) also observed heterosis for canopy spread and leaf area index in the crosses involving Virginia x Spanish and Virginia x Valencia. It was also observed by Madhavi (1988) that the highest leaf area indices were indicated by the F_1 hybrids of the crosses pertaining to Virginia x Valencia combinations. Considering the heterosis for nodule mass at harvest, it could be seen that F_1's of only one cross viz., GAUG-1 x ICG(C)8 involving a canopy combination 2x3 showed significantly high positive heterosis while the canopy combinations 2x4, 3x1, 3x3, 3x4 and 1x4 have shown a significantly negative heterosis. Even the other cross combinations in 2x3 canopy category exhibited negative heterosis. It may be stated that data pertaining to nodule mass was collected only at harvest by when, a large proportion of nodules would have got degenerated. The nodule mass at 60 days which is the most appropriate stage for the character could not be taken in F_1 generation since all the F_1 plants had to be carried till harvest without destruction, to ensure adequate population size in the F_1 and subsequent F_2 generation. Therefore the picture on nodule mass emerging at harvest might not represent true nodulation potential of the hybrids, but might at best give an indication of the heterotic levels in hybrids. Based on this, it again appears that it is only in the case of F_1's involving 2x3 combinations clearly high levels of heterosis were observed for this trait.

The work pertaining to this line i.e. heterosis for root nodulation in F_1's of different canopy combinations is practically non-existent and as such this may be considered as a study first of its kind.

Considering the heterosis for kernel yield it was clear that almost all the crosses involving the canopy combinations one and two and all except one cross i.e. TMV2 x GAUG-1 in the canopy combination of 2x2 have exhibited significant negative heterosis. A sizable proportion of the crosses in the canopy combinations of 2x3 and 3x2 together with the cross TMV 2 x GAUG-1 of 2x2 category has shown high degree of significant positive heterosis. It may be mentioned that while majority of the crosses of 2x3 and 3x2 combinations showed positive heterosis for kernel yield, only four crosses of this category has shown negative heterosis. All the other canopy combinations have not exhibited perceptible levels of heterosis. The indications obtained in present study confirming the low percentage of heterotic crosses for kernel yield in groundnut is in confirmity with the observations of Arunachalam et al., (1983 and 1984) and Wynne and Gregory (1981). The identification of heterotic hybrids for kernel yield based on the canopy characteristics of the parents involved, of course is the first attempt in this direction. According to Wynne et al., (1970), a greater degree of heterosis for yield and fruit characters were observed in the hybrids involving Virginia x Spanish combinations. The results in the present study however did not indicate any rigid trend suggested by Wynne et al., (1970), but largely the combinations involving Virginia x Spanish, Virginia x Valencia pertaining to 2x3 and 3x2 canopy combinations and only one cross pertaining to Spanish x Spanish (2x2 canopy category) resulted in spectacularly higher levels of heterosis. Results obtained by Madhavi (1988) also confirmed the observations that the combinations of 2x3 and 3x2 are more heterotic not only for kernel yield but also for canopy spread, since the parental combinations reported by her fall into these categories as per the present investigation.

A critical analysis of results obtained indicates that the proportion of F_1 hybrids showing heterosis are high in respect of the character days to flower, while heterosis for other characters such as nodule number and nodule mass, canopy diameter and pod and kernel yield are very few. While almost all the crosses exhibited heterosis for days to flower, the few heterotic crosses for canopy diameter, nodule number and mass and kernel yield which are correlated with each other based on the present study, lie in the parental canopy combinations of 2x3 and 3x2 alone. Reports of simultaneous heterosis for canopy spread as well as nodule mass and kernel yield are very rare. However, the investigations carried out by Madhavi (1988) hinted that those crosses of the parents which fall into the canopy combinations of 2x3 and 3x2 as per the present study, were characterised by a simultaneous higher levels of heterosis for canopy spread/leaf area index and pod and kernel yield. According to Wynne and Gregory (1981), there was convincing evidence that heterosis in groundnut is related to genetic divergence. Therefore when an initial choice of parents has to be made, it should be ensured that such a parental combination should lead to significant levels of heterosis for the characters such as canopy spread and nodule number and mass which are positively correlated with yield as well as kernel yield, so as to obtain desirable segregants in the subsequent generations. Arunachalam et al., (1977) had shown that very high or very low parental divergence failed to result in heterosis in triticale. According to Arunachalam et al., (1977) there is an optimum level of genetic divergence between parents to obtain heterosis in F_1 generation as well as wider degree of variance in the subsequent segregating generations. The optimum level was provided by the divergence classes two and three which incidentally is in agreement with the results of the present study. The present investigation amply indicates the canopy categorisation of the parents could be a measure of arriving at these optimum level of genetic divergence for yield components also, since it has been convincingly shown that canopy diameter was directly and positively correlated with the yield as well as other parameters related to yield. As a consequence of categorisation, it could be appreciated that canopy combinations such as 1x4 and 1x3 form a combinations of extreme degrees of divergence not conducive for heterosis. On the other hand, the combinations of 2x2 and 3x3 did not appear to consist of adequate levels of divergence leading to F_1 heterosis, while the canopy combination 2x3 appeared to ensure a combination of optimum level of genetic divergence between the parents leading to heterosis in F_1. As suggested by Arunachalam et al., (1984) the occurrence of differential frequency of heterotic crosses could be related to parental divergence and/or specific combining ability of the crosses. Thus in the present study the very few heterotic crosses for the above set of characters falling in the canopy categorisation 2x3 could be considered to have high specific combining ability to explain heterosis. The sporadic occurrence of heterosis in other crosses such as 2x2 (TMV 2 x GAUG-1) might possess either high specific combining ability or heterosis for one character only. When the magnitude of heterosis was substantial for that character the parents may have in general other contrasting attributes like high vs low general combining ability status or adoptation to divergent environments (Arunachalam et al., 1984).

5.6 COMBINING ABILITY STUDIES

The analysis of combining ability is useful for selecting them for use in hybridization in relation to gene action of the characters involved (Griffings, 1956). Gregory et al., (1980) reported significant general combining ability effects which were several times greater in magnitude than specific combining ability for yield and several components. Parker et al., (1970) estimating combining ability for 17 characters found that in a controlled environment of phytotron, estimates of general combining ability were found to be higher than specific combining ability. Wynne et al., (1970), however, reported that the estimates of specific combining ability were higher than those for general combining ability for yield and several yield components. Layrisse et al., (1980) using 10 peanut varieties two from each of the five centres of diversity in South America and F_2 generations of all possible crosses among them to estimate combining ability for yield, found that both general combining ability and specific combining ability were significant for all traits except for specific combining ability for protein percentage. It could be observed that several investigations in this line of study were indicative of divergent trends of results and as such it appears that the combining ability and gene action varied with the types of experimental material studied.

In the present investigation the parents have been identified for positive and negative general combining ability effects for a wide range characters including canopy diameter, nodule number and mass and kernel yield which were found to be the most important criteria for selection.

The results followed an interesting trend indicating that most of the varieties pertaining to canopy category 3 exhibited preponderance of positive general combining ability effects for above three characters as well as the related attributes. However, the TMV2NLM (which is a narrow leaf mutant of spanish bunch variety TMV 2) while exhibiting high positive general combining ability effects for canopy attributes revealed negative general combining ability effects for yield components. It could also be seen that the varieties pertaining to canopy category 4 showed positive general combining ability effects for all the above characters.

It is also interesting to note that the genotypes pertaining to canopy category 2 representing predominantly Spanish and Valencia varieties except MH2BC28, indicated negative general combining ability effects for canopy attributes and positive general combining ability effects for yield and yield components.

The variety MH 2 representing canopy category 1 as well as its dense canopy mutant MH2BC28 showed negative general combining ability for all the above characters.

The above trend amply indicates the role of genotype on the combining ability and gene action. The above typical trend observed could form a basis for explaining higher levels of heterosis and subsequent higher degrees of variances in segregating generations in the canopy cross combinations involving 2x3 and 3x2. It could also be seen that the preponderance of specific combining ability effects in certain 3x3 combinations involving Virginia compact canopy types leading to heterosis and higher degree of variances in the segregating generations. The mutant, TMV2NLM therefore, exhibited a different type of general combining ability pattern than the rest of the other types of canopy category 3 when used as a parent in such crosses.

The analysis of combining ability effects in F_1 and F_2 has revealed the preponderance of specific combining ability effects for several characters indicating the role of non-additive gene action, which are in confirmity with the observations of Wynne et al., (1970) and Arunachalam et al., (1984).

5.7 HERITABILITY

Heritability of the character is an important consideration for planning of an appropriate breeding strategy for the improvement of a character. Bernard (1960) suggested seed size had a higher estimates of heritability than did seed yield. Syakudo and Kawabata (1965) reported crosses of Virginia, Valencia and Spanish types, estimates of broad sense heritability were low for all traits of economic importance. According to Coffelt and Hammons (1974) broad sense estimates of heritability for 100-seed weight, pod length-to-breadth ratio were high (71-90%). They also reported low heritability estimates for number of pods, pod weight, number of seeds, seed weight and seeds per pod. Several workers including Gibori et al., (1978), Wynne and Rawlings (1978) and Sandhu and Khehra (1977) observed high heritability estimates for several yield components. However, the heritability estimates for canopy diameter, nodule number and mass were studied by these workers. In the present study heritability estimates were arrived at for several attributes including canopy diameter, number of primaries and secondaries, nodule number and mass and kernel yield in F_1 and F_2 generations. While heritability for canopy diameter was 25% in F_1 and it was only 14% in F_2. The heritability for primaries and secondaries decreased from 32 and 33% in F_1 to 16% and 28% in F_2 respectively. In the case of yield components on the other hand, the heritability estimates got enhanced in F_2. The nodule number and mass also showed similar pattern in heritability both in F_1 and F_2. By and large all the above characters registered moderate levels of heritability ranging from 14% to 33% in F_1 and F_2 generations. The results of the present study with regard to heritability of yield components are at variance with those of earlier investigations which reported very high degrees of heritability, but are in confirmity with the observations of Norden et al., (1982) who observed low heritability for several traits. It may be observed that the present trends of heritability of the above characters are in consonance with the results obtained on the combining ability estimates indicating preponderance of specific combining ability effects in F_1 and F_2 generations, thereby warranting, adoption of comprehensive and non-traditional breeding strategies and procedures designed to exploit such genetic effects.

5.8 F_2 Means and variances in relation to mating system based on canopy characterisation.

Groundnut breeding received little attention not only in India but also in more advanced countries like USA before early work by Hull, Carver and Higgins in Florida and Georgia in 1930s and by Gregory in North Carolina 1940's, Wynne and Gregory (1981). Till recently groundnut breeding in India was revolving around the simple selections from out of the populations of locally adopted varieties as well as some exotic introductions (Rao, 1976). The extent of genetic diversity in the parental material was too limited to lead to any meaningful and usable variances in the segregating populations. Unlike, in other crops like wheat, sorghum and rice it has been a general observation that F_2 generations derived from various crosses in groundnut were characterised by small population sizes with low frequencies of desirable segregants, as a result of reduction in mean and variances for the important agronomic attributes. (Dutta et al., 1986). Therefore, Dutta et al., (1986) suggested irradiation of F_1 generation and subsequent intermating to enlarge the variances for important agronomic characters in segregating generations. However, the investigations to maximize the variance in segregating generations of groundnut crosses have not been many. Despite the occurrence of perceptible variability in germplasm for canopy characters influencing wide range of other attributes, (Prasad, 1988 and Madhavi, 1988), very little effort had gone in to the studies regarding pattern of segregations and variances for important agronomic characters in the mating systems involving different canopy types. The crosses involving different botanical types however, were studied for degree of F_1 heterosis (Parker et al., 1970, Wynne et al., 1970), without adding any information in respect of the variances in segregating generations.

The present study revealed that the groundnut breeder can rely upon the canopy attributes such as canopy diameter, total dry matter and branch number at 60 days together with the total root nodule number and mass as selection criteria in view of their stability of expression and strong positive correlations with kernel yield as well as among themselves. An attempt, therefore, has been made to study means and variances for these canopy attributes, total nodule number and nodule mass and kernel yield, in the F_2 generations of the crosses involving parents with different and similar canopy types as per the characterisation and categorisation arrived at in the present study.

A critical analysis of pattern of means and variances in the F_2 generation of wide range of crosses involving the canopy types one, two, three and four has revealed the following.

1. The variances and means for the above characters viz., canopy circumference and diameter, nodule number and mass and total dry matter which have bearing on kernel yield were the least in the F_2's of the crosses involving canopy types 1x4 and 3x4.
2. The parental canopy combinations such as 2x4 and 2x1 have exhibited in the F_2 generations high variance with high mean, high variance with medium mean, high variance with low mean and medium variance with high mean for the above characters only in the 14.29% and 7.14% of their F_2 progenies respectively.
3. It was found that a large proportion of the crosses involving the parental canopy combinations of 3x3 (21.43%) and parental canopy combinations 3x2 and 2x3 (50%) exhibited high variance with high mean, high variance with medium mean, high variance with low mean and medium variance with high mean for the above important characters (Table 45), thereby indicating such parental cross combinations should be preferred in groundnut breeding.

TABLE: 45. Proportion of F_2 crosses showing simultaneous variances and meanssuch as high variance and high mean, high variance and medium mean,high variance and low mean and medium variance and high mean

PARENT CANOPY COMBINATIONS	NUMBER OF F_2 CROSSES	INTERMS OF PERCENTAGE
3X3	3	21.43
3X2 2X3	7	50.00
2X4 4X2	2	14.29
2X1 1X2	NIL	NIL
3X4 4X3	1	7.14
1X4 4X1	1	7.14
2X2	NIL	NIL

It is very clear from the present investigation that out of 91 F_2's, 14 crosses, out of which 10 pertaining largely to the canopy combinations 3x3, 3x2 and 2x3 exhibited simultaneous enhanced variance for canopy as well as reproductive attributes in the F2 generations based on high variance with high mean, high variance with medium mean, high variance with low mean and medium variance with high mean.

It could also been observed from the Table 36 that the crosses involving the induced compact canopy mutants of canopy type 4 leading to canopy category 3 (for example Compact Mutant of M13) as well as compact mutant of canopy category 3 (for example: mutant number 32-2-5 of MK374) have resulted in greater degree of variance in their F_2 generations when employed as parents as compared to the F_2's derived from the crosses involving their respective parents. This indicates that a larger degree of variance for the important agronomic characters can be generated by using a compact canopy mutants of canopy types 2 and 3 (i.e., alternate branching Virginia varieties) in cross combinations of canopy types such as 2x3, 3x2 and 3x3. Such advantages of employing new gene mutants in hybridization programmes have also been reported by Prasad (1972) in durum wheat.

An examination of the mating systems of 3x3 canopy type indicated that larger degrees of variance were exhibited in F_2's only when the TMV2NLM (a Virginia type narrow leaf mutant developed from a spanish bunch variety TMV 2) was involved as one of the parents. This could be verified through the observation of low degrees of variance for the above characters in the F_2's of the other 3x3 canopy combinations such as ICG(C) 8 x MK 374, Compact Mutant of M 13 x MK 374 and Compact Mutant of M 13 x ICG(C) 8 etc. The observation of high degree of variance in 3x3 combinations involving

TMV2NLM as one parent was due to the fact that the genotype exhibited high degree of negative general combining ability effects for yield components, and positive general combining ability effects for vegetative characters, unlike the other varieties pertaining to canopy category three which showed uniformly high general combining ability effects for canopy as well as reproductive characters studied.

Studies of this type, despite their importance in groundnut breeding, are not many. However, investigations carried out by Arunachalam et al., (1984) have shown that the frequency of heterotic crosses and the magnitude of heterosis for yield and its components were higher in crosses between the parents in intermediate divergent crosses than extreme ones. This observation appears to hold good in respect of the present study also, since the cross combinations involving the parents of intermediate canopy categories such as 2x3 and 3x2 probably representing combinations of appropriate parental genetic divergence, have shown not only higher degree of heterosis for the above characters in F_1 generation but also a wider degree of variance with relatively medium to high mean for the above characters in the F_2 generation as compared to the parental cross combinations involving extreme canopy types. The crosses involving TMV2NLM resulted in much larger degree of variance in the F_2 generations, as compared to those involving its parent TMV 2, thereby indicating that the enhanced canopy mutants of spanish bunch varieties such as TMV 2, together with compact canopy mutants of Virginia varieties could be employed as better parental types to generate larger degree of variance.

The crosses involving canopy types 2 and 3 represent the matings of Spanish and Valençia on one hand and Virginia bunch types on the other. The observation of larger degree of variances in F_2's of these combinations draws support from the studies carried out by Wynne *et al*., (1979) and Raju (1982) who observed that *Virginia* x *Valencia* and *Virginia* x *Spanish* cross combinations would be more useful in generating desirable segregants, although they did not make a specific mention of the canopy types. The occurrence of higher degrees of variance in this combination involving two and three could be due to the fact that these parental types exhibited different patterns of general combining ability effects as discussed earlier.

The present investigation leads to a specific observation that within *Virginia* varieties representing canopy type three would form more desirable parental types than the varieties of canopy type 4 in combination with plant types pertaining to canopy category 2, to generate larger degrees of variance with high mean in the F_2 generations thereby providing the groundnut breeder with wider choice for selection.

In this study the only limitation is the lack of more number of crosses in 4x4 category as well as non-availability of any crosses in 1x1 canopy category to arrive at results based on a more comprehensive investigation. However, based on a large number of parental material involved and relatively wider degrees of crosses involving all botanical types of groundnut, the indications provided for study by and large are adequate enough to draw above conclusions.

5.9 F_2 SEGREGANTS OF AGRONOMIC IMPORTANCE

Several interesting segregants combining useful attributes including high yield potential have been isolated in the F_2 generation (Table 37), most of which were from the canopy cross combinations of either 2x3 or 3x2 types. Of these only three F_2 segregants were isolated from the cross combinations of 3x3 involving induced mutants for canopy characters. The other combinations such as 2x2, 1x3, 2x1 and 2x4 resulted in very few agronomically useful segregants. This observation once again confirms the finding that 2x3 and 3x2 canopy cross combination as well as certin 3x3 cross combination involving induced mutants for canopy could result in promising breeding material leading to wider degree of variances.

It may also be observed that another canopy cross combination of 2x3 type involving an induced mutant viz., MH2BC28 x ICG(C) 8 (a derivative of interspecific hybridization) threw up an interesting segregant APS exhibiting aerial podding attribute. This segregant produced 18 aerial pods and 30 subterranean pods Prasad (1985) reported aerial podding genotypes representing spontaneous mutations for aerial podding attribute from a valencia variety 'Tatu'. In view of its higher reproductive efficiency as compared to the normal varieties, the aerial podding types, such as the mutants reported by Prasad (1985) as well as the segregant APS reported in the present study provide greater and in depth in sight into the possible structural modifications of groundnut plant leading to enhancement in the fruiting sites. The segregant APS is also characterised by a very high dry matter production. The aerial podding attribute reported by Prasad (1985 and 1988) appears to be of dominant nature. However, it is interesting to note that the aerial podding segregant was isolated from a cross involving the two subterranean bearing parents which did not possess this attribute. Therefore it is possible that this segregant might have arisen as a result of complementary action of diverse genes coming from the two parents involving which are probably genetically divergent. This may be considered as a first report of occurrence of aerial podding segregant. It should be worthwhile intensifying investigations in this direction.

5.10 MUTATIONAL ANALYSIS

The complex genetic architecture and developmental rhythm of groundnut plant has been posing challenge to the plant breeders and geneticists who have been aiming at achieving an appropriate genetic restructuring of this 'unpredictable legume' conducive for efficient agronomic management (Gregory et al., 1973, Rao, 1976; Hammons, 1976; Prasad and Kaul, 1980; and Arunachalam et al 1980). Despite extensive breeding work involving wide range of hybridizations, so far we have not been able to generate distinctly superior genetic material in terms of agronomic attributes (Rao, 1976; and Duncan et al., 1978). Wynne and Gregory (1981) however, suggested that major advance in groundnut productivity could be achieved through structural alterations in peanut plant conducive for enhancement of fruiting sites. Such an effort calls for induction of new genetic variability through a comprehensive programme of mutation breeding. In this connection it would be necessary to understand the response of groundnut varieties categorised and characterised by different canopy types to important mutagenic agents in different generations.

Such a study is expected to help in estimating the pattern of mutagen induced variances in relation to canopy category for the important attributes such as canopy diameter, branching and pod and kernel yield, which form components of selection criteria as per the results of the study.

Despite vast literature on mutation breeding in several crop plants, our knowledge of different types and frequencies of mutants that could be induced and mutagenic effectiveness and efficiency in relation to canopy characterisation in groundnut remains fragmentary. Studies carried out by Prasad *et al.*, (1984) and Prasad (1988), have indicated a differential response of sequential and alternate branching types with regard to types of mutants observed in M_2 generation. However, the response of M_1, M_2 and M_3 generations in relation to canopy development are yet to be studied in detail. The present investigation clearly brings out the genotypic differences for mutagenic treatment in all different generations. It may be noted that while, the response of sequential branching forms such as GAUG-1 and NC Ac 17090 pertaining to canopy category 2 are much different from the response of Robut 33-1 (Canopy category 3) and M 13 (canopy category 4) which exhibited the similar response pattern.

Within the canopy category 2, some difference in response was observed between NC Ac 17090 and GAUG-1 in the M_1 generation. Based on the variances for canopy attributes and yield components in different generations it could be observed that the variety GAUG-1 exhibited a high variance for these attributes in M_1 and M_2 generation and low variance in M_3 generation. In the case of NC Ac 17090 the overall variance pattern for these attributes was moderate in M_1 generation high in M_2 generation and low in M_3 generation. Despite slight differences in variances in M_1 generation, both these varieties exhibited uniformly higher degrees of variances as well as total mutation frequencies in M_2 generation and lower degrees of variances in the M_3 generation. In other words, the response of these two genotypes was diploid like or disomic inheritance pattern as in the case of diploid crop plants such as barley and other grain legumes (Brock, 1971).

Considering the response of the Virginia varieties Robut 33-1 and M 13, it could be observed that it was on similar lines. Both the varieties revealed low variances for canopy attributes and yield components in M_1 and M_2 generations and high variance in M_3 generation which is characteristic of a polysomic inheritance pattern (Swaminathan, 1968 and Brock, 1971).

Although both the sequential and alternate branching varieties of cultivated groundnut are of same ploidy level with 2n = 4x = 40 representing tetraploid nature (Stalker and Dalmacio, 1982) it is interesting to note that the two sequential branching types representing canopy type 2 have probably attained a higher degree of genetic diploidization as compared to the other two Virginia varieties with alternating branching pattern. It is also of interest to note that the chlorophyll mutation frequency is practically zero in Robut 33-1 and very low in the case of M 13 along with lower frequencies of viable mutations which are typical of polysomic nature. Considering the implications of the above findings it could be appropriate to suggest that the selection for desirable mutant types could be carried out in the M_2 generation in respect of the sequentially branching genotypes falling in canopy category 2, while such a selection to be postponed in M_3 generation, in respect of Virginia genotypes, considering their genetic nature. De 'Sa, (1984) has found diploid like behaviours of variety 'Tatu' of valencia groundnut for branching, pod number per plant, seed number per pod and seed size.

The results of De 'Sa, (1984) in Valencia groundnut and Anuradha (1987) also reported that the varieties Gangapuri and NC Ac 17090 representing the canopy type 2 showed a similar response in M_1 generation which was different from that of variety MH_2, which according to the which was different from that of variety MH_2, which according to the present study falls in canopy category 1. Although MH_2 could not be included in the present study, similar response of NC Ac 17090 and Gangapuri both pertaining to canopy type 2 agrees with the results of the present investigation, thereby suggesting the canopy characters have to be considered as a basis for assessing the genotypic response to sodium azide in M_1 generation.

This study also brings out that the genotypic response in terms of variances for the canopy and reproductive characters in M_1 generation could serve as an indication of the variability in the M_2 generation, as has been observed in respect of all the varieties. It may be argued that M_1 variation could not totally inherited in M_2 generation, however it has been reported that variation induced in M_1 generation could be taken as an indication of M_2 variability (Prasad, 1968 and 1972), supporting the observations in the present study in which moderate to high degrees of M_1 variances were observed for canopy and reproductive attributes in respect of GAUG-1 and NC Ac 17090 resulted in higher degrees of variances for the above characters and high total mutation frequencies in M_2 generation, while the lower M_1 variances for these characters lead to lower degrees of variances and mutation frequency in M_2 generation in the case of Robut 33-1 and M 13. These observations are also in confirmity with the conclusions drawn from the studies carried out by Anuradha (1987) in Valencia groundnuts. The results of this investigation further revealed one more interesting trend which has got important implications in groundnut breeding. It could be observed that the variances for canopy diameter, branch number, pod number and pod weight and kernel yield per plant were uniformly enhanced in all the varieties in M_1, M_2 and M_3 generations thereby indicating that probably these attributes were more amenable for mutational manipulation and that the enhancement of variance in one attribute probably resulted in similar variance enhancement in the rest. These observations serve as a cross check and are in confirmity of the conclusions drawn from correlation and path coefficient analysis that canopy diameter at 60 days is positively and directly correlated to the pod and kernel yield and as such could be incorporated in selection criteria. The above observations based on mutational analysis draws support from the earlier studies conducted by Prasad et al., (1984 and 1985), De 'Sa (1984) and Anuradha (1987).

5.11 MUTAGENIC EFFECTIVENESS AND EFFICIENCY

Mutagenic effectiveness and efficiency are very important considerations to assess the utility of a mutagen in relation to the genotype for plant breeding purposes. Mutagenic effectiveness is the proportion of mutations isolated per unit dose of mutagen, while the mutagenic efficiency is the proportion of mutations in relation to sterility induced. (Konzak et al., 1965). Sodium azide of the concentration of 3 mM has been selected for the mutagenic treatment in view of the reports of its efficacy and efficiency (Prasad, 1985; De Sa, 1984; and Anuradha, 1987). The results on effictiveness and efficiency of these treatments in relation to four different genotypes presented in Table 42 indicate that sodium azide at 3 mM was relatively more effective in NC Ac 17090 and GAUG-1 in that order than in the case of Robut 33-1 and M 13. The mutagenic treatment's effeciency in different genotypes, however, gave a different picture. The mutagenic treatment was most efficient in Robut 33-1 closely followed by GAUG-1 as seed sterility induced by mutagen in these varieties was of relatively lower order. In view of a higher degree of seed sterility induced in M 13 and NC Ac 17090 the efficiency of the mutagen in these varieties was of lower order. These results agree with the findings of Anuradha (1987) in Valencia groundnut. The observation of the recovery of relatively higher number of mutations per unit dose of mutagen in the two sequentially branching varieties such as GAUG-1 and NC Ac 17090 representing canopy category 2 than in the case of the two Virginia varieties justify the interpretation that the former two varieties were genetically more diplodized than the later two Virginia varieties based on the pattern of variances observed in M_2 and M_3 generations. In view of wide range of novel mutations recovered in the present study which are discussed separately, as well as considering the higher levels of mutagenic effectiveness and reasonable degrees of mutagenic efficiency, it may be stated that sodium azide could be used for mutation breeding purposes for canopy attributes and yield components leading to genetic restructuring of plant type of groundnut as suggested in the present study and supported by Prasad (1985), De 'Sa (1984) and Anuradha (1987).

5.12 MUTANTS OF AGRONOMICAL VALUE

Though mutation breeding has been employed as a tool in varietal improvement of groundnut, not many induced mutants have been released as improved varieties (Reddy, 1988). However, the work carried out by Gregory, (1955, 1961, 1968 and 1970) in North Carolina and that of Patil (1966 and 1969) in India resulted in development of commercial varieties. Prasad *et al*., (1984 and 1985) and Prasad (1988) have reported mutants with conspicuously higher yield potential in the background of wide range of canopy development in Virginia, Spanish and Valençia genotypes. It has been suggested that the dense canopy mutants developed from the sequential branching types and compact canopy mutant types of _Virginia_ types possessing high yield potential would form useful breeding material as they represented new genes for canopy development and yield, apart from their suitability for direct introduction as improved cultivars. It may be observed that some of these mutants viz., M 13 Compact Mutant, 32-2-5 of mutant of MK 374, MH2-BC28 of MH 2 used in the present study as parents in the hybridization programmes resulted in the generation of higher degrees of variances for several agronomic attributes in F_2 generation. Some of the above mutants are also being evaluated for productivity in the yield evaluation trial. (Report of Groundnut AICORPO, 1987). In the present study also the mutants CCM-1 and CCM-2 of M 13, hold out lot of promise in view of their higher yield potential and altered canopy characters in relation to the parent. As suggested by Ashley (1984) _virginia_ runner types such as M 13 suffer from the defect of wasteful branching in the post-flowering and pod development stage thereby draining out plants energy that could have been otherwise utilised for pod production. Therefore compact canopy mutants developed in this study, as well as the Compact Mutant of M 13 may be considered as 'mutational corrections' of such a wasteful canopy of the parental material.

The other mutants viz., ABM-2 and ABM-1, DCM 4, DCM 2, DCM 1 and SPM-1 of NC Ac 17090 and ABM 6 of GAUG-1 showed promising yield potential as compared to the respective sequential branching parents. It may be pointed out that in these mutants, yield enhancement was accompanied by corresponding enhancements in canopy diameter, as suggested by Prasad _et al_., (1984) and Prasad (1988), indicating direct and strong positive influence of canopy and yield of sequential branching forms also. The two mutants ABM-1 and 2 of NC Ac 17090 as well as ABM-3 to 6 of GAUG-1 represent alternate branching systems which are diagnostic characters of *Virginia* genotypes, unlike the parents. These mutants are probably of the type of TMV2NLM reported by Prasad *et al*., (1984). Such mutants are of immense value not only in groundnut breeding but also in phylogenetic studies.

All the above mutants represent new gene mutations since sodium azide treatment employed in the present study is reported to bring about mutations through antimorphic effect of genes (Prasad, *et al*., 1985) and as such form very valuable breeding material according to Prasad *et al*., (1984 and 1985).

5.13 STRATEGIES FOR EFFICIENT GROUNDNUT BREEDING

Groundnut breeding work carried out in the past was largely dependent on selection based on pod number, pod weight and kernel yield without due consideration of canopy attributes. (Coffelt and Hammons, 1973, Dorairaj, 1962 and Humphrey, 1942). As pod development in groundnut is subjected to a greater degree of interaction with the environment (Norden, 1986, Singh *et al*., 1975 and Yadava and Kumar, 1978), there is a need to employ comprehensive selection criteria involving relatively more stable attributes showing strong positive correlations with yield, in addition to pod number, pod weight and kernel weight. Based on the conclusions drawn from the present investigation, it is fairly clear that the attributes such as canopy diameter, branch number, leaf area, total dry matter and total root nodule number and mass at 60 days can be considered more stable characters showing a strong direct positive correlations with yield as well as among themselves. In view of the difficulty of screening a vast groundnut breeding material for root nodule number and mass it could be more feasible and appropriate to base the selection on canopy diameter and branch number at 60 days in addition to pod and kernel yield.

Another task of the breeder is to arrive at appropriate parental mating system which can generate wider degrees of variances for the above character combinations. This study has revealed that the parental mating system involving intermediate canopy categories such as two and three would be useful in generating the desirable variance patterns in the segregating generations. In view of the preponderance of specific combining ability effects indicative of non-additive type of gene action in the crosses, it would be desirable to postpone the selection to F_3 and subsequent generations, instead of selecting in the F_2 generation (Baker, 1968 and Arunachalam et al., 1980).

In order to ensure maintenance of adequate degrees of genetic buffering in the population, the selection pressure in F_3 may have to be modified by the way of rejection of unfit individuals from the population as suggested by Norden (1980 and 1982), rather than selection of individual plants based on the superior norms which might lead to the loss of fitness of the population. (Norden, 1980 and Arunachalam et al., 1980). Random intermating among these individuals in such a population will ensure the conservation of genetic buffering. This could be followed by further cycles of rigorous rejection of unfit individuals in the advance generations. The continuing cycles of rigorous rejection of unfit and low yielding individual plants would not only ensure the plasticity of the population but also would lead to the higher degrees of uniformity, at the same time exploiting non-additive interactions (Banks, 1976; Hammons, 1976; Wynne, 1976; Wynne and Isleib, 1980).

Since the intermating through hand pollination would be laborious and practically not feasible, it would be necessary to employ low doses of radiation treatment to induce some degree of pollen sterility leading to natural outcrossing among the individuals as suggested by Dutta *et al*., (1986).

Exploitation of induced mutations through the use of sodium azide appears to be practical and feasible groundnut breeding proposition, (Prasad *et al*., 1985 and Anuradha, 1987), as also indicated by the results of present study. In the case of sequentially branching parents such as *Spanish* and *Valencia* types it would be desirable to select for enhanced canopy development leading to higher levels of productivity as observed in the present investigation and also as suggested by Duncan *et al*., (1978); Ashley (1984) and Prasad *et al*., (1984). Such selection could be effected in the M_2 generation itself in view of the diploid like behaviour of the *Spanish* and *Valencia* types.

In *Virginia* types on the other hand it would be necessary to postpone selection to M_3 generation in view of higher degree of variances for several agronomic attributes in M_3 than M_2 indicating a polysomic nature of inheritance. Selection of compact canopy types in *Virginia* genetic background could be combined with higher levels of yield potential as this would lead to the "genetic rectification" of the wasteful vegetative growth of the *Virginia* runner types characterised by unproductive branching at post-flowering and podding phases depriving the developing pods of the necessary assimilates (Ashely, 1984). Such mutationally restructured *Virginia* canopy types have been found to result in favourable patterns of variances for agronomic attributes in the segregating populations when crossed with the other genotypes of canopy categories 2 and 3.

SUMMARY

SUMMARY

Studies on genetic manipulation of canopy and reproductive attributes in cultivated groundnut have been taken up -

(1) to understand the inter-relationship between the canopy and reproductive attributes,

(2) to develop comprehensive and efficient selection criteria based on stable character combinations to be used in the groundnut breeding,

(3) to identify appropriate parental cross combinations which could lead to higher levels of variances in the segregating generations and

(4) to study the pattern of mutagen induced variances in relation to canopy type for important agronomic attributes.

The characterisation of groundnut genotypes into the canopy categories of 1 to 4, the first being the most compact canopy type and fourth being the most spreading canopy type with intermediate canopy classes falling in the categories 2 and 3 has been carried out based on canopy circumference, canopy diameter and total dry matter at 60 days. An examination of the each of the canopy categories revealed that the extreme categories were not characterised by high stability of kernel yield. The canopy compaction in groundnut from canopy types 4 to 1 marked a shift from virginia runner forms to sequential branching types with the attainment of highest levels of stability for kernel yield in the canopy categories 2 and 3 consisting of both sequential and alternate branching virginia forms. While the yield components such as pod number per plant and pod weight per plant appeared to be less stable characters for selection in view of their higher degree of interaction with the environmental parameters, the attributes such as

canopy diameter, leaf area, total dry matter and nodule number and nodule mass per plant at 60 days were found to be relatively more stable. These attributes have also exhibited a strong direct positive correlations not only among themselves, but also with kernel yield per plant thereby indicating their suitability for being incorporated, into the criteria of selection for efficient groundnut breeding.

Analysis of the pattern of heterosis in the crosses involving the combinations of different canopy categories has revealed that the higher levels of positive heterosis for the canopy development, root nodulation and kernel yield which were positively inter-related, was observed in the crosses involving canopy categories 2 and 3 representing intermediate but adequate levels of genetic divergence conducive for higher levels of heterosis.

It was also found that the varieties pertaining to canopy category 3 exhibited preponderance of general combining ability effects for the above attributes and that the genotypes pertaining to canopy category 2 (mostly Spanish and Valencia varieties) except MH2BC28 indicated negative general combining ability effects for canopy attributes and positive general combining ability effects for yield and yield components. Analysis of combining ability effects in F_1 and F_2 revealed the preponderance of specific combining ability effects for several characters indicating the role of non-additive gene action.

While the heritability for canopy diameter and branch number decreased from moderate levels in F_1 to lower levels in F_2, the heritability estimates for yield components and nodule number and mass got enhanced from F_1 to F_2. The results on the trends of heritability of these characters were in consonance with the combining ability estimates indicating preponderant non-additive gene action.

Analysis of variances for canopy circumference, canopy diameter, total nodule number and nodule mass, mature kernel number and its weight in F_2 generations of the crosses involving the parental combinations of different canopy types indicated the incidence of wider degrees of variances for these characters in the case of cross combinations involving canopy types 2 and 3 and also certain crosses of canopy combinations of 3x3 involving the induced compact canopy mutants of Virginia types.

Several promising segregants for canopy and yield attributes were isolated mostly from the F_2 generations of the cross combinations involving canopy category 2 and 3. The F_2 of the cross MH2BC28 x ICG(C) 8 representing canopy combination of 2x3 threw up a segregant with aerial pods which could be of immense use in groundnut breeding.

The studies on mutagenesis with sodium azide at a concentration of 3 mM revealed the genotypic differences for mutagenic treatment in M_1, M_2 and M_3 generations. The sequential branching genotypes exhibited higher degrees of variances as well as total mutation frequencies in M_2 generations and lower degrees of variances in respective M_3 generations indicating their diploid like genetic nature for the above characters. The Virginia varieties on the other hand, exhibited lower degrees of variances and total mutation frequencies in M_2 generations and higher degrees of variances in the M_3 generation indicating a polysomic inheritance pattern. The study also indicated the occurrence of simultaneous enhancement of variances for the canopy diameter, branch number, pod number and pod weight, confirming the observations made through correlation studies and path coefficient analysis. These set of characters were also observed to be more amenable for mutational manipulation. It was also found that the M_1 variances could serve as an indication of M_2 variances for the above characters. The chemical mutagen sodium azide at the concentration of 3 mM was found to be useful for mutation breeding purposes for canopy attributes and yield components.

Among the mutants isolated, the alternate branching types and dense canopy mutants of sequential branching parents and compact canopy mutants of *Virginia* parents appeared to be of interest from both points of view of groundnut breeding and physiology.

Based on the results of the investigation, some strategies for efficient groundnut breeding have been suggested.

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