MORPHOLOGICAL AND RAPD BASED GENE DIVERSITY STUDIES AMONG RELEASED CULTIVARS AND PRE-RELEASE CULTURES OF GROUNDNUT (*Arachis hypogaea* L.)

by

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Miss N. SUNEETHA has satisfactorily prosecuted the course of research and that the thesis entitled **"MORPHOLOGICAL AND RAPD BASED GENE DIVERSITY STUDIES AMONG RELEASED CULTIVARS AND PRE-RELEASE CULTURES OF 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 her for a degree of any university.

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C E R T I F I C A T E

This is to certify that the thesis entitled **"MORPHOLOGICAL AND RAPD BASED GENE DIVERSITY STUDIES AMONG RELEASED CULTIVARS AND PRE-RELEASE CULTURES OF GROUNDNUT (*Arachis hypogaea* L.)** submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the Acharya N.G. Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Miss. N. SUNEETHA** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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DECLARATION

I, **Miss N. SUNEETHA** hereby declare that the thesis entitled **"MORPHOLOGICAL AND RAPD BASED GENE DIVERSITY STUDIES AMONG RELEASED CULTIVARS AND PRE-RELEASE CULTURES OF GROUNDNUT (*Arachis hypogaea* L.)"** submitted to Acharya N.G. Ranga Agricultural University, Hyderabad for the degree of **MASTER OF SCIENCE IN AGRICULTURE** is the result of original research work done by me. I also declare that the material contained in this thesis has not been published earlier.

Date: **(N. SUNEETHA)**

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LIST OF ABBREVIATIONS AND SYMBOLS

%	:	Per cent
ANOVA	:	Analysis of Variance
bp	:	Base pair
CD	:	Critical Difference
Cm	:	Centimeter
CV	:	Co-efficient of variation
df	:	Degree of freedom
DNA	:	Deoxy ribose nucleic acid
dNTP	:	Deoxy nucleotide triphosphate
et al.	:	And others
Fig.	:	Figure
G	:	Genotypic
g	:	Gram
GA	:	Genetic Advance
GAM	:	Genetic Advance as per cent of Mean
GCV	:	Genotypic Co-efficient of Variation
GM	:	General Mean
$h^2(b)$	:	Heritability in broad sense
ha	:	Hectare
HI	:	Harvest Index
Kernel L/B ratio	:	Kernel Length/Breadth ratio
Kg	:	Kilogram
ml	:	Millilitre
mM	:	Millimoles
ng	:	nano gram
no.	:	Number
P	:	Phenotypic
PCV	:	Phenotypic Co-efficient of Variation
pH	:	Power of Hydrogen
RAPD	:	Random Amplified Polymorphic DNA
RBD	:	Randomized Block Design
r_g	:	Genotypic correlation co-efficient
r_p	:	Phenotypic correlation co-efficient
rpm	:	Revolutions per minute
SEm	:	Standard error of Mean
U	:	Units
Viz.,	:	namely
µl	:	Microlitre
$\overline{X}$	:	Grand mean

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Title of the thesis	:	**"MORPHOLOGICAL AND RAPD BASED GENE DIVERSITY STUDIES AMONG RELEASED CULTIVARS AND PRE-RELEASE CULTURES OF GROUNDNUT (*Arachis hypogaea* L.)"**
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ABSTRACT

The present investigation was carried out during *Kharif*, 2006 to study the genetic divergence (D^2 statistic and RAPD markers), variability, character association and path co-efficient analysis in 29 released and pre-release cultures of groundnut. The experiment was laid out at Regional Agricultural Research Station, Tirupati in a randomized block design with three replications. Data were recorded on 16 morphological, yield and yield attributes and 10 physiological characters.

Analysis of variance indicated the existence of significant genotypic differences for all the characters except for number of primary branches number of mature pods per plant and number of immature pods per plant. The cultivars *viz.,* Tirupati-4, TG-39, Abhaya, R-2001-2, JL-24, TCG-750 and K-4 showed high mean performance for pod yield as well as for most of yield components.

Analysis of genetic parameters revealed that GCV, PCV heritability (broad sense) and genetic advance as per cent of mean were relatively high for length of primary branches, length of main axis, days to emergence, weight of immature pods per plant, number of fully expanded leaves, 100-seed weight, harvest index, pod yield per plant, leaf area duration (LAD), crop growth rate (CGR), leaf area index (LAI),

net assimilation rate (NAR), specific leaf area (SLA) at 72 DAS and seedling vigour index indicating the involvement of additive gene action. Therefore, simple phenotypic selection could be efficient to improve these characters. The remaining characters, number of primary branches per plant, days to 50 per cent flowering, leaf length, leaflet length, leaflet width, number of mature pods per plant, number of immature pods per plant, SCMR and germination percentage had moderate to low GCV, PCV, heritability and genetic advance as per cent of mean indicating the influence of non-additive gene action. Hence, selection in advanced generations would be effective for improvement of these characters.

Genetic divergence studies by Mahalanobis's D^2 analysis revealed considerable variability among 29 released and pre-release cultures of groundnut and were grouped into 9 and 8 clusters based on morphological, yield and yield attributes and physiological characters respectively. The characters, harvest index, days to mergence, length of main axis, leaf area duration, leaf area index, crop growth rate and net assimilation rate contributed maximum towards genetic divergence and this was confirmed by canonical analysis. The cultivars, TCGS-888, TCGS-913, R-2001-2, Tirupati-4, Narayani, JL-24, TCGS-645, TCGS-717 could be selected as effective parents to improve the respective morphological and physiological characters.

RAPD marker studies detected a high level of genetic variation among the 12 groundnut cultivars selected. A high degree of polymorphism was obtained with the primers OPJ-6 (11 bands), OPA-3 and OPH-7 (10 bands). The similarity index values ranged from 32.60% to 92.9% indicating a wide range of genetic diversity.

Character association studies revealed significant positive correlation of number of primary branches per plant, number of mature pods per plant, 100-seed weight, LAD, LAI, CGR, SLA and harvest index with pod yield per plant and among themselves. Path co-efficient analysis indicated that number of mature pods per plant, number of primary branches per plant, 100-seed weight, LAD, CGR, LAI at 36, 72 DAS, germination percentage and SLA at 72 DAS were important attributes directly influencing the pod yield in groundnut.

CHAPTER-I

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the most important oil seed crops of India and contributes about 30% of the total domestic supply of oil. India ranks second after China in groundnut production in the world with annual production of 8 m tonnes. The productivity in India, however, is quite low (1000 kg/ha) compared to that of the USA (3000 kg/ha), China (2600 kg/ha), Argentina (2100 kg/ha) and Indonesia (1550 kg/ha).

Groundnut is an allotetraploid (2n = 40), self-pollinating annual legume. Its seeds are valued both for its oil and protein contents. The seeds contain about 48% oil, 25% protein and 18% carbohydrates and are rich source of B-complex vitamins especially thiamine and nicotinic acid but deficient in fat soluble vitamins A and D and almost lacking in vitamin-C. Thus, the crop has great future as oilseed as well as food crop.

In Andhra Pradesh it is being cultivated in an area of 16.00 lakh hectares with an annual production of 9.8 lakh tonnes and productivity of 660 kg/ha. But the productivity of groundnut crop is very low (967 kg/ha) compared to world average (1451 kg/ha) (FAO, 2004). Majority of the area (80%) in Andhra Pradesh is under rainfed conditions. Major constraints in *Kharif* production are abiotic stresses,

(drought and low light) and biotic stresses, (late leaf spot, rust, sucking insects and leaf webber). Keeping the constraints in view, new groundnut varieties were released by Acharya N.G. Ranga Agricultural University starting from 1971. So far, 14 groundnut varieties were released from the university. More than five advanced breeding lines are in minikit testing with different special attributes like earliness, drought resistance, water use efficiency, late leaf spot resistance, Kalahasti malady resistance etc.

Evaluation of the released and pre-release varieties for different phenotypic characters *i.e.* phenotyping supplemented with DNA characterization helps in documentation in the context of intellectual property rights and in utilization of the varieties in breeding programmes. Thus, the present study was carried out to not only document the available genetic variability among released and pre-release varieties but also to use phenotyping/DNA variation data for identification of varieties which is highly essential in the present global context.

By using advanced biometric techniques such as multivariate analysis based on Mahalanobis's D^2 statistic, it has now become possible to quantify the degree of genetic divergence among a collection of genotypes as well as to assess the relative contribution of various desirable attributes of breeding and agronomic value to the total divergence. Most of the earlier studies on genetic divergence in

groundnut were carried out taking a set of genotypes from germplasm/advanced breeding lines etc. where the populations were not clearly defined with respect to their pedigree. In the present study, the genotypes selected have detailed pedigree data and morphologically clearly distinguishable which makes it easy to relate pedigree data with divergence. In the present study, divergence was estimated both based on data on morphological, yield and yield attributes as well as physiological attributes as a lot of variation has been reported for physiological traits influencing pod yield.

As per the physiological model $Y_R = C*D*_R*P$ where, Y_R – Yield potential or the genotypes C – Mean crop growth rate, D_R – Duration of reproductive growth and P = Mean fraction of C partitioned towards the reproductive organs. C is defined as drymatter produced per unit land area per unit time (gm^{-2} day^{-1}). It is the integration of intercepted radiation and radiation use efficiency. D_R and P are the integration of reproductive growth and ability of partitioning of photosynthates to pods. The crop duration is generally fixed for a given location or cropping system. It is determined by soil moisture availability and prevailing temperatures during the cropping season. D_R can be increased to some extent by reducing the duration of the vegetative phase by selecting for early emergence and profuse early flowering. Thus, in a fixed crop duration, C and P are the major determinants of the final yield (Nigam, 2004). Thus, in the present investigation,

divergence based on physiological parameters, crop growth rate, leaf area index and leaf area duration was also studied to know how these parameters vary in released and pre-release varieties of groundnut. Correlation and path-coefficients give the relationship among morphological and physiological attributes and yield which would be very useful to formulate selection criteria for improvement of yield.

The present study was therefore, carried out to assess the extent of genetic diversity among 29 released and pre-release cultivars of groundnut using biometrical techniques as well as RAPD markers with the following objectives:

1. To estimate the variability, heritability (broad sense) and genetic advance as per cent of mean for yield and yield component characters.
2. To study the morphological diversity among released and pre-release groundnut cultures through D^2 statistic.
3. To study the diversity at DNA level by using RAPDs.
4. To study character association and path analysis.

CHAPTER-II

REVIEW OF LITERATURE

A brief review of available literature related to the objectives of present investigation in groundnut (*Arachis hypogaea* L.) is presented under the following headings.

2.1 VARIABILITY AND GENETIC PARAMETERS

2.2 GENETIC DIVERGENCE

2.3 CHARACTER ASSOCIATION

2.4 PATH CO-EFFICIENT ANALYSIS

2.1 GENETIC PARAMETERS (VARIABILITY, HERITABILITY AND GENETIC ADVANCE AS PER CENT OF MEAN)

The success of any breeding programme depends on the amount of variability present for different characters in a population and its efficient management. The genetic co-efficient of variability gives an useful measure of the magnitude of genetic variance present in the population. Estimation of genetic variability alone cannot indicate the possible improvement achieved through selection, but it should be used in conjunction with heritability and genetic advance.

The degree of success depends on the magnitude of heritability [h^2 (b)] as it measures the relative amount of the heritable portion of variability. Genetic advance (GA) under selection gives an idea about

how much of the genetic gain obtained was due to selection. Hence, the estimates of genetic variability, heritability and genetic advance had an immense value in identifying superior genotypes.

Kassam *et al.* (1975) reported that the slow early growth of groundnut was found to be due to the slow development of LAI. They also reported that LAI reached large values upto 5.5 to 7.0 and a large leaf area was normally maintained until just before maturity.

Balaiah *et al.* (1975) reported high heritability along with moderate to high co-efficients of variation for number of primaries, length of primaries, number of mature pods, pod yield and height of main axis.

Williams *et al.* (1976) reported that maintenance of high leaf area during pod filling period is important since sinks seemed to be not limiting. Maintenance of high LAI is advantageous especially in *Kharif* season due to low photosynthetic rate under low light conditions.

Studies of Enyi (1977) on growth aspects of two groundnut varieties, a sequential branching type, Natal common and an alternate type, 'Domodo Edible' indicated greater grain to leaf ratio (grain weight at harvest/LAD between pod initiation and final sampling') in spreading types than bunch types. Duncan *et al.* (1978) reported that maximum light interception occurred when the LAI was three.

Siva Kumar and Shaw (1978) identified that the marked increase in CGR at later part of the growing season could be due to a combination of decreased leaf area and increased dry weights.

Janamatti (1979) found no differences in NAR amongst the four bunch groundnut genotypes during the vegetative phase (0-25 days). In all, NAR decreased during flower initiation (25-40 days), pod initiation and pod development (40-70 days) stages. There was a decrease in NAR during the peak pod-filling period.

Sudhakar Rao (1980) reported that the cultivars of groundnut differed in total chlorophyll content of leaves and opined that the dark green colour and leaf thickness might be due to higher chlorophyll content. Labana *et al.* (1980) observed high heritability and genetic advance for 100-kernel weight and number of secondary branches.

Harisingh *et al.* (1982) from their studies on genetic variability and heritability for morpho-physiological attributes in groundnut reported significant difference among genotypes and a high range of variability for biological yield, harvest index, number of pods per plant and pod yield. The differences between phenotypic and genotypic variances were high for biological yield. Harvest index and pod yield had low heritability values while shelling percentage showed high heritability value.

Nagabhushanam *et al.* (1982) observed that genetic advance was high for number of mature pods and moderate for plant height and pod

yield per plant. Heritability was high for number of primary branches, days to flowering, number of mature pods, shelling percentage, harvest index and pod yield.

Sandhu and Khehra (1983) reported that epistatic variance was the major component in inheritance of leaflet length and width. Murthy *et al.* (1983) reported highest CGR at 50 DAS and again at 75 DAS.

Chauhan and Shukla (1985) noticed high GCV for pod yield per plant in both bunch and spreadings types. High heritability was recorded for pod yield, mature pods, days to maturity and pods per plant and low heritability for shelling percentage and harvest index in bunch group and number of primary branches in spreading type.

Bhagat *et al.* (1986) observed high heritability and genetic advance for pod yield per plant and shelling percentage. Kandaswami *et al.* (1986) reported high heritability for plant height, number of primary branches while number of mature pods, shelling percentage, harvest index and pod yield showed moderate heritability and high GCV.

Naidu *et al.* (1987) reported high GCV, PCV, heritability and genetic advance for number of mature pods, number of primary branches and pod yield. High heritability and low genetic advance were recorded for shelling percentage. Nadaf and Habib (1987) reported high heritability for days to 50 per cent flowering and 100-kernel weight.

Reddy *et al.* (1987) observed high heritability and genetic advance for height of main axis, number of primary branches, kernel yield, and pod yield whereas high heritability and moderate genetic advance for shelling percentage.

Swamy Rao *et al.* (1988) reported low PCV, GCV, heritability and genetic advance as per cent of mean for leaf length and leaf breadth in groundnut. Number of primary branches exhibited high variability, heritability and genetic advance as per cent of mean whereas pod yield showed moderate variability coupled with low heritability and genetic advance as per cent of mean.

Manoharan *et al.* (1990) reported highest phenotypic co-efficient of variation for pod yield per plant followed by pod number. Low heritability was reported for pod number, shelling percentage and pod yield per plant. Though genetic advance for pod yield per plant and pod number was also high they had poor heritability values indicating that they are controlled by non additive gene action.

Vaddoria and Patel (1990) reported high estimates of genetic parameters for 100-seed weight, harvest index and number of mature pods. Number of primary branches exhibited low heritability.

Rami Reddy (1991) obtained higher PCV and GCV values for number of immature and mature pods per plant and pod yield per plant. Number of immature pods per plant showed low heritability. Shelling

percentage had low genetic advance and heritability. Days to flowering recorded moderate PCV and GCV values.

Reddy and Gupta (1992) recorded high variability and genetic advance for pod yield, number of mature pods, shelling out-turn and harvest index. Manoharan and Ramalingam (1993) reported higher heritability but low genetic advance for kernel weight, days to 50% flowering and shelling per cent. Number of primary branches recorded lower heritability. Pod yield showed highest genetic advance.

Ganeshan and Sudhakar (1995) reported higher genetic variability coupled with high heritability and genetic advance for primary branches. Pod yield per plant showed moderate values of variability but higher heritability coupled with high genetic advance. Mature pods per plant showed moderate values of GCV, heritability and genetic advance.

Anuradha (1995) studied advanced generation pure line cultures of 28 genotypes of groundnut for variability and genetic diversity in physiological attributes and reported low values of GCV, heritability and genetic advance for SLA at 90 DAS. LAI at 30 DAS was observed to exhibit moderate heritability.

Varman and Raveendran (1996) observed high heritability for plant height, number of branches per plant, number of mature pods per plant, number of pegs per plant and 100-kernel weight. Harvest index had low genetic advance. Shelling out-turn showed low heritability.

Varman *et al.* (1996) reported that the CGR increased upto pod formation (50-70 DAS) and then decreased. LAI was maximum during pod formation (50-70 DAS) and then decreased. Jaya Lakshmi (1997) reported high GCV and heritability for harvest index whereas SLA showed low GCV and high heritability.

Khurram *et al.* (1998) estimated variability, broad sense heritability and genetic advance in groundnut. High phenotypic and genotypic variances were recorded for pod weight per plant. High GCV, PCV were observed for kernel yield per plant, pod weight per plant and number of primary branches. Heritability was high for number of days to flowering. High GA and heritability for pod weight per plant indicated that additive gene effects were more important for this trait which offers scope for its improvement through mass selection.

Vasanthi *et al.* (1998) from their study in advanced breeding lines found high heritability and genetic advance for 100-kernel weight, shelling percentage, SMKP and days to 50 per cent flowering.

Desai *et al.* (1999) reported that LAI increases from very low level, early in the season to maximum value, ranging from about 4-7 and the maximum LAI occurs during the early-to-mid pod filling stage. The CGR values showed an increase from a very low value early in the season to a maximum at about 60-90 days after planting. The maximum values of CGR reported in different experiments averaged 19.6 ± 4.2 gm^{-2} day^{-1}.

Rudraswamy *et al.* (1999) reported moderate genetic advance and high heritability for number of immature pods, pod yield per plant and shelling percentage. Singh and Singh (1999) observed high heritability for plant height, primary branches, pod yield per plant, shelling percentage and 100-kernel weight.

Rajora *et al.* (1999) observed low GCV, moderate heritability and low GAM for germination percentage in lablab bean.

Sharma *et al.* (2000) in their variability studies, noticed high GCV, PCV, heritability and genetic advance as per cent of mean for CGR at 50-70 DAS.

Naik *et al.* (2000) observed high GCV for pod weight per plant, 100-kernel weight and plant height suggesting that selection for these characters would be more effective. GCV was low for number of primaries per plant, number of pods per plant, shelling percentage and sound mature kernel percentage. High heritability was observed for 100-kernel weight and number of primary branches indicating that they were least influenced by environment. Medium heritability values were observed for plant height and pod weight per plant. The genetic advance as per cent of mean was high for pod weight per plant and 100-kernel weight. So phenotypic selection for the improvement of these characters would be effective.

Rostini *et al.* (2000) studied variability and heritability of chlorophyll content on yield in 40 genotypes and reported wide variability and moderate heritability for chlorophyll content (estimated from chlorophyll meter Minolta SPAD 502), leaf area index, leaf number and seed weight per plant.

Vijayasekhar (2002) reported high GCV, PCV, heritability and genetic advance as percent of mean for harvest index, 100-seed weight and shelling percentage. Low estimates of heritability, variability and genetic advance were observed for primary branches per plant, plant height, pods per plant and number of mature pods per plant. Vasanthi and Raja Reddy (2002) reported moderate to high heritability coupled with moderate to high genetic advance for pod yield per plant.

Bindu Madhava *et al.* (2003) observed significant genetic variation for SCMR (SPAD chlorophyll meter reading) and specific leaf area among three non nodulating lines in groundnut.

Vasanthi *et al.* (2003) from their studies on heritability observed moderate heritability, GCV, PCV and genetic advance for SPAD chlorophyll meter reading, mature pods per plant, primaries and secondaries per plant, weight of the plant, pod weight per plant, and immature pods per plant. They also reported that the traits that conferred water use efficiency, high SPAD and low SLA showed moderate to high heritability and moderate to low GAM. They inferred that there

was more scope for bringing improvement in SPAD through phenotypic selection than in SLA.

Seethala Devi (2004) reported moderate to high heritability and genetic advance as per cent of mean for pod yield per plant and harvest index and hence opined that they are governed by additive gene action and are fixable in early generations with simple selection methods. SPAD chlorophyll meter reading showed low variability and low genetic advance and are hence governed by non-additive gene action.

Ravi Kumar (2005) reported high GCV and PCV values for pod yield per plant, mature pods per plant and 100-seed weight. Moderate co-efficients of variation were obtained for harvest index, plant height while low co-efficients variations were observed for shelling percentage, days to 50 per cent flowering, primary branches per plant and SCMR. High heritability estimates were observed for 100-seed weight, shelling percentage, harvest index, SCMR, plant height, primary branches per plant and mature pods per plant. Genetic advance as per cent of mean was high for 100-seed weight, mature pods per plant, harvest index and plant height while moderate GAM was recorded for shelling percentage, days to 50% flowering, primary branches per plant and SCMR.

Suneetha *et al.* (2005) reported high heritability coupled with high genetic advance as per cent of mean for number of mature pods, number of immature pods. High heritability coupled with moderate genetic advance as per cent of mean was observed for days to 50% flowering,

height of the main axis, 100-seed weight and pod yield per plant. Number of primary branches and shelling percentage registered high heritability coupled with low genetic advance as per cent of mean.

2.2 GENETIC DIVERGENCE

2.2.1 Mahalanobis's D^2 analysis

The success of any breeding programme is determined by the amount of variability present for different characters in a population and its efficient management. Morphological similarity, eco-geographic diversity, phylogenetic relationships *etc.,* were the few earlier methods used for discriminating divergent populations, which are reinstated by more scientific and advanced biometric techniques viz., multivariate analysis based on Mahalanobis's D^2 statistic and semigraphic method of metroglyph analysis. By Mahalanobis generalized distance estimated by D^2 statistic (Maurya and Singh, 1977) estimation of degree of divergence between biological populations and computation of relevant contributions of different components to total divergence is done. Selection of parents for hybridization programme based on Mahalanobis's D^2 statistic is more reliable method as the requisite knowledge in respect of a mass of characters is available prior to crossing programme.

Arunachalam *et al.* (1984) studied heterosis in relation to genetic divergence. They concluded that the frequency of heterotic crosses and

the magnitude of heterosis for yield and its components were high in crosses between parents in intermediate divergence crosses than the extreme ones.

Durgaprasad *et al.* (1985) employed D^2 statistics to study genetic divergence using a representative sample of 40 genotypes from four varietal groups of groundnut *viz.,* Spanish bunch, Valencia, Virginia bunch and Virginia runner. Divergence estimates were based on 17 characters and were grouped into sixteen clusters. The diversity with in bunch groups was high enough to form sixteen clusters. The clustering pattern of the varieties remained same when the experiment was repeated on a sub sample of 48 germplasm lines in the next season. They identified that bunch x bunch crosses involving divergent parents identified could combine earliness with productivity and could complement bunch x runner crosses. It was also indicated that flowering time, weight of mature pods and shelling percentage were important in assessing the genetic divergence.

Nadaf *et al.* (1986) used multivariate analysis using Mahalanobis's D^2 statistic to group 83 genotypes from 18 countries on the basis of yield per plot and other six agronomic characters. The genotypes formed nine clusters that were not related to their groupings by geographic origin. Variation in pod yield accounted for 88 per cent of total variation between clusters, but number of developed pods, days to 50 per cent

flowering and 100-seed weight were important in accounting for divergence within clusters.

Venkateswarlu (1988) grouped 57 intra and inter sub-specific cross derivatives of groundnut into 13 clusters. The pattern of distribution into clusters was at random and either botanical grouping or parentage showed no influence. The characters, harvest index, 100-pod weight, number of nodes on main axis, number of secondaries and number of immature pods per plant were found to be the major contributors towards divergence.

Golakia and Makne (1991) studied 24 Spanish bunch groundnut genotypes using Mahalanobis's D^2 statistic and grouped them into six clusters. Grouping of genotypes in different clusters was not related to their geographical origin. The characters, pod yield, kernel yield, days to 50% flowering, primary branches, developed pods, and 100-kernel weight contributed to 90 per cent of total divergence.

Reddy and Reddy (1993) evaluated 48 genotypes (43 Spanish and 5 Virginia) from different geographical origin and grouped them into six clusters and confirmed the existence of variability between the genotypes for all 12 characters studied. Geographical diversity was not related to genetic diversity. They also reported that 100-pod weight (36 g) number of secondaries per plant (31%) and harvest index (15%) accounted for more than 82 per cent of the total divergence.

Anuradha (1995) based on canonical root analysis grouped 30 genotypes into 13 clusters and reported maximum contribution of harvest index, pod yield and kernel yield towards divergence

Nayak *et al.* (1997) studied 128 genotypes of groundnut belonging to Spanish, Valencia, Virginia bunch and Virginia runner types on 18 characters using D^2 statistic and grouped into 15 clusters. D^2 clustering pattern revealed lack of relationship between geographic origin and genetic diversity of genotypes.

Choudhary *et al.* (1998) employed D^2 analysis and grouped 30 groundnut genotypes into five clusters. Clustering pattern of genotypes into different clusters did not show any relationship with respect to their pedigree and place of breeding and grouped into five clusters.

John Joel *et al.* (1998) reported that D^2 analysis among the groundnut genotypes for nine characters established the presence of moderate genetic diversity by forming three clusters and the clustering pattern did not show any relationship with the geographic origin.

Venkataravana *et al.* (2000) through Mahalanobis's D^2 analysis grouped 144 groundnut genotypes into seven groups based on 15 characters. They found that the distribution of genotypes in different clusters was not according to their geographical origin. They also observed that cluster VII with only one type, ICGV 86564 recorded the highest mean values for most of the traits *viz.,* pod yield per plant,

shelling percentage, 100-kernel weight, SMK weight, kernel yield per plant, harvest index, oil percentage and oil yield per plant.

Vijayasekhar (2002) through Mahalanobis's D^2 analysis grouped 65 genotypes into 10 clusters. The mode of distribution of genotypes of various clusters was at random suggesting that there was no correlation between geographical distribution and genetic diversity. The characters, harvest index, 100-seed weight and shelling percentage contributed maximum towards genetic divergence in both D^2 analysis and canonical root analysis.

Jain *et al.* (2003) reported that the highest contribution towards total divergence was through haulms yield per plant (26.22%) followed by dry pod yield per plant (19.66%) and opined that the genotypes involved in the diverse clusters could be used as promising parents in intermating for obtaining high heterotic response and better segregants.

Dashora and Nagda (2004) studied divergence among 52 genotypes taking 12 characters which were grouped into 11 clusters. Maximum contribution from haulms yield per plant followed by dry pod yield per plant and 100-kernel weight.

Hemanth Kumar (2004) studied divergence among 54 groundnut genotypes through D^2 statistic. He reported formation of 11 clusters based on morphological and biochemical characters whereas 17 clusters based on physiological characters respectively. The mode of distribution

of genotypes into different clusters for morphological and biochemical characters was at random and independent of each other suggesting that there was no relationship between geographical origin and genetic diversity while clustering pattern of genotypes for physiological characters was related to geographical origin, no regular demarcation was discernible in the pattern of constellation of genotypes into various clusters.

Studies on gene diversity among botanical varieties of groundnut by Ferguson *et al.* (2004) showed relative similarity of three varieties of groundnut in subspecies *fastigiata* namely *fastigiata*, *vulgaris* and *aequatoriana*.

Garjappa *et al.* (2005) studied genetic divergence in 200 genotypes of groundnut through by Mahalanobis's D^2 statistic and principal component analysis (PCA). They were grouped into 12 clusters through principal component analysis. They reported that number of secondaries per plant contributed maximum towards divergence followed by days to maturity and total drymatter per plant.

2.2.2 Divergence at molecular level using RAPD markers

Traditionally a combination of morphological and agronomic traits has been used to measure genetic diversity, but most of the vegetative characteristics are influenced by environmental factors, and show continuous variation. DNA based studies of divergence are not

influenced by environment. Thus, variation at DNA level could be measured through DNA based technologies which gives more accurate assessment of diversity.

RAPD is a PCR based assay which detects nucleotide sequence polymorphisms in DNA through use of a primer of arbitrary nucleotide sequence (Welsh and Mc Clelland, 1990; Williams *et al.,* 1990).

RAPD analysis has been used for distinguishing different genotypes within a crop species (Williams *et al.,* 1990). The available literature on RAPD analysis in groundnut has been furnished hereunder.

Extensive variation for morphological and physiological characteristics existed in both wild and cultivated groundnut (Halward *et al.,* 1993), but abundant DNA polymorphism has been observed only in wild diploid *Arachis* species (Kochert *et al.,* 1991, Halward *et al.,* 1993).

Dwivedi *et al.* (2001) employed RAPD analysis for assessment of genetic diversity among selected groundnut germplasm. Twenty-six accessions and eight decamer primers were selected for RAPD assay. Eight primers generated 939 amplified fragments among which 176 were polymorphic with an overall polymorphism of 18.74%. The polymorphism among primers ranged from 8.73% to 33.08%. The amplified fragments per primer ranged from 3.19 to 5.73 with an average of 4.51 per primer. Genetic similarity ranged from 59.0% to 98.8% with an average of 86.2%. Most of the accessions, including inter-specific

derivatives showed high degree of genetic similarity. The cluster analysis grouped accessions into five different clusters. The accessions in each cluster could not be associated with their country of origin, known parentage, sub-species classification, pod, seed characteristics and their reaction to abiotic and biotic stresses.

Stalker *et al.* (2001) carried out molecular marker studies in various parental and hybrid progenies of groundnut. They concluded that lines with different pedigrees contain different sources of resistance genes and components of leaf spot resistance may be inherited separately. Markers can be associated with resistance and agronomic traits in populations of *Arachis hypogaea* and in inter-specific crosses with *A.cardenasii* and their pedigree. They opined that there was little molecular variation in *A.hypogaea* that can be identified by molecular marker analysis but markers could be associated with agronomic traits and this technology holds great promise for increasing breeding efficiency in peanut.

Dwivedi and Gurtu (2002) conducted 18 RAPD assays to study genetic diversity among germplams with varying levels of resistance to early leaf spot. The primers, G20, J17, V15 and V16 produced greater polymorphic differences. The accessions were grouped into three clusters and crossing of diverse genotypes was suggested for the development of recombinant inbred lines to identify DNA markers linked with early leaf spot resistance.

Dwivedi and Varma (2002) in their study to assess diversity among 37 groundnut genotypes differing in drought tolerance traits reported that molecular diversity studies will be useful to assess the heterotic potential of crosses and their ability to release transgressive segregation in later generations and diversity estimated will also be useful to select diverse lines for mapping and genetic enhancement. Their results proved that the populations derived from genetically diverse parents were expected to release transgressive segregants with high harvest index and such progenies should perform better under drought environments.

Nagaraja Reddy *et al.* (2004) in their studies on molecular diversity for resistance to leaf spot and rust in parents and segregating population of a cross in groundnut by RAPD analysis by using ten oligonucleotide primers reported that ten primers produced polymorphic bands ranging from 16.6% to 100% with an average of 62% per primer. They opined that RAPD assays could be efficient in identifying DNA polymorphism provided suitable primers are used. Their studies indicated less variation in Spanish groundnut compared to wild species and this may be attributed to recent origin and genome complexity of the crop.

Radhakrishna *et al.* (2004) studied 12 released cultures and reported wide genetic diversity among released cultivars i.e. within cultivated groundnut. They concluded that with RAPD technique,

sufficient polymorphism can be detected in cultivated groundnut which would help in genetic mapping.

Ferguson *et al.* (2004) in their studies on gene diversity among botanical varieties in peanut using SSR markers observed greater differentiation between varieties compared to between continents. Maximum differentiation was observed among continents within varieties for three varieties *hypogaea*, var. *fastigiata* and var. *vulgaris*. Very similar levels of diversity was observed with in botanical varieties.

32 accessions of wild species of *Arachis* belonging to twenty five species of six sections were used to study genetic relationship using RAPDs by Nalini Mallikarjuna *et al.* (2005). Twenty nine primers belonging to OPH 1-20 and OPM 1-9 were used and all the primers showed polymorphic bands and the number of bands varied from five to thirty three. Similarity values (S_{ij}) ranged from 0 to 49% with an average of 15%. Grouping of wild species was as per their relationship with each other.

Garcia *et al.* (2006) in their RAPD marker analysis of 40-chromosome inter-specific hybrid derivatives from the four crosses reported that reciprocal recombination and/for translocations were the predominant mechanisms for exchange of chromosomal segments. In their study, analysis of mapped and species specific RAPD markers in BC_1F_1 to BC_1F_3 hybrids indicated that alien germplasm retention decreased with every generation of inbreeding.

Shivapriya *et al.* (2006) from their molecular diversity studies of rice using RAPD markers observed considerable amount of diversity among the varieties. They evaluated 65 local rice accessions and three improved rice varieties using sixteen primers. The primers generated 112 marker levels with 74.1% polymorphism. Dendrogram constructed based on molecular polymorphism unveiled considerable amount of diversity among the varieties.

2.3 CHARACTER ASSOCIATION

Genetic improvement of yield is the primary concern to plant breeder as yield is a complex, quantitatively inherited character and is highly influenced by the environment. A sound knowledge on the extent of association of yield components among themselves and with the yield is essential for improving the yield. Character association analysis measures the actual relationship between various plant characters and helps the plant breeder in fixing selection criteria for pod yield in parental lines and segregating populations. Correlation co-efficient reveals the type, nature and magnitude of correlation between any pair of characters. Phenotypic correlation is the association between two characters which can be directly observed but more influenced by the environment. It measures the environmental deviations together with non-additive gene action. Genotypic correlation is the correlation of breeding values *i.e.* (Additive + Additive x Additive gene action).

A knowledge of the association of yield components with each other and with yield is helpful in improvement of yield for which direct selection is not effective. A brief review of available literature on the association of the characters in groundnut is presented hereunder.

Shettar (1974) studied 42 varieties and reported that pod yield had positive correlation with height of main axis, number of primary branches and number of mature pods and negative correlation with number of days to flowering, shelling percentage and number of pods.

Williams *et al.* (1975) reported that kernel growth rate early in the reproductive phase of groundnut was influenced by CGR.

Balaiah *et al.* (1980) from their studies observed that pod yield had positive significant association with number of primaries, secondaries and mature pods.

Ramakrishna Raju *et al.* (1981) reported positive significant association of number of mature pods and 100-kernel weight with pod yield. Length of main axis exhibited negative significant association with pod yield.

Nagabhushanam *et al.* (1982) reported that yield in groundnut showed positive significant association with number of primary branches, number of secondary branches, days to flowering, number of mature pods, shelling outturn and 100-kernel weight and it was

negatively correlated with length of main axis and number of immature pods.

Alam *et al.* (1985) observed that pod yield per plant had positive association with number of pods per plant, days to maturity and plant height. Shelling percentage had negative association with 100-kernel weight.

Reddy *et al.* (1987) reported that primary yield components of groundnut *viz.,* shelling percentage, kernel yield and number of mature pods per plant showed positive correlation with each other and with pod yield.

Madhavi (1988) reported that LAI in the initial stages had positive correlation with pod yield, kernel yield and number of pods. She also observed strong correlation of LAI from 60 days with pod yield, kernel yield and total dry matter. She concluded that initial LAI together with initial drymatter could be employed profitably as selection criteria to select productive genotypes in groundnut breeding.

Tekale *et al.* (1988) observed positive and significant correlation of pod weight per plant and dry pod yield per plant with plant height, branches per plant, developed pods per plant and total pods per plant. Swamy Rao *et al.* (1988) reported positive correlation of number of mature pods with flower number and leaf length.

Correlation studies of Nadaf and Habib (1989) revealed that pod yield was positively correlated with number of developed pods and number of primary branches. Pod yield showed highly significant association with kernel yield and pods per plant.

Abraham (1990) studied 42 bunch varieties of groundnut and observed that kernel yield had significant positive correlation with pods per plant, kernels per plant, 100-kernel weight and shelling percentage.

Sharma and Varshney (1990) observed that the yield of mature pods per plant had positive association with number of mature pods, number of immature pods, 100-kernel weight, yield of immature pods and biological yield.

Correlation studies of Rajkumar (1991) revealed positive significant association of pod yield with shelling percentage. Vaddoria and Patel (1992) reported that pod yield in *Virginia* runner type had positive significant association with harvest index, shelling percentage, number of mature pods per plant, 100-seed weight and number of primary branches per plant.

Pushkaran and Nair (1993) reported that pod yield exerted positively significant association with haulm yield, number of mature pods, number of immature pods, and shelling percentage.

Correlation studies of Reddy *et al.* (1994) revealed that the physiological characters, harvest index, crop growth rate and total dry

matter accumulation are the important yield contributing traits in groundnut.

Wright *et al.* (1994) reported significant negative association of specific leaf area with harvest index. They concluded that selection for low specific leaf area in peanuts may be appropriate in water limited systems, where both pod yield for human consumption and vegetative yield for animal fodder need to be maximised.

Anuradha (1995) observed that crop growth rate between 30-60 DAS and harvest index expressed significant positive association with pod yield.

Ursal *et al.* (1995) noticed positive association of number of fully expanded leaves with pod yield.

Uddin *et al.* (1995) reported significant positive correlation of seed yield per plant with days to maturity, seeds per plant, plant height and primary branches per plant but was negatively associated with shelling percentage and 100-seed weight.

Patra *et al.* (1995) found that LAI at 50 and 70 DAS had positive significant influence on number of pods per plant, shelling percentage, 100-kernel weight and pod yield. It was concluded that LAI at 70 DAS along with drymatter accumulation at 70 DAS were key growth variables positively influencing pod and oil yields in groundnut.

Varman *et al.* (1996) reported negative non significant association of length of main axis with pod yield.

Ofori (1996) observed negative correlation between number of pods per plant and 100-seed weight but positive correlation of both with seed yield.

Moinuddin (1997) observed strong positive association of pod yield with number of mature pods per plant, 100-kernel weight and biomass per plant. It was also revealed that haulm yield per plant and shelling percentage had negative correlation with pod yield.

Arjunan *et al.* (1997) reported positive non-significant association of pod weight with specific leaf area and non-significant negative association of specific leaf area with harvest index.

Islam and Rasul (1998) observed significant positive correlations between days to 50% flowering and days to maturity and between shelling percentage and seed yield. Highest negative correlation was noticed between number of developed pods per plant and seed weight.

Vasanthi *et al.* (1998) from their study in advanced breeding lines found that pod weight per plant possessed significant positive correlation with SMKP and significant negative association with days to 50% flowering.

Rajora *et al.* (1999) evaluated ten genotypes of lablab bean and observed positive significant association of germination percentage with seed yield per plant.

Singh and Singh (1999) reported that yield improvement could be achieved by selection for days to 50% flowering, plant height, number of primary branches, number and weight of pods per plant and kernel weight.

Antony *et al.* (2000) observed that plant height had a negative relationship with number of branches per plant and NAR. Plant height had positive relationship with leaf area index, CGR and harvest index. Leaf area index and CGR were positively correlated whereas it had significant negative relationship with NAR. Yield had positive correlation with leaf area index and NAR.

Studies of Sharma *et al.* (2000) on variability and character association in cowpea reported positive significant association of NAR with grain yield whereas CGR expressed positive non-significant association with grain yield.

Rostini *et al.* (2000) reported positive genetic correlation between yield and chlorophyll content at 16 days after flowering and negative genotypic correlation between yield and leaf angle and leaf number.

Sanjeeva Kumar *et al.* (2000) reported that CGR had increased as crop growth progressed and was highest between 60 and 90 DAS in all

the cultivars belonging to Virginia and Spanish groups. LAI, IAR and CGR significantly affected pod yields in Virginia group but had no definite trend in cultivars of the Spanish group.

Nageswara Rao *et al.* (2001) reported significant correlations between SLA with SPAD chlorophyll meter readings (SCMR) and suggested that SCMR could be used as a rapid, low-cost, non-destructive technique to screen large breeding populations.

Vijayasekhar (2002) reported that pod yield per plant had highly significant positive association with kernel yield per plant, harvest index and pods per plant. Bindu Madhava *et al.* (2003) observed highly significant positive phenotypic correlaton between kernel yield and SLA. Trivikrama Reddy (2003) reported significant positive correlation of pod yield per plant, 100-kernel weight, mature pods and pods per plant with kernel yield.

Reddy *et al.* (2003) observed a positive correlation between SCMR and seed yield and negative correlation between SCMR and SLA and substantiated the conclusion that SCMR was a potential physiological trait to employ as a surrogate for transpiration efficiency.

Seethala Devi (2004) noticed positive association of leaflet length and SCMR with pod yield.

Hemanth Kumar (2004) reported significant positive association of kernel yield per plant with mature pods per plant, 100-kernel weight and

harvest index and positive non-significant association with shelling percentage.

Lakshmidevamma *et al.* (2004) reported that pod yield had significant but negative association with shelling percentage. Days to 50% flowering, number of branches per plant, plant height, number of mature pods and kernel yield had significant positive association.

Sreedevi *et al.* (2004) in their correlation studies, observed positive significant association of pod yield with crop growth rate (CGR). CGR expressed positive significant association with LAI. NAR showed negative association with yield.

Correlation studies of Sirisha (2005) revealed positive association of pod yield with number of primary branches, immature pods and harvest index. Number of primary branches exhibited positive association with number of mature pods per plant.

Studies of Venkateswarulu (2005) showed that pod yield was positively correlated with number of mature pods per plant and kernel yield per plant. Suneetha *et al.* (2005) reported that pod yield had high and significant positive association with number of mature pods and harvest index. Days to 50% flowering and height of main axis were negatively correlated with pod yield per plant.

Kalmeshwer Gouda Patil *et al.* (2006) reported that pod yield per plant had significant positive association with number of pods per plant

and shelling percentage. Number of branches per plant showed non-significant positive association with pod yield per plant.

2.4 PATH CO-EFFICIENT ANALYSIS

Path co-efficient analysis is a statistical device developed by Wright (1921) which helps in partitioning of the correlation co-efficients into direct and indirect effects of independent variable on dependent variable. The correlation co-efficients do not give a complete picture of the casual basis of association. Path co-efficient analysis of different components of yield brings out relative importance of their direct and indirect effects and give a clear understanding of their association with yield. Thus, path co-efficient analysis helps in formulating the selection criteria based on these direct and indirect effects. Hence, path co-efficient analysis is of much important in any plant breeding programme. A brief review of literature available on path co-efficient analysis is presented hereunder.

Sandhu and Khangura (1972) from their studies reported a strong association of pod yield with number of primary branches, number of mature pods and shelling percentage.

From their studies, Badwal and Singh (1973) indicated that number of mature pods had high positive direct effect on pod yield in semi spreading and erect types. Shelling percentage showed indirect effect on pod yield through number of mature pods. Yadava *et al.* (1981)

reported that pod number and primary branches had maximum direct effect on pod yield. Pod yield was also directly affected by days to first flowering and plant height.

Studies of Nigam *et al.* (1984) revealed that selection for increased mature seed yield per plant would be possible by selecting the component characters such as mature pods per plant, mature pod weight and mature seeds per plant individually or in combination.

Sudarshanam (1985) observed that number of mature pods per plant and 100-seed weight had maximum positive direct effect on pod yield in Spansih group whereas 100-kernel weight had maximum direct effect in Virginia group.

Reddi (1986) reported that kernel yield had maximum positive direct effect on pod yield followed by number of mature pods per plant. Durga Rani *et al.* (1987) found that number of primaries, secondaries, number of pods, kernel weight, shelling percentage and 100-kernel weight had exhibited positive direct effect on yield.

Abraham (1990) reported that kernels per plant and 100-kernel weight had high positive direct effect on kernel yield of 42 bunch varieties. The indirect effects of pods per plant and shelling percentage via kernels per plant and sound mature kernels and shelling percentage via 100-kernel weight were appreciable and positive indicating that

kernels per plant and 100-kernel weight were the major yield contributors.

Raj Kumar (1991) reported that dry weight of the plant, number of mature pods per plant and harvest index had high positive direct effect on yield. From their studies, Vaddoria and Patel (1992) reported that harvest index exerted the highest positive effect on pod yield followed by number of primary branches.

Uddin *et al.* (1995) reported that days to maturity, primary branches per plant and nuts per plant had large direct effects on seed yield per plant. Ursal *et al.* (1995) identified that kernel weight per plant had maximum direct effect on pod yield followed by 100-kernel weight, days to maturity and number of branches per plant.

Patra *et al.* (1995) reported that LAI at 50 and 70 DAS had positive and significant influence on number of pods per plant, shelling percentage, 100-kernel weight, pod yield and oil content. Varman and Raveendran (1996) reported that highest direct effect of pod yield was nullified by indirect effect via shelling out-turn.

Moinuddin (1997) observed strong positive association of pod yield with number of mature pods per plant, 100-kernel weight and biomass per plant and also their direct effects were positive and high in almost all environments. Haulm yield and shelling per cent exhibited negative association and negative direct effect on pod yield.

Jaya Lakshmi (1997) reported that harvest index was positively associated with SLA in parents and F_1 (but exhibited non-significant association in F_3 generation).

Islam and Rasul (1998) noticed highest positive direct effect of shelling percentage on yield.

Vasanthi (1998) reported high positive divert effect of 100-pod weight on pod yield followed by 100-kernel weight. Cherian Mathews *et al.* (2000) noticed maximum direct effect of kernel yield per plant followed by plant height on dry pod yield per plant.

Rajora *et al.* (1999) in their path co-efficient analysis of lablab bean reported positive direct effect of germination percentage on seed yield per plant.

Sah *et al.* (2000) reported that seed yield per plant had high direct effect on pod as well as oil yield per plant. Number of pods per plant, 100-seed weight and oil yield per plant had high and positive association with pod yield but their direct effects were very low and they contribute mainly through seed yield per plant.

Johar Singh and Mohinder Singh (2001) reported that the number of primary branches had maximum positive direct effect on pod yield. It was followed by 100-kernel weight, sound mature kernel percentage, harvest index and number of fruiting nodes. Main shoot height had largest negative direct effect via number of primary branches and also

via 100-kernel weight, sound mature kernel percentage and harvest index.

Studies of Vijayasekhar (2002) indicated maximum direct effect of kernel yield per plant on pod yield followed by pods per plant and harvest index. High and positive indirect effect of kernel yield per plant was exerted through harvest index while pods per plant and harvest index contributed through kernel yield per plant.

Makhanlal *et al.* (2003) reported that the direct effect of plant height, number of mature pods per plant and root length on pod yield per plant was high and positive.

Trivikram Reddy (2003) reported high positive direct effect of pod yield, mature pods per plant, pods per plant, 100-kernel weight and harvest index on kernel yield in groundnut.

Reports of Chaitanya Varma (2004) showed that 100-kernel weight and shelling percentage had high positive direct effects on kernel yield. The positive indirect effects of most of the characters were exerted through pods per plant and sound mature kernels per plant.

Sreedevi *et al.* (2004) observed positive direct effect of LAI and CGR at 70 DAS on pod yield in greengram.

Hemanth Kumar (2004) reported positive moderate indirect effect of SLA on kernel weight through SCMR. CGR at 60 days showed high positive direct effect on kernel weight per plant. Negative indirect effect

through SLA at 60 DAS after sowing was also observed. The direct effect of pod weight per plant on kernel weight per plant was high. High and positive indirect effects were observed through LAI at 90 days and harvest index. The indirect effect through CGR at 90 DAS was positive and moderate.

Lakshmidevamma (2004) noticed that kernel yield per plant had exerted the highest positive direct effect on pod yield whereas shelling percentage exerted high but negative direct effect on pod yield. Indirect effects of the components characters *i.e.* days to 50 per cent flowering, plant height, number of branches per plant, number of mature pods per plant and test weight were found to be high through kernel yield on pod yield.

Seethala Devi (2004) reported that in parents, SPAD chlorophyll meter reading and in crosses sound mature kernel per cent exhibited high positive direct effect on pod yield per plant.

Nagda and Joshi (2004) reported highest positive direct effect of harvest index on pod yield per plant followed by haulms yield. Among indirect effects, the influence of 100-kernel weight through harvest index was positive and strong followed by indirect effect of shelling per cent through haulms yield.

Studies of Suneetha *et al.* (2005) indicated that harvest index and exerted the highest positive direct effect on pod yield per plant followed

by 100-kernel weight. Days to maturity, number of primary branches, number of mature pods, shelling percentage and 100-pod weight also exhibited positive direct effect but of lower magnitude while days to 50% flowering, height of main axis had high negative direct effects.

Kameshwer Gouda Patil *et al.* (2006) observed that number of pods per plant, shelling percentage and sound mature kernel per cent had the maximum direct effect on pod yield per plant.

CHAPTER-III

MATERIALS AND METHODS

The present investigation was carried out during *kharif*, 2006 at Regional Agricultural Research Station, Tirupati, situated at an altitude of 182.90 m above mean sea level, 13° N latitude and 79° E longitude. The soil is sandy clay loam with medium fertility. The materials used and methods followed pertaining to the present investigation are presented hereunder.

3.1 MATERIALS

The experimental material consisted of 29 released/pre-release cultures/advanced breeding lines of groundnut. The material was made available for the study by the Senior Scientist (Plant Breeding), Regional Agricultural Research Station, Tirupati. The details of genotypes and their pedigree information are furnished in the Table 1. In the subsequent chapters, released/pre-release cultures/advanced breeding lines would be referred as genotypes/cultivars.

3.2 METHODS

3.2.1 Field layout

The experiment was laid out in a randomised block design replicated thrice. The crop was sown on 13th July 2006. Each genotype was sown in three rows of 5 m length and 0.9 m width with a spacing of 30 cm between the rows and 10 cm between the plants with in rows.

3.2.2 Crop husbandry

The field was ploughed and harrowed until a fine tilth of soil was obtained. The crop was raised under rainfed conditions during *kharif*, 2006 and was fertilized at 20 kg N, 40 kg P_2O_5, 50 kg K_2O and 500 kg gypsum ha^{-1} in the form of urea, single super phosphate and muriate of potash respectively. Weeding and plant protection operations were taken up as and when needed during the crop growth uniformly to all genotypes.

3.2.3 Data recording

Observations were recorded on randomly chosen five competitive plants in each genotype in each replication for all morphological characters except days to 50 per cent flowering and days to emergence. Based on destructive sampling data on 3 plants at 18 days interval, physiological parameters *viz.,* LAD, LAI, CGR, NAR, SLA were calculated. The mean values of selected competitive plants were averaged and expressed as mean of the respective characters. The details of data recorded were as follows.

3.2.3.1 Morphological, yield and yield attributes

Days to emergence

Number of days taken from sowing to complete emergence of the seedlings were recorded.

Number of primary branches per plant

Number of all primary branches originating from the main axis were counted as number of primary branches per plant at the time of harvest.

Length of main axis (cm)

Length of main axis was calculated in centimetres from the collar region to the tip of the main axis.

Length of primary branches (cm)

Length of primary branches was measured in centimetres from the collar region to the tip of the primary branches.

Days to 50 per cent flowering

Number of days taken from sowing to the attainment of flowering by 50 per cent of the plants in each genotype and in each replication were recorded.

Leaflet length at 70 DAS (cm)

Leaflet length was measured in centimetres on basal leaflets of third leaf.

Leaflet width at 70 DAS (cm)

Leaflet width was measured on basal leaflets of third leaf.

Length of leaf at 70 DAS (cm)

Length of leaf was measured in centimeters from the base of the petiole to the tip of leaf where two top leaflets originated.

Number of fully expanded leaves at 80 DAS

At 80 days after sowing, number of fully expanded leaves were counted.

Number of mature pods per plant

Number of well filled and matured pods per plant were counted and mean value of total number of mature pods stripped from five plants gave the number of mature pods per plant.

Number of immature pods per plant

The number of immature pods per plant was estimated from the average of total number of immature pods collected from five plants.

Weight of immature pods per plant (g)

Weight of immature pods from five random plants was recorded and the mean was worked out for estimating weight of immature pods per plant.

100-seed weight (g)

Hundred kernels at random were counted and weighed for each genotype in each replication and recorded as 100-seed weight.

Shelling percentage (%)

Shelling percentage was calculated using the formula

$$\text{Shelling (\%)} = \frac{\text{Kernel yield/plant (g)}}{\text{Pod yield/plant (g)}} \times 100$$

Mean value of shelling percentage calculated from five randomly selected plants was recorded as shelling percentage.

Harvest Index (%)

Harvest Index was calculated by using the formula

$$\text{Harvest Index} = \frac{\text{Economic yield per plant (g)}}{\text{Biological yield per plant (g)}} \times 100$$

Mean value of five sample plants per replication was recorded as harvest index in percentage.

Pod yield per plant (g)

Weight of mature pods per plant was taken and the mean value of weight of mature pods from five plants was recorded as weight of mature pods per plant.

3.2.3.2 Physiological characters

Data for the following characters were recorded on sampled plants.

Leaf area duration (LAD) (dm^2 day)

Leaf area duration (LAD) was recorded at 36, 54, 72 and 90 DAS. Leaves were collected from three plants from each treatment in each

replication for calculating LAD. Leaf area was estimated using a leaf area meter (LI-COR Model-3100). The formula used was

$$LAD = \frac{A_1 + A_2}{2} \times (t_2 - t_1)$$

Where,

A_1 = leaf area at time t_1

A_2 = leaf area at time t_2.

Crop growth rate (CGR) (g m^{-2} day^{-1})

Crop growth rate (CGR) was recorded at 36, 54, 72 and 90 DAS using the formula

$$CGR = \frac{w_2 - w_1}{(t_2 - t_1)} \times \frac{1}{p}$$

Where,

w_1, w_2 are plant dry weights per square meter at times t_1 and t_2 respectively and p is the land area.

Dry weights were taken based on three plants after oven drying at 90°C for two days.

Leaf area index (LAI)

Leaf area index (LAI) was estimated at 18, 36, 54, 72 and 90 DAS using the formula

$$LAI = \frac{\text{Total leaf area}}{\text{Unit ground area}}$$

Three plants leaf area was measured by using leaf area meter (LI-COR model-3100) and the average was taken.

Net assimilation rate (NAR) (g dm^{-2} day^{-1})

Net assimilation rate (NAR) was calculated by using the formula at 36, 54, 72 and 90 DAS.

$$NAR = \frac{w_2 - w_1}{t_2 - t_1} \times \frac{\log_e A_2 - \log_e A_1}{A_2 - A_1}$$

where,

w_1, w_2 – Plant dry weights at times t_1 and t_2 respectively

A_1, A_2 – Leaf area at times t_1 and t_2 respectively.

Specific leaf area (SLA) (cm^2 g^{-1})

Specific leaf area (SLA) was recorded at 18, 36, 54, 72 and 90 DAS days after sowing. Leaves were collected from three plants from each genotype in each replication and leaf area was estimated using a leaf area meter (LI-COR Model-3100). They were dried in a hot air oven at 90°C for two days and dry weight was recorded. The formula used was

$$SLA = \frac{\text{Leaf area } (cm^2)}{\text{Leaf dry weight (g)}} \times 100$$

SCMR

Soil Plant Analytical Development (SPAD) chlorophyll meter readings (SCMR) was recorded at 60 DAS with SPAD chlorophyll meter

(SPAD-502, Minolta corp., Ramsey, NJ). Measurements were made on the 3rd leaf from top of main axis of five plants.

Germination percentage

Germination percentage was calculated by using the formula

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds sown}} \times 100$$

Ten seeds were raised under *in-vitro* conditions and germination percentage was recorded.

Seedling vigour index

Seedling vigour index (SVI) was calculated by using the formula

SVI = Total length of seedling x Germination percentage

Total length of seedling was measured in centimeters and it was multiplied with germination percentage to get seedling vigour index.

Harvest index

Harvest index (HI) was estimated after harvest using the formula

$$\text{Harvest Index} = \frac{\text{Economic yield / plant (g)}}{\text{Biological yield / plant (g)}} \times 100$$

Economic yield and biological yield was estimated from five plants and the average was taken to calculate harvest index.

3.3 STATISTICAL ANALYSIS

The data collected on competitive plants in all the entries in different replications were averaged replication wise and mean values were subjected for statistical analysis as follows

i. Analysis of variance
ii. Estimation of genetic parameters *viz.,* genotypic and phenotypic coefficients of variation, heritability (broad sense), genetic advance and genetic advance as per cent of mean.
iii. Estimation of genetic divergence using Mahalanobis's D^2 analysis.
iv. Estimation of phenotypic and genotypic correlations and
v. Path co-efficient analysis.

3.3.1 Analysis of variance

The data for different characters were statistically analysed as per Panse and Sukhatme (1961).

$$Y_{ij} = \mu + g_i + r_j + e_{ij}$$

Where,

y_{ij} = phenotypic observation in i^{th} genotype and j^{th} replication
μ = General mean
g_i = Effect of i^{th} genotype
r_j = Effect of j^{th} replication
e_{ij} = Random error associated with i^{th} genotype and j^{th} replication.

The analysis of variance for each character was carried out as indicated below.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-ratio
Replication	(r-1)	RSS	M_r	M_r / M_e
Genotypes	(t-1)	VSS	M_v	M_v / M_e
Error	(r-1) (t-1)	ESS	M_e	
Total	(rt-1)			

Where,

r = number of replications

t = number of genotypes

M_r = Mean sum of squares due to replications

M_v = Mean sum of squares due to genotypes

M_e = Mean sum of squares due to error

The significance test was carried out by referring to 'F' table value given by Fisher and Yates (1967).

3.3.2 Estimation of genetic parameters

The data obtained from the analysis of variance were used to estimate the following genetic parameters.

3.3.2.1 Phenotypic and genotypic variance

The phenotypic and genotypic variances were estimated according to the method of Lush (1940)

Genotypic variance($\sigma^2 g$) =

$$\frac{\textit{Mean squares due to genotypes} - \textit{Mean squares due to error}}{\textit{Number of replications}}$$

Phenotypic variance ($\sigma^2 p$) = ($\sigma^2 g$) + variance due to error ($\sigma^2 c$)

3.3.2.2 Phenotypic and genotypic coefficients of variation (PCV) and (GCV)

These were computed according to Burton (1952)

$$\text{Phenotypic co-efficient of variation (\%)} = \frac{\text{Phenotypic standard deviation}}{\text{General mean}} \times 100$$

$$\text{Genotypic co-efficient of variation (\%)} = \frac{\text{Genotypic standard deviation}}{\text{General mean}} \times 100$$

Categorization of the range of variation was affected as proposed by Sivasubramanian and Menon (1973).

Less than 10%	:	Low
10-20%	:	Moderate
More than 20%	:	High

3.3.2.3 Heritability in broad sense [h² (b)]

Heritability in broad sense was estimated using the formula of Allard (1960).

$$\text{Heritability } [h^2 (b)] = \frac{\text{Genotypic variance } (\sigma^2 g)}{\text{Phenotypic variance } (\sigma^2 p)} \times 100$$

As suggested by Johnson *et al.* (1955), [h^2 (b)] estimates were categorised as

Low	:	0-30%
Medium	:	30-60%
High	:	61% and above

3.3.2.4 Genetic advance (GA)

This was estimated as per the formula proposed by Lush (1940) and Johnson *et al.* (1955).

$$GA = k. \sigma p . h^2 (b)$$

Where,

σp = Phenotypic standard deviation

h^2 (b) = Heritability in broad sense

K = Selection differential at 5% selection intensity, which accounts to a constant value of 2.06 (Lush, 1940).

3.3.2.5 Genetic advance as per cent of mean (GAM)

$$GAM = \frac{GA}{Grand\ mean} x\ 100$$

The range of genetic advance as per cent of mean was classified as suggested by Johnson *et al.* (1955).

Low	:	less than 10%
Medium	:	10-20%
High	:	More than 20%

3.3.3 Genetic divergence

3.3.3.1 Genetic divergence studies through Mahalanobis's D^2 statistic

The data collected on different characters were analysed through Mahalanobis's generalised distance (D^2) and canonical root analysis.

Mahalanobis's generalised distance (D^2)

Genetic diversity between genotypes was estimated using D^2 analysis as given by Mahalanobis (1936). The D^2 value between 'i^{th}' and 'j^{th}' genotypes for 'P' characters were calculated as

$$D_{ij}^2 = P \sum_{t=1} (\bar{Y}_{it} - \bar{Y}_{jt})$$

Where,

$\bar{Y}_{it}$ = Uncorrelated mean value of i^{th} genotype for t character.

$\bar{Y}_{jt}$ = Uncorrelated mean value of j^{th} genotype for 't' character.

D^2_{ij} = D^2 value between i^{th} and j^{th} genotypes.

Test of significance

Variances were calculated for all the characters under the study and significance was tested. Analysis of covariance for the character

pairs was estimated on the basis of mean values (Panse and Sukhatme, 1961). A dispersion table was prepared from the estimates. After testing the differences between genotypes for each of the characters, a simultaneous test of significance of differences between the mean values of a number of correlated variables was done (Rao, 1952) by using 'V' statistic which inturn utilised Wilk's 'λ' criterion (Wilks, 1932). The sum of squares and sum of products of error and error plus variety variance-covariance matrix were used for this purpose.

The estimates of 'λ' (Wilk's criterion) were done using the following formula

$$\lambda = \frac{(E)}{(E+V)}$$

Where,

(E) = Determinant of error matrix

(E + V) = Determinant of error + varieties matrix

The significance of 'λ' was tested by

$X^2_{pq} = V = -m \log_e \lambda$

Where,

m = n – (p+q+1)/2 with pq degree of freedom

n = Degree of freedom of error + varieties

p = Number of characters

q = Number of genotypes – 1

$\log_e \lambda = 2.3407 \log_{10} \lambda$

Transformation of correlated variables

Transformation was done using pivotal condensation method. Transformation of correlated variables into standardised uncorrelated ones was done before working out the D^2 values because computation of D^2 values was reduced to simple enumeration of differences in mean values of various characters of the two genotypes *i.e.,* Σdi^2.

Computation of D^2 values

The D^2 values between 'i^{th}' and 'j^{th}' genotypes for 'p' characters was calculated as

$$D_{ij} = P \Sigma_{t=1} (Y_{it} - Y_{jt})^2$$

Where,

Y_{it} = Uncorrelated mean value of i^{th} genotype for t character.

Y_{jt} = Uncorrelated mean value of j^{th} genotype for t character.

D^2_{ij} = D^2 value between i^{th} and j^{th} genotype.

Testing the significance of D^2 values

The D^2 values obtained for a pair of genotypes were taken as the calculated value of x^2 and tested against tabulated x^2 at 'p' degree of freedom where 'p' is the number of characters considered.

Determination of group constellations or clusters

Grouping of the genotypes into different clusters was done by using Tocher's method as described by Rao (1952). The criterion used in

clustering by this method is that any two variables belonging to the same cluster should at least, on an average show a smaller D^2 value among themselves than those belonging to two different clusters.

The first step in grouping of the genotypes into different clusters was to arrange the genotypes in the order to know their relative distance from each other. For this purpose, D^2 values of all the possible combinations in each genotype was arranged in increasing order of the magnitude in a tabular form as described by Singh and Chaudhary (1977). To start with, the genotypes having the smallest distance from each other were considered first to which third population having the smallest average D^2 value from the first two genotypes were added. Then comes the nearest fourth genotype and so it goes on. At certain stage, when it was felt that after adding a variety, there was an abrupt increase in the average D^2 value, then that variety was not considered for inclusion in that cluster. Like this the process was continued till all the genotypes were included in one or the other cluster. After the formation of the clusters, the average inter and intra-cluster divergence distances were calculated.

Average intra-cluster distance

For the measurement of intra-cluster distances, the formula used was $\Sigma D^2_j / n$.

Where,

D^2_j = The sum of distances between all possible combinations (n) of the populations included in a cluster.

Average inter-cluster distance

Clusters were taken one by one and their distance from other cluster was calculated. The distance between two clusters was the sum of the D^2 values between the members of other clusters divided by the product of number of genotypes in both the clusters under consideration.

Cluster diagram

The square root of average D^2 was used to denote the distance in cluster diagram.

Contribution of individual characters towards divergence

In all combinations, each character was ranked on the basis of its contribution towards divergence between two entries ($d_i = Y_{it} - Y_{ij}$). Rank 1 was given to the highest mean difference and rank 'p' to the lowest difference, where 'p' is the total number of characters. Percentage contribution of each character (x) towards divergence was calculated using the formula.

$$X = \frac{N \times 100}{M}$$

Where,

N = Number of genotype combinations where the character ranked first

M = All possible combinations of number of genotypes

3.3.3.1.2 Canonical analysis

Canonical analysis was used to verify the clustering pattern obtained by Mahalanobis's D^2 statistic. The canonical vectors or roots were calculated to represent the genotypes in the graphical form (Rao, 1952).

Calculation of sum of squares and sum of products

The correlated standard means were transformed into uncorrelated standardized variables. For each character and character contributions, sum of squares and sum of products were computed using the transformed variables to obtain the matrix of variances and covariances (matrix A). From matrix A, matrix $(A)^p$ was derived where 'p' is the number of characters.

Calculation of the first vector

The first approximate trial vector was obtained by first getting the column totals of matrix $(A)^p$ and then by dividing each of the column totals by the highest quantity among them. The canonical vectors were determined by iteration starting with the trial vector. The second approximation vector was obtained by multiplying each column of matrix $(A)^p$ with the first trial vector by the highest value among them. This new vector was then used as a trial vector and the procedure was repeated

till the elements of the two approximation vectors were same. The vectors were then standardized by dividing them by the correlated sum of squares of these vectors. The first root 'λ_1' was calculated as the 'p^{th}' root of the highest column total of the last approximation.

Calculation of the second vector

For getting the second vector 'λ_2' the original $(A)^p$ matrix was transformed and represented as $(B)^p$. Each $(I, j)^{th}$ element in $(B)^p$ was calculated as follows:

$(I, j)^{th}$ element = $(A)^p - \lambda_1 X_i^{th}$ element of the first vector

The procedure followed in case of matrix 'A' was repeated to obtain second canonical root.

Estimation of 'Z' values

From the values of Y_1, Y_2, ... Y_{ij}, the mean values of characters Z_1, Z_2, Z_3 were calculated as $Z_1 = (Y)(V_1)$; $Z_2 = (Y)(V_2)$; $Z_3 = (Y)(V_3)$.

Contribution of vectors towards divergence

Total contribution of all vectors was given by sum of diagonal elements in matrix A.

$$\text{Per cent of vector } 1 (\lambda_1) = \frac{\lambda_1 \times 100}{\text{Total contribution of all vectors}}$$

$$\text{Per cent of vector } 2 (\lambda_2) = \frac{\lambda_2 \times 100}{\text{Total contribution of all vectors}}$$

3.3.4 Character association

Genotypic and phenotypic correlation co-efficients were calculated using the method given by Johnson *et al.* (1955).

3.3.4.1 Genotypic correlation co-efficients (r_g)

$$r_g(x_i x_j) = \frac{\mathrm{cov}_g(x_i x_j)}{\sqrt{V_g(x_i) V_g(x_j)}}$$

Where,

$r_g(x_i x_j)$ = Genotypic correlation between 'i^{th}' and 'j^{th}' characters

$V_g(x_i)$ = Genotypic variance of 'i^{th}' character

$V_g(x_j)$ = Genotypic variance of 'j^{th}' character

$cov_g(x_i x_j)$ = Genotypic covariance between 'i^{th}' and 'j^{th}' characters.

3.3.4.2 Phenotypic correlation coefficients (r_p)

$$r_p(x_i x_j) = \frac{\mathrm{cov}_p(x_i x_j)}{\sqrt{V_p(x_i) V_p(x_j)}}$$

Where,

$r_p(x_i x_j)$ = Phenotypic correlation between 'i^{th}' and 'j^{th}' characters

$V_p(x_i)$ = Phenotypic variance of 'i^{th}' character

$V_p(x_j)$ = Phenotypic variance of 'j^{th}' character

$Cov_p(x_i x_j)$ = Phenotypic covariance between 'i^{th}' and 'j^{th}' characters.

The significance of correlation co-efficients was tested by comparing the genotypic and phenotypic correlation co-efficients with table value (Fisher and Yates, 1967) at (n-2) degree of freedom at 5% and 1% levels of significance, where 'n' denotes the number of treatments used in the calculations.

3.3.5 Path co-efficient analysis

The direct and indirect effects of the yield components on the yield were estimated by path co-efficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

The path co-efficients were obtained by solving the 'p' normal equations following the matrix method given by Singh and Chaudary (1977).

The following set of simultaneous equations were found and solved for estimating direct and indirect effects.

$$r_{1y} = p_{1y} + r_{12}p_{2y} + r_{13}p_{3y} + \ldots\ldots\ldots\ldots + r_{1i}p_{iy}$$
$$r_{2y} = r_{21}p_{1y} + p_{2y} + r_{23}p_{3y} + \ldots\ldots\ldots\ldots + r_{2i}p_{iy}$$
$$\vdots$$
$$r_{iy} = r_{i1}p_{1y} + r_{i2}p_{2y} + r_{i3}p_{3y} + \ldots\ldots\ldots\ldots + p_{iy}$$

Where,

r_{1y} to r_{iy} = Co-efficients of correlation among causal factors

p_{1y} to p_{iy} = Direct effects of characters '1' to i on character 'y'

The above equations were written in matrix form as under:

$$\underset{A}{\begin{pmatrix} r_{1y} \\ r_{2y} \\ r_{3y} \\ . \\ . \\ . \\ r_{iy} \end{pmatrix}} = \underset{C}{\begin{pmatrix} 1 & r_{12} & r_{13} \ldots\ldots\ldots\ldots r_{1i} \\ r_{21} & 1 & r_{23} \ldots\ldots\ldots\ldots r_{2i} \\ r_{31} & r_{32} & 1 \ldots\ldots\ldots\ldots r_{3i} \\ & & \\ & & \\ r_{i1} & r_{i2} & r_{i3} \ldots\ldots\ldots\ldots r_{ii} \end{pmatrix}} \underset{B}{\begin{pmatrix} p_{1y} \\ p_{2y} \\ p_{3y} \\ . \\ . \\ . \\ p_{iy} \end{pmatrix}}$$

Then $B = [C]^{-1}A$

Where,

$$[C] = \begin{pmatrix} C_{11} & C_{12} & C_{13} \ldots\ldots\ldots\ldots C_{1i} \\ C_{21} & C_{22} & C_{23} \ldots\ldots\ldots\ldots C_{2i} \\ . & . & \\ . & . & \\ . & . & \\ C_{i1} & C_{i2} & C_{i3} \ldots\ldots\ldots\ldots C_{ii} \end{pmatrix}$$

Then, direct effects were calculated as follows:

$$P_{1y} = \sum_{i=1}^{I} C_{1i}\, r_{1y}$$

$$P_{2y} = \sum_{i=2}^{I} C_{2i}\, r_{2y}$$

$$P_{iy} = \sum_{i=1}^{I} C_{ij}\, r_{iy}$$

Besides the direct and indirect effects, the residual effect which measures the contribution of the characters not considered in the causal scheme was obtained.

Residual effect (P_{RY}) = $1-[p_{1y}r_{1y} + p_{2y}r_{2y} + \ldots\ldots\ldots + p_{iy}r_{iy}]^2$

Where,

P_{RY} = Residual effect

P_{iy} = Direct effect of x_i on y

r_{iy} = Correlation coefficient of x_j and y

The scales for path coefficients as proposed by Lenka and Mishra (1973) are as follows:

Value of direct or indirect effect	Rate of scale
0.00-0.09	Negligible
0.10-0.19	Low
0.20-0.29	Moderate
0.30-0.99	High
More than 1.00	Very high

3.4 DIVERGENCE STUDIES BY USING RAPD MARKERS

Detection of molecular polymorphism among twelve selected genotypes of groundnut was performed using RAPD markers.

3.4.1 Plant materials

The materials used for the study comprised 12 genotypes of groundnut. The genotypes were sown in pots under sterile conditions. Afterwards 15 days old healthy leaf samples were used for DNA extraction.

3.4.2 Extraction of plant DNA

DNA was extracted as per modified CTAB (Cetyl trimethyl ammonium bromide) method given by Murray and Thompson (1980).

a) Healthy leaves were collected from young plants (10 days old) and brought to laboratory.
b) The leaves were cut into small pieces and homogenized completely with liquid nitrogen using pestle and mortar.
c) Leaf powder was taken into 2 ml eppendorf tube, and 1 ml of pre heated (65°C) extraction buffer (containing 2% (CTAB, 100 mM Tris, 20 mM EDTA, 1.4 M Nacl, 1% PVP and 1% β-mercaptoethalnol) was added and mixed thoroughly.
d) Contents were mixed by vortexing for few minutes and incubated at 60°C for 1 hr. Tubes were shaken once in 15 minutes.
e) Samples were kept aside for 5 minutes.
f) Samples were centrifuged at 10,000 rpm for 10 minutes.
g) Supernatant was collected and to the supernatant equal volume of phenol (25 phenol: 24 chloroform:1isoamyl alcohol) was added and centrifuged at 10,000 rpm for 10 minutes.
h) Supernatant was collected. RNAase (for each 100 µl of sample, 1 µl of RNAase) was added and kept aside for 10 minutes. To it equal volume of chloroform: octonol (24:1) was added and mixed by inversion. Tubes were kept in hot water bath for 30

minutes at 60°C and later centrifuged at 10,000 rpm for 10 minutes.

i) Supernatant was collected and to it half volume of 5 M Nacl and double the volume of 95% ethanol was added. Tubes were kept at -20°C for 1 hour.

j) Samples were centrifuged at 10,000 rpm for 10 minutes.

k) Supernatant was collected and to it 200 µl of isopropanol and 10 µl of sodium acetate was added and kept at -20°C for overnight.

l) Samples were centrifuged at 13,000 rpm for 20 minutes.

m) Supernatant was discarded. To the pellet 400 µl of 70% ethanol was added and centrifuged at 10,000 rpm for 10 minutes. This step was repeated twice.

n) Pellet was allowed to dry and after drying pellet was dissolved in 150 µl of distilled water and stored at -20°C for further use.

3.4.3 Random amplification of polymorphic DNA (RAPD) – optimisation of polymerase chain reaction (PCR)

Standardization of PCR reaction was done by varying the concentration of template DNA (25, 50, 75 and 100 ng), Taq polymerase (0.5, 1.0 and 1.5 units) and $Mgcl_2$ (concentration 3.0, 5.0 and 7.5 mM). The standardized amplification assay was as follows: Template DNA 25 ng, Taq DNA polymerase (*Genei*) 0.5 units, $MgCl_2$ 5mM; dNTP (Genei) 100 µl each, primer (operon technology USA) 1 µM, Buffer (Genei) 10x in

a reaction volume of 25 µl. Amplification was carried out on Corbett research thermocycler with the following temperature profile. The initial denaturation of template DNA at 94°C for 5 min followed by 45 cycles of denaturation at 92°C for 1 min, annealing at 37°C for 1 min, extension at 72°C for 2 min with final elongation at 72°C for 5 minutes.

3.4.4 Primer survey and selection

Primer screening was carried out using 60 primers from OP series (Operon Technology, USA) for molecular variation analysis. The primer which gave reproducible and recordable amplifications was used to analyze variability of the species. The list of primers used in the study are given in Table 2.

3.4.5 Agarose gel electrophoresis (AGE)

To the amplified product obtained after the PCR reaction (25 µl), 5 µl gel loading dye (Bromophenol Blue) was added and loaded into individual wells of 1% agarose gel. 1 kb ladder (Fermantas) was loaded in first lane as marker in 1 x TBE buffer. Electrophoresis was carried out at 100 v for 3 h and the gel was stained with ethidium bromide (1 µg/ml). After electrophoresis the gel was observed under U.V. light using Alpha innotech corporation geldoc system.

3.4.6 Scoring and data analysis

Each amplified product was considered as RAPD marker. Data were entered using a matrix in which all observed bands or characters

were listed. The RAPD pattern of each isolate was evaluated, assigning character state '1' to all the bands that could be reproducible and detected in the gel and 'O' for the absence of band.

The data matrix thus generated was used to calculate Jaccard's similarity coefficient for each pair-wise comparison. The co-efficients were calculated *in silico* following Jaccard (1908), using the following formula.

Similarity co-efficient = a/n

Where,

a = Number of matching bands for each pair of comparision

n = Total number of bands observed in two samples.

The similarity co-efficients were subjected to Unweighted Pair-Group Method of Arithmetic Average (UPGMA) cluster analysis to group the isolates based on their overall similarities. Statistical Package for Social Sciences (SPSS) was used for the cluster analysis and subsequent dendrogram preparation.

Table 1: Details of 29 released and pre-release cultivars of groundnut

S.No.	Cultivar	Pedigree	Salient characteristic features
1.	Tirupati-1	Selection from germplasm line EC 106983/3A	Erect growth habit with four primaries, moderate stature foliage, light green, leaflets narrow with whitish ashy coat on both the surfaces, suitable for scarce and low rainfall areas of Andhra Pradesh, also suitable for late sown conditions of rice fallows and coastal sands, highest shelling outturn of 76-79%, SMK 95%, oil content 49% (seeds), 100-pod weight 70-80 g, 100-seed weight 33-36 g, pods small, two seeded, slightly beaked, reticulated with slight constriction, non-dormant, duration-100 days.
2.	Tirupati-2	Gang-1 x NC Fla-14	Erect growth habit with 4 to 5 primaries, foliage light green, leaflets large and ablong, medium stature, possesses high peg strength and recommended for light textured black soil areas, more suitable for *rabi* cultivation. Tolerant to Kalahasti malady, shelling out-turn 75-76%, oil 49%, non-dormant, SMK 90%, pods small 2 seeded, reticulated, shallow to moderate constriction and moderate beak, duration 105 days.
3.	Tirupati-3	Isogenic selection from TMV-10	Virginia bunch type, dark green foliage, 6-7 primaries, 3-4 secondaries, narrow leaflets, dormant, shelling out-turn 70-73%, pods 2-seeded, medium bold, without constriction, slight reticulation. Testa colour red. Kalahasti malady resistant. LLS tolerant, duration 120-135 days. High oil content (52%).
4.	Tirupati-4	JL-24 x AH 316/s	Erect growth habit with 4-5 primaries, foliage green with large leaflets, suitable for both *Kharif* and *rabi* seasons, tolerant to mid-season moisture stress, shelling out-turn 72-76%, oil 49%, non-dormant, pods 2 seeded medium bold with moderate to deep constriction moderate reticulation and slight beak. 100 pod weight 100-150 g, 100-kernel weight 43-47 g. Duration 105 days.
5.	Narayani	JL-24 x Ah 316/s	Erect growth habit with 4-5 primaries, leaflets long and large, elliptical and green, stem with light greenish purple pigmentation. Suitable for both the seasons, tolerant to mid-season moisture stress. Synchronous maturity of pods,

Contd….

S.No.	Cultivar	Pedigree	Salient characteristic features
			light-red testa, shelling out-turn 75-76%, oil content 49%, pods, 2-seeded, medium bold with moderate constriction, moderate reticulation and slight beak, 100-pod weight 90-100 g, 100-kernel weight 40-45 g, duration-100 days.
6.	Kalahasti	TCG-1709 x TCG-1518	Decumbent growth habit, short stature, leaflets short, broad and oval shaped, dark green with 6-8 primaries, resistant to Kalahasti malady and recommended for *rabi* cultivation through out Andhra Pradesh specifically to endemic areas of Kalahasti malady suitable for high rainfall areas, shelling out-turn 74-76%, oil content 52%, pods 2 seeded, medium bold with shallow constriction, slight reticulation and moderate beak, SMK 85-90%, 100-pod weight 95-105 g, 100-kernel weight, 50 g and red testa. Duration 105-110 days.
7.	Prasuna	TCG-1717 x TCG-1518	4 to 5 primaries, dark green foliage, medium sized, elliptical leaflets, medium bold pods with slight constriction, reticulation and moderate beak. 105-110 days duration, testa rose, moderately tolerant to Kalahasti malady, moderately tolerant to LLS and sucking insects. Oil content 50%.
8.	Abhaya	K-134 x TAG-24	Short and compact type, pods mostly 3-seeded, reticulated with slight beak. Leaflets narrow, elliptical and dark green, pods slender and medium bold. Testa colour rose. Duration 105-110 days, high WUE, drought and LLS tolerant, tolerant to sucking insects and spodoptera. High oil content (52%).
9.	TCGS-156	Chico x NCAC-17090	Oblong, elliptic, medium size leaflets, erect, green foliage, medium bold pods with moderate constriction, smooth pod surface and prominent beak. Rose testa. Duration 105 days. Moderately tolerant to LLS. Oil 47%, leaf tip pointed, tapering, leaflet margin is wavy.
10.	TCGS-653	JL-24 x ICGV-86031	Erect, 4-5 primaries, leaflets narrow, elliptical, dark green, pods 2-seeded, medium bold, smooth with slight constriction and beak. 110 days duration. Rose testa, oil-49%.

Contd….

S.No.	Cultivar	Pedigree	Salient characteristic features
11.	TIR-23	K-134 x TAG-24	Short stature, dark green foliage, pods reticulated, high WUE, pods 2-seeded with no constriction. Susceptible to LLS.
12.	TCGS-888	TIR-46 x JUG-37	Short, compact plant type, 5-6 primaries, narrow leaflets, oval and dark green, duration 95 days. High WUE and drought tolerant. Thin pod shell. Smooth pods with slight to moderate constriction, slight beak, flesh testa.
13.	TCGS-913	Tirupati-4 x TIR-45	Short, compact plant type, 5-6 primaries, leaflets narrow, medium sized, oval and dark green. 95 days duration, high WUE, LLS susceptible, pods 2-seeded.
14.	K-134	JL-24 x Kadiri-3	Erect growth habit, leaflets dark green, long and narrow with wavy margin, 4-5 primaries tolerant to drought and late leaf spot, recommended for cultivation in low rainfall and high rainfall areas. Pegs strong, stays green upto harvest, shelling out-turn 75-77%, oil content 49%. Pods 2-3 seeded, slight constriction, light reticulation and slight beak, 100-pod weight 80-90 g, 100-kernel weight 38-42 g. SMK 85-90%, dormant upto 15 days. Duration 105-110 days.
15.	K-4	DH-3-30 x NCAC-2230	Short stature, leaflets short, broad, light green, ovate to obovate, 4-5 primaries, pegs strong and sturdy, pods clustered around the main tap root in the soil, suitable for *rabi* cultivation in coastal sands and rice fallows. 100-pod weight 80-90 g, 100-kernel weight 38-42 g. Shelling out-turn 74%, pods medium bold with basal portion of pods slightly bolder than apical portion (tapering) with moderate reticulation and moderate beak, oil content 48%. Duration 90 days.
16.	K-6	JL-24 x Ah 316/s	Erect growth habit, with four primaries, light green leaflets, large and oblong, recommended for *rabi* cultivation, oil content 48%, pods medium bold. Shelling out-turn 72%. Duration 95-100 days.

Contd….

S.No.	Cultivar	Pedigree	Salient characteristic features
17.	TCGS-717	Selection from Tirupati-4	Erect, narrow leaflets compared to Tirupati-4. Duration 105 days, 4-5 primaries, green foliage, tolerant to mid-season stress, shelling out-turn 72-76%, oil 49%, non dormant, pods 2 seeded with no constriction, moderate reticulation and slight beak. 100-seed weight 43-47 g. 100-pod weight 100-150 g.
18.	TCGS-722	Selection from Tirupati-4	Erect, 4-5 primaries, green foliage, tolerant to mid-season stress, shelling out-turn 72-76%, oil 49%, non dormant, pods 2 seeded, slight constriction, moderate reticulation. 100-pod weight 100-150 g, 100-kernel weight, 43-47 g. Duration 105 days.
19.	TCGS-750	Tirupati-3 x ICGV-86031	Short Virginia bunch, leaflets round, dark green, medium sized, leaves and stems hairy. 5-6 primaries, pods 2-seeded ,slight constriction, smooth, slight beak. Tolerant to sucking insects. 110-120 days duration.
20.	TG-47	TAG-24 x TG-19	Short, statured, compact type, narrow, dark green and elliptic leaflets, pods mostly 3-seeded, bold with moderate constriction and beak. Tolerant to LLS, 115-120 days duration. Oil content 45%. Pods with slight reticulation.
21.	TG-39	Not available	Short statured, compact type, narrow, dark green and elliptic leaflets, pods 2 seeded, bold with moderate constriction and beak. Tolerant to LLS. Duration 115-120 days, oil content 45%.
22.	TCGP-6	JL-24 x ICG-86031	Tall, erect, leaflets broad, elliptic, dark green and thick. Pods bold, mostly 2-seeded, moderate reticulation, moderate constriction, 105-110 days duration.
23.	JL-24	Selection from EC-94943	Erect, 4-5 primaries, broad, elliptic, dark green leaflets, pods 2 seeded, smooth, slight beak. Testa rose. Pods with moderate constriction. Duration 105 days.

Contd….

S.No.	Cultivar	Pedigree	Salient characteristic features
24.	TMV-2	Selection from Gudiyatham bunch	Erect growth habit, leaflets light green and large. Pods small with moderate reticulation, slight constriction and slight beak, shelling out-turn 76-77%, oil per cent 49%. Duration 105 days.
25.	TCGS-645	JL-24 x ICGV-86398	Virginia bunch, leaflets broad and round, dark green with ashy coat. Pods mostly 2-seeded, medium bold with slight reticulation and beak, tolerant to sucking insects and spodoptera.
26.	TCGS-91	JL-24 x EC-76446 (292)	Erect, leaflets narrow, elliptic, light green, pods 2-seeded, reticulated with slight constriction and beak. Duration 105 days, rose testa, tolerant to LLS.
27.	JL-501	Selection from TAG-24	Decumbent type, dark green, elliptic leaflets, pods 2-seeded medium bold, 4-5 primaries, LLS tolerant, duration 110 days.
28.	R-2001-2	ICGS-11 x ICG-4728	Decumbent type, dark green foliage, 4-5 primaries. Pods 2-seeded, LLS tolerant. 110 days duration.
29.	TIR-9	ICGS-76 x CSMG-84-1	Short, compact, dark green foliage, leaflets round, narrow, pods mostly 2-seeded, smooth with slight reticulation and constriction. High WUE and drought tolerant. Rose testa.

Table 2: List of random primers along with their nucleotide sequence used for PCR amplification in groundnut.

Sl. No.	Primer code	Nucleotide sequence (5' – 3')
1	OPA – 1	CAG GCC CTT C
2	OPA – 2	TGC CCA GCT G
3	OPA – 3	AGT CAG CCA C
4	OPA - 4	AAT CGG GCT G
5	OPA – 5	AGG GGT CTT G
6	OPA - 6	GGT CCC TGA C
7	OPA - 7	GAA ACG GGT G
8	OPA - 8	GTG ACG TAG G
9	OPA - 9	GGG TAA CGC C
10	OPA - 10	GTG ATC GCA G
11	OPA – 11	CAA TCG CCG T
12	OPA – 12	TCG GCG ATA G
13	OPA – 13	CAC GAC CCA C
14	OPA – 14	TCT GTG CTG G
15	OPA – 15	TTC CGA ACC C
16	OPA – 16	AGC CAG CGA A
17	OPA – 17	GAC CGC TTG T
18	OPA – 18	AGG TGA CCG T
19	OPA – 19	CAA ACG TCG G
20	OPA – 20	GTT GCG ATC C
21	OPH – 1	GTC GGA GAA
22	OPH - 2	TCG GAC GTG A
23	OPH – 3	AGA CGT CCA C
24	OPH – 4	GGA AGT CGC C
25	OPH – 5	AGT CGT CCC C
26	OPH – 6	ACG CAT CGC A
27	OPH – 7	CTG CAT CGT G
28	OPH – 8	GAA ACA CCC C
29	OPH – 9	TGT AGC TGG G
30	OPH – 10	CCT ACG TCA G

Table 2 contd…

Sl. No.	Primer code	Nucleotide sequence (5’ – 3’)
31	OPH – 11	CTT CCG CAG T
32	OPH – 12	ACG CGC AGT T
33	OPH – 13	GAC GCC ACA C
34	OPH – 14	ACC AGG TTG G
35	OPH – 15	AAT GGC GCA G
36	OPH – 16	TCT CAG CTG G
37	OPH – 17	CAC TCT CCT C
38	OPH – 18	GAA TCG GCC A
39	OPH – 19	CTG ACC AGC C
40	OPH – 20	GGG AGA CAT C
41	OPJ – 1	CCG GGC ATA A
42	OPJ - 2	CCC GTT GGG A
43	OPJ – 3	TCT CCG CTT G
44	OPJ – 4	CCG AAC ACG G
45	OPJ – 5	CTC CAT GGG G
46	OPJ – 6	TCG TTC CGC A
47	OPJ – 7	CCT CTC GAC A
48	OPJ – 8	CAT ACC GT G
49	OPJ – 9	TGA GCC TCA C
50	OPJ – 10	AAG CCC GAG G
51	OPJ – 11	ACT CCT GCG A
52	OPJ – 12	GTC CCG TGG T
53	OPJ – 13	CCA CAC TAC C
54	OPJ – 14	CAC CCG GAT G
55	OPJ – 15	TGT AGC AGG G
56	OPJ – 16	CTG CTT AGG G
57	OPJ – 17	ACG CCA GTT C
58	OPJ – 18	TGG TCG CAG A
59	OPJ – 19	GGA CAC CAC T
60	OPJ – 20	AAG CGG CCT C

CHAPTER-IV

RESULTS

The data collected on 16 morphological, yield and yield attributes and 10 physiological attributes of 29 released and pre-release cultures of groundnut were subjected to biometrical analyses *i.e.* variability, genetic divergence (through D^2 statistic and RAPD markers), character association and path co-efficient analysis. The results obtained from these investigations are furnished in this chapter under the following headings.

4.1 MEAN PERFORMANCE

4.2 GENETIC PARAMETERS

4.3 GENETIC DIVERGENCE

4.4 CHARACTER ASSOCIATION

4.5 PATH CO-EFFICIENT ANALYSIS

4.1 MEAN PERFORMANCE

The analysis of variance for different morphological, yield and yield attributes and physiological characters was done separately.

4.1.1 Morphological, yield and yield attributes

The data recorded on sixteen morphological, yield and yield attributes were subjected to analysis of variance and is presented in Table 3. The analysis of variance for most of the morphological, yield and yield attributes revealed significant differences among the cultivars

except for number of primary branches per plant, number of mature pods per plant and number of immature pods per plant. The mean performance of these twenty nine cultivars is presented in Table 4.

4.1.1.1 Days to emergence

The range for days to emergence varied from 4.00 days to 6.67 days (Prasuna and TCGP-6) with a general mean of 5.01 days. The cultivars, Tirupati-1, Tirupati-2, Narayani, TCGS-156, TCGS-653, TMV-2 and TCGS-913 showed early emergence.

4.1.1.2 Number of primary branches per plant

Number of primary branches per plant ranged from 4.87 to 7.13 with a general mean of 5.79. Most of the cultivars had five branches per plant except TG-47 (seven primary branches per plant).

4.1.1.3 Length of main axis (cm)

The mean length of main axis ranged from 20.45 to 49.61 cm, with a general mean of 31.67 cm. Among the cultivars, TG-47 was the shortest (20.45 cm) and Narayani (49.61 cm) was the tallest. Thirteen cultivars exceeded the general mean value.

4.1.1.4 Length of primary branches (cm)

The mean ranged from 21.69 to 51.14 cm with a general mean of 35.59 cm. The cultivar, Narayani recorded maximum length (51.14 cm)

whereas it was minimum in TG-39 (21.69 cm). Thirteen cultivars recorded greater value than the general mean.

4.1.1.5 Days to 50 per cent flowering

The range for days to 50 per cent flowering varied from 26.33 to 36.67 with a general mean of 31.53. The cultivars *viz.,* Tirupati-1, Tirupati-2 and K-134 were earlier in flowering than the remaining cultivars.

4.1.1.6 Leaflet length at 70 DAS (cm)

Mean leaflet length ranged from 3.61 cm to 5.86 cm with a general mean of 4.85 cm. The cultivars *viz.,* TCGS-91, TCGS-722 and TCGS-717 showed highest leaflet length and TG-47 showed lowest leaflet length.

4.1.1.7 Leaflet width at 70 DAS (cm)

The mean leaflet width ranged from 1.59 cm to 2.55 cm with a general mean of 2.19 cm. The cultivars *viz.,* TCGS-91, TCGS-156, TCGS-722 showed highest leaflet width and TCGS-888 and TG-47 showed lowest leaflet width.

4.1.1.8 Length of leaf at 70 DAS (cm)

Length of leaf was highest for TCGS-913 (6.64 cm) and lowest for K-4 (4.53 cm) with a general mean of 5.56 cm. Mean leaf length was also high in cultivars, Narayani, TCGS-91 and Tirupati-4.

4.1.1.9 Number of fully expanded leaves at 80 DAS

The mean ranged from 39.00 to 82.67 with a general mean of 55.13. The cultivar, TCGS-717 recorded maximum number of fully expanded leaves (82.67) while TCGS-913 had minimum number of fully expanded leaves at 80 DAS.

4.1.1.10 Number of mature pods per plant

The cultivar, Tiruapti-4 recorded the highest number of mature pods per plant (24.73) while TCGS-913 registered the lowest number of mature pods per plant (11.67). Sixteen cultivars showed more number of matured pods per plant than the general mean (17.60).

4.1.1.11 Number of immature pods per plant

The mean ranged from 4.53 to 12.93 with a general mean of 8.59. In twelve cultivars it was above the general mean value. The cultivar, TIR-9 recorded the highest (12.93) whereas TCGS-645 recorded the lowest value for this trait.

4.1.1.12 Weight of immature pods per plant (g)

The mean weight of immature pods per plant ranged from 0.80 to 6.20 g. Among the cultivars, TG-47 recorded the highest weight of immature pods per plant (6.20 g) whereas TCGS-156 recorded the lowest value (0.80 g). Eleven cultivars exceeded the general mean value (2.53 g).

4.1.1.13 100-seed weight (g)

The 100-seed weight ranged from 21.33 g to 49.33 g with a general mean of 34.85 g. TMV-2 (21.33) and TG-39 (49.33) recorded the lowest and highest 100-seed weight values respectively. Thirteen cultivars exceeded the general mean value (34.85 g).

4.1.1.14 Shelling percentage

The mean ranged from 43.11 to 60.94 per cent. The cultivar, Abhaya recorded the highest shelling percentage (60.94) while TG-39 registered the lowest shelling percentage (43.11). The character general mean was (52.00). Thirteen cultivars exceeded the general mean value.

4.1.1.15 Harvest Index

The mean ranged from 31.70 to 63.66 with an average of 46.24. Among the cultivars, Tirupati-3 recorded the lowest harvest index (31.70) while R-2001-2 recorded the highest harvest index (63.66). Fourteen cultivars recorded higher harvest index than the general mean (46.24).

4.1.1.16 Pod yield per plant (g)

The mean pod yield per plant ranged from 9.13 g to 18.40 g with a general mean value of 13.44 g. The cultivar, Tirupati-4 showed highest pod yield per plant (18.40 g) while TMV-2 recorded the lowest pod yield per plant (9.13 g). Seventeen cultivars exceeded the general mean value (13.44 g).

4.1.2 Physiological characters

The physiological characters viz., leaf area duration (LAD), crop growth rate (CGR), leaf area index (LAI), net assimilation rate (NAR) and specific leaf area (SLA) were estimated at every 18 days interval upto 90 DAS. For subsequent analysis, the data of physiological characters which were found statistically significant were considered.

The data recorded on 10 physiological characters were subjected to analysis of variance and is presented in Table 5. The treatment differences among the twenty nine cultivars were significant for all the characters studied and the mean performance of these cultivars is presented in Table 6.

4.1.2.1 Leaf Area Duration (LAD) (dm^2.day)

LAD at 54 DAS registered an overall mean of 155.81 dm^2.day with means ranging from 87.80 dm^2.day to 242.95 dm^2.day. The cultivar, JL-24 recorded maximum value (242.95 dm^2.day) followed by Tirupati-3 (221.55 dm^2.day) while TIR-9 exhibited minimum value (87.80 dm^2.day). LAD at 72 DAS ranged from 123.11 dm^2.day (TCGS-645) to 323.34 dm^2.day (JL-24) with a general mean of 226.21 dm^2.day. General mean of LAD at 90 DAS was 270.47 dm^2.day with means ranging from 202.28 dm^2.day to 358.67 dm^2.day. The cultivar, TCGS-717 recorded the highest mean value (358.67 dm^2.day) whereas TCGS-645 recorded the

lowest mean value (202.28 dm^2.day). There was an increase in the means of LAD from 54 to 90 DAS in all the cultivars.

4.1.2.2 Crop growth rate (CGR) (g cm^{-2} day^{-1})

AT 54 DAS, CGR showed a general mean of 10.97 cm^{-2} day^{-1} with means ranging from 5.50 g cm^{-2} day^{-1} (Tirupati-1) to 16.40 g cm^{-2} day^{-1} (Prasuna). CGR at 72 DAS was highest in the cultivar, Tirupati-4 (33.18 g cm^{-2} day^{-1}) and lowest in TCGS-653 (15.31 g cm^{-2} day^{-1}) with a general mean of 21.36 g cm^{-2} day^{-1}. Thirteen cultivars were superior over general mean. An increasing trend in all the cultivars was observed in CGR from 54 to 72 DAS.

4.1.2.3 Leaf Area Index (LAI)

At 36 DAS, the cultivar, JL-24 recorded maximum LAI (3.14) while TCGS-913 showed minimum value (0.81). Twelve cultivars were superior over the general mean (1.87). LAI at 54 DAS ranged from 1.89 to 5.71 with a general mean of 3.74. The cultivar, K-134 showed the highest LAI at 54 DAS (5.71) followed by TCGS-717 (5.70), while the cultivar, TCGS-645 showed the lowest mean value (1.89). An increasing trend in all cultivars was observed from 36 DAS to 54 DAS. LAI at 72 DAS ranged from 2.66 to 6.18 with a general mean value of 4.57. Similar increasing trend was observed in all cultivars from 54 DAS to 72 DAS. The cultivar, JL-24 showed the highest LAI (6.18) while TCGS-645 showed the lowest LAI (2.66) at 72 DAS.

4.1.2.4 Net Assimilation Rate (NAR) (g dm^{-2} day^{-1})

The mean values of NAR at 36 DAS varied from 0.03 g dm^{-2} day^{-1} to 0.10 g dm^{-2} day^{-1} with a general mean of 0.05 g dm^{-2} day^{-1}. The cultivar, TCGS-717 recorded the highest NAR at 36 DAS (0.10 g dm^{-2} day^{-1}) while TCGS-750 recorded the lowest NAR value (0.03 g dm^{-2} day^{-1}) at 36 DAS. Ten cultivars exceeded the general mean value (0.05 g dm^{-2} day^{-1}). NAR at 54 DAS was high in cultivars, Kalahasti, Abhaya, TCGS-913, K-134, TG-39 and TCGS-645. All these cultivars recorded the highest mean value of 0.04 and the cultivars, Prasuna, TCGS-156, TCGS-717 and TCGS-750 showed lowest value (0.02). The general mean value was 0.03. A decreasing trend was observed in the value of NAR from 36 days to 54 days.

4.1.2.5 Specific leaf area (SLA) (cm^2 g^{-1})

SLA at 18 DAS ranged from 177.15 cm^2 g^{-1} to 325.11 cm^2 g^{-1}. The cultivar, TCGS-750 showed high mean SLA at 18 DAS (325.11 cm^2 g^{-1}) while the cultivar, JL-501 showed the lowest mean value (177.15 cm^2 g^{-1}). The general mean value was 232.03 cm^2 g^{-1}. SLA at 36 DAS varied from 171.27 cm^2 g^{-1} to 254.52 cm^2 g^{-1} with a general mean of 207.27 cm^2 g^{-1}. The cultivar, Kalahasti exhibited the highest mean value (254.52 cm^2 g^{-1}) whereas TCGS-888 recorded the lowest value (171.27 cm^2 g^{-1}). There was a decreasing trend in the mean values of SLA from 18 DAS to 36 DAS.

The cultivar, Kalahasti showed maximum SLA value (225.87 cm^2 g^{-1}) at 54 DAS whereas TCGS-888 showed minimum value (150.21 cm^2 g^{-1}) with a general mean value of 186.11 cm^2 g^{-1}. Similar decreasing trend was observed in the value of SLA from 36 to 54 DAS in all the cultivars. SLA at 72 DAS ranged from 93.14 cm^2 g^{-1} (TCGS-750) to 180.46 cm^2 g^{-1} (K-4) with a general mean of 134.68 cm^2 g^{-1}. Again decreasing trend was observed in the values of SLA from 54 to 72 DAS.

4.1.2.6 SCMR

The mean values of SCMR among the cultivars ranged from 39.40 (TCGS-717) to 47.23 (TCGS-750) with a general mean of 43.30. The cultivars, TCGS-750 (47.23), TCGS-653 (46.10) and TCGS-913 (46.77) showed higher SCMR values among the cultivars studied.

4.1.2.7 Germination percentage

Most of the cultivars showed good germination ranging from 61.07% (TCGS-750) to 90.00% except TCGS-653 (71.56%), TCGS-888 (77.34%), K-4 (75.35%), K-6 (75.00%), TCGS-722 (65.88%), TCGS-750 (61.07%), TG-39 (71.56%), TCGS-645 (75.00%), R-2001-2 (79.37%) and Tirupati-9 (75.00%) with a general mean of 79.53%.

4.1.2.8 Seedling vigour index

The cultivar, R-2001-2 expressed higher seedling vigour index (1420.33), while K-4 showed the lowest value (593.48). The general

mean value was 855.44. Twelve cultivars expressed superior seedling vigour index than the general mean.

4.1.2.9 Harvest Index

Mean harvest index ranged from 31.70 (Tiruapti-3) to 63.66 (R-2001-2). Fourteen cultivars recorded higher harvest index than the general mean.

4.1.2.10 Pod yield per plant (g)

Pod yield per plant varied from 9.13 g to 18.40 g. Among all cultivars, Tirupati-4 recorded higher pod yield per plant (18.40 g) followed by K-4 (17.00 g), TG-47 (17.00 g) and TCGP-6 (16.53 g). The cultivar, TMV-2 recorded the lowest pod yield per plant (9.13 g). Mean values of seventeen cultivars were higher than the general mean for pod yield per plant.

4.2 GENETIC PARAMETERS

The estimates of variability (Genotypic and phenotypic co-efficients of variation), heritability (broad sense), genetic advance and genetic advance as per cent of mean for various morphological, yield, yield attributes and physiological characters are presented in Table 7 and 8 respectively.

4.2.1 Morphological, yield and yield attributes

The maximum genotypic co-efficient of variation (GCV) was observed for weight of immature pods per plant (39.97%), length of primary branches (21.31%) and length of main axis (20.38%) in decreasing order of their magnitude. Maximum phenotypic co-efficient (PCV) was registered for weight of immature pods per plant (72.06%) followed by number of immature pods per plant (35.25%), number of mature pods per plant (26.51%), length of primary branches (26.13%), length of main axis (24.39%), pod yield per plant (24.31%), number of fully expanded leaves (23.35%) and 100-seed weight (21.74%).

Moderate GCV values were observed for 100-seed weight (17.81%), harvest index (16.05%), number of fully expanded leaves (16.04%), pod yield per plant (15.54%), days to emergence (15.25%), number of immature pods per plant (14.83%), number of mature pods per plant (10.87%), leaflet width (10.70%) and leaflet length (10.59%). Moderate PCV values were recorded for days to emergence (17.26%), harvest index (17.09%), number of primary branches per plant (16.54%), shelling percentage (14.63%), leaflet length (12.80%), leaflet width (12.71%), leaf length (12.39%) and days to 50 per cent flowering (12.25%). Low GCV values were observed for days to 50 per cent flowering (9.25%), leaf length (9.24%), shelling percentage (6.93%) and number of primary branches per plant (4.17%).

Heritability was high for characters, harvest index (88.20%), days to emergence (78.10%), leaflet width (70.85%), length of main axis (69.80%), leaflet length (68.46%), 100-seed weight (67.08%) and length of primary branches (66.53%). Moderate heritability estimates were registered for days to 50 per cent flowering (56.99%), leaf length (55.60%), number of fully expanded leaves (47.16%), pod yield per plant (40.86%) and weight of immature pods per plant (30.76%). Low heritability values were recorded for shelling percentage (22.45%), number of immature pods per plant (17.70%), number of mature pods per plant (16.81%) and number of primary branches per plant (6.34%).

Genetic advance was moderate for harvest index (14.36%) followed by length of primary branches (12.74%), number of fully expanded leaves (12.51%), length of main axis (11.11%) and 100-seed weight (10.47%). Low genetic advance values were recorded for days to 50 per cent flowering (4.54%), shelling percentage (4.20%), pod yield per plant (2.75%), number of mature pods per plant (1.62%), days to emergence (1.39%), weight of immature pods per plant (1.15%), number of immature pods per plant (1.10%), leaflet length (0.88%), leaf length (0.79%), leaflet width (0.41%) and number of primary branches per plant (0.13%).

Genetic advance as per cent of mean (GAM) was highest for weight of immature pods per plant (45.66%), length of primary branches (35.81%), length of main axis (35.07%), harvest index (31.06%), 100-

seed weight (30.04%), days to emergence (27.76%), number of fully expanded leaves (22.68%) and pod yield per plant (20.46%). Moderate values were recorded for leaflet width (18.56%), leaflet length (18.06%), days to 50 per cent flowering (14.39%), leaf length (14.19%), and number of immature pods per plant (12.85%), while low values were registered for number of mature pods per plant (9.18%), shelling percentage (6.77%) and number of primary branches per plant (2.16%).

4.2.2 Physiological characters

High GCV estimates were recorded for LAI at 36 DAS (32.38%), LAI at 54 DAS (27.00%), LAD at 54 DAS (24.96%), LAD at 72 DAS (23.48%), CGR at 54 DAS (22.99%), CGR at 72 DAS (20.21%), seedling vigour index (SVI) (20.15%) and NAR at 36 DAS (20.04%). Moderate GCV values were recorded for LAI at 72 DAS (19.98%), NAR at 54 DAS (18.69%), LAD at 90 DAS (17.40%), harvest index (16.05%), SLA at 72 DAS (16.03%), pod yield per plant (15.54%) and SLA at 18 DAS (11.41%). Low GCV values were observed for SLA at 54 DAS (8.58%), SLA at 36 DAS (6.60%), germination percentage (4.78%) and SCMR (3.83%).

PCV estimates were highest for LAI at 36 DAS (41.01%), LAI at 54 DAS (29.81%), NAR at 36 DAS (29.43%), seedling vigour index (27.21%), NAR at 54 DAS (26.01%), LAD at 54 DAS (25.17%), pod yield per plant (24.31%), CGR at 54 DAS (23.72%), LAD at 72 DAS (23.65%), CGR at 72 DAS (20.71%) and LAI at 72 DAS (20.41%). Moderate GCV estimates were obtained for SLA at 72 DAS (18.61%), LAD at 90 DAS (17.83%),

harvest index (17.09%), SLA at 18 DAS (14.74%), SLA at 54 DAS (13.05%) and SLA at 36 DAS (11.11%). GCV values were low for germination percentage (7.74%) and SCMR (6.47%).

Heritability estimates were high for LAD at 72 DAS (98.59%), LAD at 54 DAS (98.34%), LAI at 72 DAS (95.85%), CGR at 72 DAS (95.26%), LAD at 90% (95.22%), CGR at 54 DAS (93.91%), harvest index (88.20%), LAI at 54 DAS (82.04%), SLA at 72 DAS (74.19%) and LAI at 36 DAS (62.34%). Moderate heritability values were observed for SLA at 18 DAS (59.95%), seedling vigour index (54.81%), NAR at 54 DAS (51.61%), NAR at 36 DAS (46.38%), SLA at 54 DAS (43.26%), pod yield per plant (40.86%), germination percentage (38.06%), SLA at 36 DAS (35.31%) and SCMR (34.90%).

Maximum genetic advance was recorded for seedling vigour index (262.84%) followed by LAD at 72 DAS (108.64%), LAD at 90 DAS (94.58%), LAD at 54 DAS (79.45%), SLA at 18 DAS (42.24%), SLA at 72 DAS (38.31%) and SLA at 54 DAS (21.65%). Moderate genetic advance values were observed for SLA at 36 DAS (16.74) and harvest index (14.36). The characters, CGR at 72 DAS (8.68%), germination percentage (5.87%), CGR at 54 DAS (5.03%), pod yield per plant (2.75%), SCMR (2.02%), LAI at 54 DAS (1.89%), LAI at 72 DAS (1.84%), LAI at 36 DAS (0.98%), NAR at 36 DAS (0.01%) and NAR at 54 DAS (0.01%) showed low genetic advance.

Genetic advance as per cent of mean was maximum for LAI at 36 DAS (52.67%), LAD at 54 DAS (50.99%), LAI at 54 DAS (50.38%), LAD at 72 DAS (48.03%), CGR at 54 DAS (45.89%), CGR at 72 DAS (40.63%), LAI at 72 DAS (40.29%), LAD at 90 DAS (34.97%), harvest index (31.06%), seedling vigour index (30.73%), SLA at 72 DAS (28.44%), NAR at 36 DAS (28.12%), NAR at 54 DAS (27.65%) and pod yield per plant (20.46%). Moderate genetic advance as per cent of mean was recorded for SLA at 18 DAS (18.20%) and SLA at 54 DAS (11.63%). The characters, SLA at 36 DAS (8.08%), germination percentage (6.07%) and SCMR (4.66%) registered low genetic advance as per cent of mean.

4.3 GENETIC DIVERGENCE

4.3.1 Genetic divergence using Mahalanobis's D^2 statistic based on data of morphological, yield and yield attributes

Genetic divergence among twenty nine cultivars of groundnut was quantitatively assessed by adopting Mahalanobis's D^2 statistic and canonical root analysis based on pod yield and other morphological characters.

4.3.1.1 Test with Wilk's criterion and analysis of variance for dispersion of cultivars

Significant differences between cultivars based on the pooled effects of all the traits were tested by Wilk's 'λ ' (statistic) criterion. The significance of 'λ' (statistic) values was tested by 'x^2' at 448 degrees of

freedom. The 'λ' statistic value (1085.27**) was significant indicating that the cultivars differed significantly when all the characters were considered simultaneously. The analysis of variance of dispersion of twenty nine cultivars is presented in Table 9. The significance of cultivars clearly indicated the significant pooled effect of all characters between different cultivars. Hence, further analysis was made to estimate D^2 values.

4.3.1.2 Mahalanobis's D^2 values

The mean values of twenty nine cultivars $[(x_1)-(x_2)]$ were transformed into standardized uncorrelated mean values $[(y_1)-(y_2))]$. The D^2 values were computed for all the possible 29 (29-1/2) = 406 pairs of cultivars. The highest D^2 value of 57.76 was found between the clusters V and IX.

4.3.1.3 Grouping of cultivars

All the twenty nine cultivars of groundnut were grouped into nine clusters using Tocher's method (Singh and Chaudhary, 1977). The distribution of the cultivars into clusters is presented in Table 10 and illustrated in Fig.1. Cluster I had maximum number of 13 cultivars, whereas cluster III comprised 6 cultivars, cluster V had 4 cultivars, while cluster II, IV, VI, VII, VIII and IX had one cultivar each respectively.

4.3.1.4 Intra and inter-cluster average distances

The average intra and inter-cluster D^2 and D values of various cluster are furnished in Table 11. Maximum intra-cluster D^2 (26.83) and D (5.18) distances were recorded by cluster V while minimum distance was noticed in clusters II, IV, VI, VII, VIII and IX as they included single cultivar each. Inter-cluster average D^2 values ranged from 11.02 to 57.76. Maximum inter-cluster D^2 value was observed between cluster V and IX (57.76) while minimum inter-cluster D^2 value was found between IV and VIII (11.02).

4.3.1.5 Cluster means for various characters

The cluster means for each of sixteen characters are furnished in Table 12. Considerable differences between clusters were observed for most of the characters studied. Mean number of days to emergence was maximum in cluster VI (6.67) and minimum in clusters II (4.00), IV (4.00) and VIII (4.00). Cluster VII had maximum number of primary branches per plant (6.20) while cluster II had minimum number of primary branches per plant (5.47). Mean values of length of main axis ranged from 24.85 (cluster III) to 49.61 (cluster VIII). Length of primary branches ranged from 26.98 in cluster III to 51.14 in cluster VIII. Cluster IX had maximum mean (36.00) for days to 50 per cent flowering and minimum in cluster II (27.33).

Mean values of leaflet length varied from 4.31 (cluster III) to 5.55 (cluster VII). Leaflet width was highest in cluster IV (2.55) and lowest in cluster IX (1.89). Cluster VIII showed maximum leaf length (6.47) whereas in cluster IX it was low (5.09).

Mean for number of fully expanded leaves was minimum (42.33) in cluster II and maximum (82.67) in cluster VII. Maximum number of mature pods per plant was identified in cluster VI (19.80) whereas the value was minimum in cluster IV (16.87). Cluster VIII exhibited maximum number of immature pods per plant (10.87) and cluster VII showed minimum number of immature pods per plant (6.20). Weight of immature pods per plant ranged from 0.80 (cluster IV) to 4.60 (cluster VII). Highest 100-seed weight was found cluster III (43.11) while it was lowest in cluster II (21.33). Shelling percentage was maximum in cluster IV (73.71) and minimum in cluster VIII (55.23). Mean value of harvest index ranged from 31.70 (cluster IX) to 54.87 (cluster V). Pod yield per plant was maximum in cluster VIII (15.67) whereas it was minimum in cluster II (9.13).

4.2.1.6 Relative contribution of characters towards diversity

The number of times that each of the sixteen characters appeared in first rank and its respective per cent contribution towards diversity is presented in Table 13 and Fig.2.

Among all the characters studied, harvest index contributed maximum (33.50%) to the diversity by taking first rank 136 times, followed by days to emergence (17.00%) ranking 69 times first, length of main axis (8.62%) with 35 times ranking first, leaflet length (6.40%) ranking 26 times first. The characters, 100-seed weight, pod yield per plant, leaf length, weight of immature pods per plant, days to 50 per cent flowering, leaflet width, number of fully expanded leaves, shelling percentage, length of primary branches, number of primary branches per plant and number of immature pods per plant contributed 5.91, 5.17, 4.68, 4.43, 3.69, 3.45, 2.46, 0.99, 0.25 and 0.25 per cent respectively to the total genetic divergence. On contrary, number of mature pods per plant did not contribute towards genetic divergence.

4.3.1.7 Cluster diagram

A cluster diagram was constructed with the help of D^2 values showing the relationship between different populations (Fig.3). The highest distance between two clusters was exhibited between cluster V and IX (57.76) indicating greatest divergence while the least distance was recorded between cluster IV and VII (11.02) indicating least genetic divergence among the nine clusters formed.

4.3.1.8 Canonical root analysis

In the canonical variate analysis, the number of variables were reduced to a linear expression called the principal components and these

accounted for most of the variation produced by these characters. The second and succeeding principal components were formed similarly to account for residual variability. The first and second principal components (Z_1 and Z_2) were used to obtain a scattered distribution of the cultivars on a graph. When represented graphically considering all the characters together based on genetic divergence, the cultivars differed widely.

4.3.1.9 Canonical roots

Canonical root analysis was carried out in twenty nine cultivars of groundnut as per the method suggested by Rao (1952). Values of the five canonical roots and the percentage of variation expressed by them are presented in Table 14. First canonical root accounted for 33.03 per cent of variability while second and third roots accounted for 18.50 and 14.55 per cent respectively. Fourth and fifth vectors accounted for 8.17 and 7.23 per cent of total variability respectively. Five canonical roots accounted for 81.47 per cent of total variability. Mean values of the canonical variates for three roots x, y and z are furnished in Table 15.

4.3.1.10 Contribution of vectors towards divergence

For five canonical vectors, the amount of contribution of all the characters towards diversity is presented in Table 16. In Z_1 vector, maximum contribution towards genetic divergence was observed by harvest index (0.775), followed by number of mature pods per plant

(0.213), weight of immature pods per plant (0.154), 100-seed weight (0.152), number of immature pods per plant (0.080), pod yield per plant (0.056), leaf length (0.048), days to 50 per cent flowering (0.048), days to emergence (0.034) and number of primary branches per plant (0.016). Negative contribution to divergence was shown by remaining characters *viz.,* length of main axis, length of primary branches, leaflet length, leaflet width, number of fully expanded leaves and shelling percentage.

In Z_2 vector, the characters, days to emergence (0.470), 100-seed weight (0.295), number of fully expanded leaves (0.239), days to 50 per cent flowering (0.207), pod yield per plant (0.201), number of mature pods per plant (0.199), number of immature pods per plant (0.130), weight of immature pods per plant (0.128), number of primary branches per plant (0.056) and leaflet width (0.051) had positive contribution to the total diversity in their decreasing order. On contrary, the characters, length of main axis, length of primary branches, leaflet length, shelling percentage and harvest index showed negative contribution to diversity.

In Z_3 vector, days to emergence (0.613), shelling percentage (0.406), leaflet length (0.302), leaflet width (0.296), harvest index (0.286), number of mature pods per plant (0.159), length of main axis (0.065) and pod yield per plant (0.037) showed positive contribution to total diversity, whereas number of primary branches, length of primary branches per plant, days to 50 per cent flowering, leaf length, number of fully expanded leaves, number of immature pods per plant, weight of

immature pods per plant and 100-seed weight expressed negative contribution to the diversity.

In vector Z_4, positive contribution was shown by 100-seed weight (0.554), weight of immature pods per plant (0.412), leaf length (0.404), days to emergence (0.245), length of main axis (0.232), leaflet width (0.159), leaflet length (0.125), length of primary branches (0.028) and number of primary branches per plant (0.004). On contrary, days to 50 per cent flowering, number of fully expanded leaves per plant, number of mature pods per plant, number of immature pods per plant, shelling percentage, harvest index and pod yield per plant exhibited negative contribution.

In the Z_5 vector, pod yield per plant (0.614), number of fully expanded leaves (0.473), leaf length (0.326), length of main axis (0.255), length of primary branches (0.250), number of primary branches per plant (0.245), weight of immature pods per plant (0.235), harvest index (0.142), days to emergence (0.072), leaflet width (0.055), number of mature pods per plant (0.054) and leaflet length (0.036) had positive contribution to the diversity. Negative contribution was reported by days to 50 per cent flowering, 100-seed weight and shelling percentage.

A three dimensional plot was illustrated in the Fig.4 depicting the special distribution of twenty nine groundnut cultivars using principal component analysis (PCA). Wider distribution of the cultivars was

observed indicating the presence of considerable diversity in the cultivars.

4.3.2 Genetic divergence using Mahalanobis's D^2 statistic based on the data of physiological characters

4.3.2.1 Test with Wilk's criterion and analysis of variance for dispersion of cultivars

Wilk's 'λ' (statistic) criterion was used to test the significance of differences between the cultivars based on the pooled effects of all characters. The significance of 'λ' (statistic) values was tested by 'x^2' at 532 degrees of freedom. The 'λ' statistic value (1590.07**) was significant indicating that the cultivars differed significantly when all the characters were considered simultaneously. The analysis of variance of dispersion of 29 cultivars is furnished in Table 17. The significance of cultivars clearly indicated the significant pooled effect of all characters between different cultivars. Hence, further analysis was made to estimate D^2 values.

4.3.2.2 Mahalanobis's D^2 values

Mean values of twenty nine cultivars [(x_1)- (x_2)] were transformed into standardized uncorrelated mean values [(y_1)- (y_2)]. D^2 values were computed for all the possible 29 (29-1)/2 = 406 pairs of cultivars.

4.3.2.3 Grouping of cultivars

All the twenty nine cultivars of groundnut were grouped into eight clusters using Tocher's method (Singh and Chaudhary, 1977). The distribution of the cultivars into clusters is presented in Table 18 and illustrated in Fig.5. Cluster I and II included maximum number of eleven cultivars each while cluster VI had two cultivars. The clusters III, IV, V, VII and VIII comprised of one cultivar each respectively.

4.3.2.4 Intra and Inter-cluster average distances

The average intra and inter-cluster D^2 and D values of various clusters are furnished in Table 19. Maximum intra-cluster D^2 (102.41) and D (10.12) distances were observed in cluster II while minimum distance was noticed in clusters III, IV, V, VII and VIII as they included single cultivar each. Inter-cluster average D^2 values ranged from 78.49 to 772.28. The highest inter-cluster D^2 values was noticed between cluster VI and VII (772.28), while the lowest inter-cluster D^2 value was recorded between cluster III and VII (78.49).

4.3.2.5 Cluster means for various characters

Cluster means for different physiological characters are presented in Table 20. Leaf area duration (LAD) at 54 DAS was highest in cluster IV (242.95) and lowest in cluster III (117.65). LAD at 72 DAS was maximum in cluster IV (323.34) and minimum in cluster VII (123.11). LAD at 90 DAS ranged from 202.28 (cluster VII) to 358.67 (cluster V).

Cluster IV exhibited maximum mean crop growth rate (CGR) at 54 DAS (15.72) while it was minimum in cluster VIII (9.30). CGR at 72 DAS was highest in cluster VI (30.96) and minimum in cluster VIII (15.61). Leaf area index (LAI) at 36 DAS ranged from 1.10 (cluster VII) to 3.14 (cluster IV). Cluster V recorded highest value of LAI at 54 DAS (5.70), while cluster VII showed lowest value of LAI at 54 DAS (1.89). LAI at 72 DAS was maximum in cluster IV (6.18) and minimum in cluster VII (2.66). Mean net assimilation rate (NAR) at 36 DAS varied from 0.04 (cluster III) to 0.10 (cluster V). Mean NAR at 54 DAS was maximum in cluster VI and VII (0.04) and minimum in cluster V (0.02).

Mean specific leaf area (SLA) at 18 DAS was maximum (247.35) in cluster VII and minimum (214.10) in cluster VI. Cluster VII had highest SLA at 36 DAS (225.09) while it was minimum in cluster I (198.08). SLA at 54 DAS was high in cluster III (217.74) and low in cluster I (175.01). Highest mean of SLA at 72 DAS was observed in cluster V (160.12) and it was lowest in cluster I (122.40). Cluster VIII exhibited higher mean SCMR (45.57) while cluster V exhibited least mean SCMR (39.40). Clusters IV, V, VI and VII recorded maximum value (100.00) of germination percentage and cluster VII showed minimum value (93.33). Seedling vigour index was observed to be maximum in cluster III (1420.33) while minimum in cluster VI (633.50). Harvest index ranged from 35.85 (cluster V) to 63.66 (cluster III). Cluster VI recorded

maximum pod yield per plant (17.27) whereas cluster II registered lowest pod yield per plant (12.65).

4.3.2.6 Relative contribution of characters towards diversity

Relative contribution of different physiological characters towards diversity is presented in Table 21 and Fig.6. Among the characters studied, LAD at 54 DAS contributed maximum (34.48%) to the diversity as it appeared in the first position 140 times followed by LAI at 72 DAS (20.20%) ranking first 82 times, LAD at 72 DAS (12.81%) ranking 52 times first, CGR at 72 DAS (12.32%) ranking 50 times first, CGR at 54 DAS (8.37%), 34 times ranking first, harvest index (4.68%) ranking 19 times first and SLA at 72 DAS (3.20%) ranking 13 times first. The characters, seedling vigour index, NAR at 54 DAS, SLA at 18 DAS, LAD at 90 DAS and LAI at 54 DAS contributed 2.22, 0.49, 0.49, 0.25 and 0.25 per cent respectively to the total genetic divergence. The characters, LAI at 36 DAS, NAR at 36 DAS, SLA at 36 DAS, SLA at 54 DAS, germination percentage and pod yield per plant did not contribute to the total genetic divergence at all.

4.3.2.7 Cluster diagram

A cluster diagram was drawn with the help of D^2 values, showing relationship between different populations (Fig.7). The highest distance between two clusters was observed between cluster VI and VII (772.28), indicating greatest divergence whereas minimum distance was observed

between cluster III and VII (78.49) indicating least genetic divergence among the eight clusters formed.

4.3.2.8 Canonical root analysis

Canonical root analysis was performed in twenty nine cultivars of groundnut as per the method suggested by Rao (1952). Values of four canonical roots and percentage of variation expressed by them are presented in Table 22. First canonical root accounted for 50.84 per cent of variability, second canonical root accounted for 27.53 per cent of variability while canonical roots three and four accounted 7.95 and 4.78 per cent of variability respectively. Four canonical roots accounted for 91.11 per cent of total variability. Mean values of the canonical variates for three roots x, y and z are presented in Table 23.

4.3.2.9 Contribution of vectors towards divergence

The amount of contribution of characters towards diversity for four canonical vectors is furnished in Table 24.

In Z_1 vector, maximum contribution towards genetic divergence was observed by leaf area duration (LAD) at 54 DAS (0.567) followed by LAD at 72 DAS (0.451), LAI at 54 DAS (0.336), CGR at 72 DAS (0.297), LAD at 90 DAS (0.176), CGR at 54 DAS (0.161), NAR at 54 DAS (0.144), SLA at 72 DAS (0.140), SCMR (0.130), SLA at 18 DAS (0.106), pod yield per plant (0.097), SLA at 36 DAS (0.071), germination percentage (0.057), harvest index (0.053) and LAI at 36 DAS (0.013) in their

decreasing order. On contrary, LAI at 72 DAS, NAR at 36 DAS, SLA at 54 DAS and seedling vigour index showed negative contribution to the diversity.

In vector Z_2, the characters, LAI at 72 DAS (0.639), LAD at 54 DAS (0.355), seedling vigour index (0.301), NAR at 54 DAS (0.199), SLA at 18 DAS (0.177), harvest index (0.161), LAD at 90 DAS (0.127), germination percentage (0.122), CGR at 54 DAS (0.093), LAI at 36 DAS (0.061), pod yield per plant (0.053) and SLA at 54 DAS (0.050) exhibited positive contribution to the diversity whereas LAD at 72 DAS, CGR at 72 DAS, LAI at 54 DAS, NAR at 36 DAS, SLA at 36 DAS, SLA at 72 DAS and SCMR had negative contribution.

In Z_3 vector, positive contribution towards diversity was through CGR at 54 DAS (0.282), germination percentage (0.279), SLA at 36 DAS (0.261), seedling vigour index (0.235), LAD at 72 DAS (0.209), LAD at 54 DAS (0.184), SLA at 72 DAS (0.119), LAI at 54 DAS (0.084), NAR at 36 DAS (0.083), LAI at 36 DAS (0.051) and pod yield per plant (0.037). Remaining characters exhibited negative contribution to the total diversity.

In Z_4 vector, the characters, NAR at 54 DAS (0.220), LAD at 54 DAS (0.178), SLA at 36 DAS (0.152), LAI at 54 DAS (0.133), LAD at 72 DAS (0.128), SLA at 18 DAS (0.089), LAI at 36 DAS (0.084), seedling vigour index (0.076), harvest index (0.066) and NAR at 36 DAS (0.050)

recorded positive contribution to the total diversity. Remaining all characters had negative contribution.

A three dimensional plot was illustrated in Fig.8 depicting special distribution of twenty nine groundnut cultivars using principal component analysis (PCA). Wider distribution of the cultivars was observed indicating the presence of considerable diversity among the cultivars.

4.3.3 Genetic divergence at molecular level using RAPD markers

Morphological variability is very high in groundnut. But the variation observed at DNA level using different markers like RFLP and RAPD was found to be low initially. With the use of more number of primer combinations, substantial polymorphism was detected among different cultivars of cultivated groundnut. In the present study, 12 groundnut varieties/advanced breeding lines were subjected to RAPD analysis to study the level of diversity at molecular level and to establish genetic similarities among them using 60 primers.

4.3.3.1 Primer selection and survey

The DNA was isolated from leaves of 10 days old seedlings of 12 cultivars of groundnut and the quality was verified spectrophotometrically as well as through agarose gel electrophoresis. The results indicated that the isolated DNA was of good quality.

Primer survey was carried out using 60 primers from operon series of OPA, OPJ and OPH. Out of 60 primers screened, only seven primers gave scorable bands with high percentage of polymorphism (Table 25). Hence, these seven primers were chosen for measuring the diversity. The selected primers gave a total of 58 amplification products out of which 48 amplificaiton products were found to be polymorphic (82.75%).,

PCR amplification with the selected primers was done before scoring for presence or absence of bands. Number of amplified products obtained were specific to each primer and ranged from 5 to 11. The maximum polymorphism (82.75%) was observed with OPJ-6 (11 bands), OPA-3 (10 bands), OPH-7 (10 bands) followed by OPH-20 (8 bands), OPA-19 (7 bands), OPJ-1 (7 bands) and OPJ 4 (5 bands). The bands obtained were polymorphic with respect to size of the fragments amplified, which ranged from 100 to 7000 bp (Fig.9-15).

4.3.3.2 Similarity index

Banding profiles obtained with 7 primers for 12 cultivars of groundnut were analyzed on the basis of presence or absence of band. Jaccard's similarity co-efficients among 12 cultivars were calculated to establish the genetic relationship and are presented in Table 26. The similarity index values ranged from 32.6% to 92.9%, indicating the presence of wide range of genetic diversity at molecular level among the 12 cultivars. The maximum genetic similarity was found between the

cultivars, Kalahasti and Narayani (92.90%), TCGS-913, and TG-47 (86.50%), TCGS-750 and TG-47 (85.00%), TG-47 and Narayanai (82.50%), TG-47 and Abhyaa (82.50%), Abhaya and Narayani (81.40%), TCGS-913 and Narayani (80.50%), TCGS-653 and Kalahasti (80.00%), Abhaya and Prasuna (80.00%), TCGS-750 and Kalahasti (78.3%), TCGS-750 and Abhaya (79.5%), TCGS-653 and Narayani (77.3%) and TG-47 and TCGS-888 (77.1%). The cultivars, TCGS-645 and Narayani (59.60%%), TCGS-645 and TCGS-653 (59.60%), Narayani and Tirupati-4 (52.40%), and TCGS-750 and Tirupati-3 (52.20%) had moderate similarity whereas minimum similarity was found between TCGS-645 and Tirupati-4 (32.60%). In general, the cultivars Tirupati-4 and Tirupati-3 exhibited least similarity with other cultivars and were considered to be genetically more distinct and diverse.

4.3.3.3 Cluster analysis

The abundant phenotypic variation in groundnut was reflected at the DNA level also. Similarity co-efficients were subjected to Unweighted Pair Group method on Arithmetic Average (UPGMA) using paired matrix values. The total number of bands obtained were 58 out of which 48 bands were polymorphic. The dendrogram (Fig.16) exhibited variable degree of relationships among the cultivars studied and consisted of six closely knit groups.

S.No.	Group	Cultivars
1.	Group 1	Narayani, Kalahasti and TCGS-653
2.	Group 2	TCGS-913, TG-47 and TCGS-750
3.	Group 3	Prasuna, Abhaya and TCGS-888
4.	Group 4	TCGS-645
5.	Group 5	Tirupati-3
6.	Group 6	Tirupati-4

Group-I comprised 3 cultivars, which could be further grouped into 2 sub-clusters (1a and 1b), group 2 comprised 3 cultivars which could be further grouped into 2 sub-clusters (2a and 2b) and group 3 comprised three cultivars and again grouped into 2 sub-clusters (3a and 3b) whereas group 4, 5, and 6 comprised one cultivar each. Narayani of the first group and cultivar Tirupati-4 of the sixth group were the two extremes in the dendrogram between which all the other cultivars were distributed. In the dendrogram, the maximum similarity (92.90%) was observed between the cultivars Narayani and Kalahasti of group 1a and minimum of 32.60% was found between the cultivars TCGS-645 of group 4 and Tirupati-4 of group 6.

Group 1a comprised Narayani and Kalahasti which were closely related (92.9%) to each other indicating very low genetic variation between them. Group 1b consisted of one cultivar, TCGS-653 which was genetically closer to both Narayani and Kalahasti.

Group 2 also included 2 sub clusters (2a and 2b). The maximum similarity in this sub-cluster was 86.5 per cent. Group 2a comprised TCGS-913 and TG-47 which were closely related having 86.5 per cent

similarity indicating low genetic variation between them while group 2b included TCGS-750.

Group 3 included 3 cultivars which were sub-grouped into 2 sub clusters (3a and 3b). 3a included two cultivars (Prasuna and Abhaya) having 80 per cent similarity. 3b included single cultivar (TCGS-888) which was genetically dissimilar. Group 4, 5 and 6 comprised one cultivar each *viz.,* TCGS-645, Tirupati-3 and Tirupati-4 respectively indicating wide variability in these cultivars.

4.4 CHARACTER ASSOCIATION

4.4.1 Morphological, yield and yield attributes

The genotypic and phenotypic correlation co-efficients of pod yield per plant with its component characters *viz.,* days to emergence, number of primary branches per plant, length of main axis, length of primary branches, days to 50 per cent flowering, leaflet length, leaflet width, leaf length, number of fully expanded leaves, number of mature pods per plant, number of immature pods per plant, weight of immature pods per plant, 100-seed weight, shelling percentage and harvest index and among themselves were calculated and presented in Table 27.

In general, the genotypic correlation co-efficients were higher than the corresponding phenotypic correlation co-efficients. The magnitude and direction of association had almost matched.

Pod yield per plant exhibited highly significant positive association with number of mature pods per plant (r_p = 0.3913; r_g = 1.1435). Positive and significant association was also observed with number of primary branches per plant (r_p = 0.3197; r_g = 2.0384) followed by weight of immature pods per plant (r_p = 0.2999; r_g = 0.6758), 100-seed weight (r_p = 0.2283; r_g = 0.1405). Number of fully expanded leaves, days to emergence, number of immature pods per plant, harvest index, days to 50% flowering, length of primary branches and leaflet width showed positive non-significant association with pod yield per plant in their decreasing order. Whereas negative non-significant association of pod yield per plant was observed with shelling percentage, leaflet length, length of main axis and leaf length.

Days to emergence had positive significant association with days to 50 per cent flowering (r_p = 0.223; r_g = 0.280). Pod yield per plant, 100-seed weight, weight of immature pods per plant, number of primary branches, number of fully expanded leaves and number of mature pods per plant exhibited positive non significant association. On contrary, number of immature pods per plant, length of main axis, leaf length, length of primary branches, harvest index, leaflet length, shelling percentage and leaflet width recorded negative non-significant association with days to emergence.

Number of primary branches per plant exhibited positive significant association with pod yield per plant (r_p = 0.3197; r_g = 2.0384)

followed by weight of immature pods per plant (r_p = 0.2786; r_g = 2.1819), number of mature pods (r_p = 0.2694; r_g = 1.7726), 100-seed weight (r_p = 0.2118; r_g = 0.6591) while number of fully expanded leaves, harvest index and days to 50 per cent flowering, showed non-significant association. On contrary, number of primary branches per plant registered negative significant association with shelling percentage (r_p = -0.3476; r_g = -1.0223). The characters, leaf length, length of primary branches, leaflet length, length of main axis, number of immature pods per plant and leaflet width recorded negative non-significant association.

Length of main axis exhibited positive significant association with length of primary branches (r_p = 0.7454; r_g = 1.0249), leaflet length (r_p = 0.5615; r_g = 0.7357), leaflet width (r_p = 0.5062; r_g = 0.6948), leaf length (r_p = 0.4361; r_g = 0.6950) and number of mature pods (r_p = 0.3092; r_g = 0.5702) while shelling percentage and number of fully expanded leaves recorded positive non-significant association with length of main axis. Negative significant association was observed with 100-seed weight, (r_p = -0.4477; r_g = -0.5795), days to 50 per cent flowering (r_p = -0.3576, r_g = -0.5579), harvest index (r_p = -0.3359; r_g = -0.4121). The characters, weight of immature pods per plant, number of immature pods per plant and pod yield per plant exhibited negative non-significant association.

Length of primary branches had positive significant association with leaflet length (r_p = 0.4749; r_g = 0.6625), leaflet width (r_p = 0.4029; r_g = 0.5913), number of mature pods (r_p = 0.3610; r_g = 0.6242) and leaf length (r_p = 0.3321; r_g = 0.6036) whereas with shelling percentage, number of fully expanded leaves, pod yield and number of immature pods per plant it exhibited positive non-significant association. It showed negative significant association with harvest index (r_p = -0.4537; r_g = -0.5724) and 100-seed weight (r_p = -0.4483; r_g = -0.6986) and days to 50 per cent flowering (r_p = -0.3576; r_g = -0.5579) whereas with weight of immature pods per plant it showed negative non-significant association.

Days to 50 per cent flowering expressed positive significant association with 100-seed weight (r_p = 0.3416; r_g = 0.5353). The characters, number of fully expanded leaves, harvest index, weight of immature pods per plant, pod yield per plant and number of immature pods per plant showed positive non-significant association. Negative significant association was recorded with leaflet length (r_p = -0.2887; r_g = -0.4284), leaflet width (r_p = -0.2668; r_g = -0.3925) and leaf length (r_p = -0.2167; r_g = -00.4086). Number of mature pods per plant, and shelling percentage expressed negative non-significant association.

Leaflet length had positive significant association with leaflet width (r_p = 0.8461; r_g = 0.8933) and leaf length (r_p = 0.7118; r_g = 0.7779) and number of mature pods per plant (r_p = 0.2520; r_g = 0.3620). Positive non

significant association was observed with number of fully expanded leaves, number of mature pods per plant and shelling percentage. Negative significant association was found with harvest index (r_p = -0.4540; r_g = -0.5581), 100-seed weight (r_p = -0.4164; r_g = -0.6083) and number of immature pods per plant (r_p = -0.2593; r_g = -0.5584). Weight of immature pods per plant and pod yield per plant expressed negative non-significant association.

Leaflet width expressed highest positive significant association with leaf length (r_p = 0.5830; r_g = 0.6166), and number of mature pods per plant (r_p = 0.2753; r_g = 0.5217). Shelling percentage and pod yield per plant exhibited positive non-significant association. Negative significant association of leaflet width was observed with harvest index (r_p = =0.4669; r_g = -0.5938), 100-seed weight (r_p = -0.3633; r_g = -0.5065) and number of immature pods per plant (r_p = -0.2611; r_g = -0.6815). The characters, weight of immature pods per plant and number of fully expanded leaves recorded negative non-significant association.

Leaf length exhibited positive non-significant association with number of mature pods per plant. Remaining characters *viz.,* number of immature pods per plant, 100-seed weight, harvest index, weight of immature pods per plant, number of fully expanded leaves, shelling percentage and pod yield per plant exhibited negative non-significant association with leaf length.

Number of fully expanded leaves had positive significant association with number of mature pods per plant (r_p = 0.3878; r_g = 0.7111). Pod yield per plant, weight of immature pods per plant and number of immature pods per plant showed positive non-significant association. Negative non-significant association was recorded with harvest index, 100-seed weight and shelling percentage.

Number of mature pods per plant registered positive significant association with pod yield per plant (r_p = 0.3913; r_g = 1.1435). Weight of immature pods per plant and number of immature pods per plant exhibited positive non-significant association. Negative non-significant association was noticed with 100-seed weight, shelling percentage and harvest index.

Number of immature pods per plant recorded positive significant association with weight of immature pods per plant (r_p = 0.2905; r_g = -0.1577). Positive non-significant association was noticed with pod yield per plant, 100-seed weight and harvest index. Shelling percentage had negative non-significant association with number of immature pods per plant.

Weight of immature pods per plant showed positive significant correlation with 100-seed weight (r_p = 0.4221; r_g = 0.8560) and pod yield per plant (r_p = 0.2999; r_g = 0.6758). Harvest index showed positive non-significant association. Shelling percentage (r_p = -0.4944; r_g = -1.1741)

had negative significant association with weight of immature pods per plant.

100-seed weight had positive significant association with harvest index (r_p = 0.2712; r_g = 0.3282) and pod yield per plant (r_p = 0.2283; r_g = 0.1405). Shelling percentage exerted negative non-significant association with 100-seed weight. Shelling percentage registered negative non-significant association with harvest index and pod yield per plant. Harvest index recorded low positive association with pod yield per plant.

4.4.2 Physiological characters

Character association of different physiological characters with pod yield per plant and among themselves were estimated and presented in Table 28.

Pod yield per plant showed positive significant association with CGR at 54 DAS (r_p = 0.3208; r_g = 0.5282), LAD at 54 DAS (r_p = 0.2529; r_g = 0.4086), LAD at 90 DAS (r_p = 0.2449; r_g = 0.3393), and LAI at 72 DAS (r_p = 0.2159; r_g = 0.3267). LAD at 72 DAS, germination percentage, SLA at 72 DAS, CGR at 72 DAs, LAI at 54 DAS, seedling vigour index, LAI at 36 DAS, harvest index, SCMR, NAR at 36 DAS, SLA at 36 DAS, SLA at 18 DAS and SLA at 54 DAS showed positive non-significant association with pod yield per plant. Negative non-significant association of pod yield per plant was observed with NAR at 54 DAS.

Leaf area duration (LAD) at 54 DAS had positive significant association with LAD at 72 DAS (r_p = 0.8875; r_g = 0.8934), LAD at 90 DAS (r_p = 0.8460; r_g = 0.8748), LAI at 72 DAS (r_p = 0.8338; r_g = 0.8603), LAI at 54 DAS (r_p = 0.8062; r_g = 0.8923), LAI at 36 DAS (r_p = 0.0.6695; r_g = 0.8490), SLA at 72 DAS (r_p = 0.4830; r_g = 0.5605), CGR at 72 DAS (r_p = 0.4540; r_g = 0.46690 CGR at 54 DAS (r_p = 0.4490; r_g = 0.4683), pod yield per plant (r_p = 0.2529; r_g = 0.4086), NAR at 36 DAS (r_p = 0.2401; r_g = 0.3357) and SLA at 54 DAS (r_p = 0.2278; r_g = 0.3284). Positive non-significant association was observed with germination percentage, SLA at 36 DAS and SLA at 18 DAS. Harvest index (r_p = -0.4413; r_g = -0.4648), seedling vigour index, SCMR exhibited negative significant association with LAD at 54 DAS and NAR at 54 DAS exhibited negative non-significant association with LAD at 54 DAS.

LAD at 72 DAS registered positive significant association with LAI at 72 DAS (r_p = 0.9795; r_g = 0.9883), LAD at 90 DAS (r_p = 0.9552; r_g = 0.9749), LAI at 54 DAS (r_p = 0.8975; r_g = 1.0043), SLA at 72 DAS (r_p = 0.5320; r_g = 0.6235), LAI at 36 DAS (r_p = 0.4578; r_g = 0.5867), CGR at 72 DAS (r_p -.4548; r_g = 0.4724), CGR at 54 DAS (r_p = 0.4163; r_g = 0.4333), NAR at 36 DAS (r_p = 0.3179; r_g = 0.4367) and germination percentage (r_p = 0.2273; r_g = 0.3877). The characters, pod yield per plant, SLA at 54 DAS and SLA at 36 DAS registered positive non-significant association. Negative significant association was exhibited with harvest index (r_p = -0.4677; r_g = -0.5018), seedling vigour index

(r_p = -0.4506; r_g = -0.6161) and SCMR (r_p = -0.2936; r_g = -0.4743). NAR at 54 DAS and SLA at 18 DAS exhibited negative non-significant association.

LAD at 90 DAS recorded positive significant association with LAI at 72 DAS (r_p = 0.9558; r_g = 0.9765), LAI at 54 DAS (r_p = 0.8054; r_g = 0.9670), SLA at 72 DAs (r_p = 0.5667; r_g = 0.6897), CGR at 72 DAS (r_p = 0.5178; r_g = 0.5529), CGR at 54 DAS (r_p = 0.4445; r_g = 0.4673) and LAI at 36 DAS (r_p = 0.4364; r_g = 0.5698). The characters, NAR at 36 DAS (r_p = 0.3227; r_g = 0.4521), germination percentage (r_p = 0.2729; r_g = 0.4660), pod yield per plant (r_p = 0.2449; r_g = 0.3393) also showed positive significant association with LAD at 90 DAS. SLA at 54 DAS and SLA at 36 DAS had positive non-significant association. Negative significant association was exhibited with seedling vigour index (r_p = -0.4808; r_g = -0.6408), harvest index (r_p = -0.4791; r_g = -0.5284), SCMR (r_p = -0.2784; r_g = -0.5219) and NAR at 54 DAS (r_p = -0.2124; r_g = -0.2639) while SLA at 18 DAS exhibited negative non-significant association.

CGR at 54 DAS had positive significant association with LAI at 72 DAS (r_p = 0.4233; r_g = 0.4453), LAI at 36 DAS (r_p = 0.4041; r_g = 0.5057), LAI at 54 DAS (r_p = 0.3428; r_g = 0.3854), pod yield per plant (r_p = 0.3208; r_g = 0.5282) and NAR at 36 DAs (r_p = 0.2320; r_g = 0.3290). The characters, SLA at 36 DAS, CGR at 72 DAS, SLA at 72 DAS, SLA at 54 DAS, SLA at 18 DAS and germination percentage showed positive non-

significant association. Harvest index (r_p = -0.3586; r_g = -0.3753) and NAR at 54 DAS (r_p = -0.3180; r_g = -0.4564) showed negative significant association. Seedling vigour index and SCMR exhibited negative non-significant association with CGR at 54 DAS.

CGR at 72 DAS recorded positive significant association with LAI at 72 DAS (r_p = 0.4711; r_g = 0.4997), LAI at 54 DAS (r_p = 0.3860; r_g = 0.4257) and LAI at 36 DAS (r_p = 0.2777; r_g = 0.3439). The characters, pod yield per plant, germination percentage, SLA at 72 DAS and NAR at 54 DAS reported positive non-significant association. Seedling vigour index (r_p = -0.3852; r_g = -0.6047) SCMR (r_p = -0.2937; r_g = -0.4296), harvest index (r_p = -0.2712; r_g = -0.2948) and SLA at 54 DAS (r_p = -0.2253; r_g = -0.3241) showed negative significant association whereas SLA at 18 DAS, SLA at 36 DAS and NAR at 36 DAS registered negative non-significant association.

Positive significant association of LAI at 36 DAS was recorded with LAI at 72 DAS (r_p = 0.4535; r_g = 0.5799) and LAI at 54 DAS (r_p = 0.4490; r_g = 0.5665). SLA at 36 DAS, SLA at 72 DAS, SLA at 54 DAS, pod yield per plant, germination percentage and SLA at 18 DAS showed positive non-significant association. Negative significant association was obtained with harvest index (r_p = -0.3327; r_g = -0.4039) and NAR at 54 DAS (r_p = -0.2430; r_g = -0.1408) whereas SCMR, seedling vigour index and NAR at 36 DAS registered negative non-significant association.

LAI at 54 DAS had positive significant association with LAI at 72 DAS (r_p = 0.8589; r_g = 0.9918), SLA at 72 DAS (r_p = 0.4886; r_g = 0.6356), NAR at 36 DAS (r_p = 0.2970; r_g = 0.5176) and germination percentage (r_p = 0.2324; r_g = 0.3751) while SLA at 54 DAS, SLA at 36 DAS, pod yield per plant and SLA at 18 DAS showed positive non-significant association. Harvest index (r_p = -0.4692; r_g = -0.5319), seedling vigour index (r_p = -0.3747; r_g = -0.6758) and SCMR (r_p = -0.3124; r_g = -0.5569) exhibited negative significant association. NAR at 54 DAS recorded negative non-significant association.

LAI at 72 DAS had highest positive significant association with SLA at 72 DAS (r_p = 0.5098; r_g = 0.6091). Positive significant association was also obtained with NAR at 36 DAS (r_p = 0.3071; r_g = 0.4160), germination percentage (r_p = 0.2318; r_g = 0.4375) and pod yield per plant (r_p = 0.2159; r_g = 0.3267). SLA at 54 DAS and SLA at 36 DAS recorded positive non-significant association with LAI at 72 DAS. Seedling vigour index (r_p = -0.4647; r_g = -0.6222) and harvest index (r_p = -0.4336; r_g = -0.4812) had negative significant association. Negative significant association was also found with SCMR (r_p = -0.2861; r_g = -0.4646). NAR at 54 DAS and SLA at 18 DAS had negative non-significant association.

NAR at 36 DAS reported positive significant association with germination percentage (r_p = 0.3019; r_g = 0.4799). SLA at 72 DAS, pod yield per plant, seedling vigour index and SLA at 36 DAS showed positive non-significant association. Negative non-significant association was

found with SCMR, harvest index, NAR at 54 DAS, SLA at 18 DAS and SLA at 54 DAS.

NAR at 54 DAS registered positive non-significant association with harvest index, SLA at 36 DAS, germination percentage and SCMR. Negative non-significant association was found with seedling vigour index, SLA at 54 DAS, SLA at 18 DAS, pod yield per plant and SLA at 72 DAS.

SLA at 18 DAS showed positive significant association with SLA at 36 DAS (r_p = 0.3361; r_g = 0.7600) and SLA at 54 DAS (r_p = 0.3294; r_g = 0.6262). SCMR and pod yield per plant showed positive non-significant association. The characters, germination percentage, seedling vigour index, harvest index and SLA at 72 DAS exhibited negative association.

SLA at 36 DAS had positive significant association with SLA at 54 DAS (r_p = 0.4666; r_g = 1.1575). It had positive non-significant association with SLA at 72 DAS, seedling vigour index, pod yield per plant and SCMR. Negative association was observed with harvest index and germination percentage.

SLA at 54 DAS recorded positive significant association with SLA at 72 DAS (r_p = 0.2582; r_g = 0.4333) and seedling vigour index (r_p = 0.2429; r_g = 0.2304). Germination percentage and pod yield per plant had positive non-significant association with SLA at 54 DAS. The

characters, SCMR and harvest index had negative non-significant association with SLA at 54 DAS.

SLA at 72 DAS had positive significant association with germination percentage (r_p = 0.2213; r_g = 0.5584). Pod yield per plant showed positive non-significant association. Seedling vigour index and SCMR exhibited negative significant association. Harvest index exhibited negative non-significant association.

SCMR recorded positive non-significant association with seedling vigour index, pod yield per plant and harvest index while germination percentage had negative non-significant association with SCMR.

Germination percentage showed positive non-significant association with seedling vigour index and pod yield per plant. Harvest index had negative non-significant association.

Seedling vigour index showed positive significant association with harvest index (r_p = 0.2986; r_g = 0.4481) whereas pod yield per plant and harvest index had positive non-significant association.

4.5 PATH CO-EFFICIENT ANALYSIS

The correlation co-efficients between pod yield and its components partitioned into direct and indirect effects through path co-efficient analysis for different morphological, yield and yield attributes and physiological attributes in twenty nine cultivars of groundnut were presented in Table 29 and 30 and illustrated in fig.17-20..

4.5.1 Morphological, yield and yield attributes

The results of path co-efficient analysis revealed that contribution to pod yield per plant was from number of mature pods per plant (P = 0.3047; G = 0.7030), leaflet width (P = 0.2162; G = -1.3755), days to emergence (P = 0.1937; G = -0.7929), 100-seed weight (P = 0.1910; G = 3.6850), number of primary branches per plant (P = 0.1773; G = 1.6598), number of immature pods per plant (P = 0.1729; G = 0.9209), leaf length (P = 0.1347; G = -2.7770), harvest index (P = 0.1067; G = 1.8072), length of primary branches (P = 0.0931; G = -1.1651), weight of immature pods per plant (P = 0.0801; G = 1.9392), number of fully expanded leaves (P = 0.0796; G = -0.3156) and shelling percentage (P = 0.0624; G = 5.2504). The highest negative direct effect on pod yield per plant was from leaflet length followed by days to 50 per cent flowering and length of main axis.

Days to emergence showed highest positive indirect effect through 100-seed weight (P = 0.0368; G = 0.9403) followed by leaflet length (P = 0.0257; G = -0.4171), number of primary branches per plant (P = 0.0161; G = 0.3933), weight of immature pods per plant (P = 0.0099; G = 0.4432), length of main axis (P = 0.0088; G = -0.5095), number of fully expanded leaves (P = 0.0069; G = -0.0438) and number of mature pods per plant. Number of immature pods per plant, leaf length, days to 50 per cent flowering, length of primary branches per plant, harvest index, shelling percentage and leaflet width exerted negative indirect effects.

Number of primary branches per plant exhibited positive indirect effect through number of mature pods per plant (P = 0.0821; G = 1.2462), 100-seed weight (P = 0.0404; G = 2.4286), weight of immature pods per plant (P = 0.0222; G = 4.2311), days to emergence (P = 0.0175; G = -0.1879), leaflet length (P = 0.0130; G = -2.5474), number of fully expanded leaves (P = 0.0108; G = -0.4232), harvest index (P = 0.0057; G = 0.2428) and length of main axis (P = 0.0027; G = -1.0200). It had negative indirect effect through shelling percentage, leaf length, number of immature pods per plant, days to 50 per cent flowering, length of primary branches and leaflet width.

Length of main axis had positive indirect effect through leaflet width (P = 0.1095; G = -0.9557), number of mature pods per plant (P = 0.0942; G = 0.4008), length of primary branches (P = 0.0694; G = -1.1941), leaf length (P = 0.0588; G = -1.9299), days to 50 per cent flowering (P = 0.0245; G = -0.3859), shelling percentage (P = 0.0058; G = 1.6870) and number of fully expanded leaves (P = 0.0054; G = -0.0226). On contrary, it showed negative indirect effect through leaflet length, 100-seed weight, harvest index, days to emergence, weight of immature pods per plant, number of immature pods per plant and number of primary branches per plant.

Length of primary branches exerted positive indirect effect on pod yield per plant through number of mature pods per plant (P = 0.1100; G = 0.4388), leaflet width (P = 0.0871; G = -0.8134), leaf length

(P = 0.0447; G = -1.6763), days to 50 per cent flowering (P = 0.0225; G = -0.3353), shelling percentage (P = 0.0103, G = 2.4685), number of fully expanded leaves (P = 0.0085; G = -0.0634) and number of immature pods per plant (P = 0.0008; G = -0.2650). Negative indirect effects were observed through leaflet length, 100-seed weight, harvest index, length of main axis, days to emergence, number of primary branches per plant and weight of immature pods per plant.

Days to 50 per cent flowering exhibited positive indirect effect through leaflet length (P = 0.0763; G = -2.6101), 100-seed weight (P = 0.0652; G = 1.9727), days to emergence (P = 0.0431; G = -0.2222), length of main axis (P = 0.0207; G = -1.2629), number of primary branches per plant (P = 0.0164; G = 0.2857), harvest index (P = 0.0152; G = 0.2331), number of immature pods per plant (P = 0.0136; G = 0.4783), number of fully expanded leaves (P = 0.0132; G = -0.1466) and weight of immature pods per plant (P = 0.0098; G = 0.5212). Negative indirect effects were through leaflet width, number of mature pods per plant, length of primary branches, leaf length and shelling percentage.

Leaflet length had positive direct effect through leaflet width (P = 0.1830; G = -1.2370), leaf length (P = 0.0959; G = -2.1603), number of mature pods per plant (P = 0.0768; G = 0.2541), length of primary branches (P = 0.0442; G = -0.7719), shelling percentage (P = 0.0029; G = 1.5602), number of fully expanded leaves (P = 0.0025; G = -0.0355)

and days to 50 per cent flowering (P = 0.0198; G = -0.2963). It exerted negative indirect effect through 100-seed weight, harvest index, number of immature pods per plant, length of main axis, days to emergence, number of primary branches per plant and weight of immature pods per plant.

Leaflet width showed positive indirect effect through number of mature pods per plant (P = 0.0839; G = 0.3668), leaf length (P = 0.0786; G = -1.7123), length of primary branches (P = 0.0375; G = -0.6890), days to 50 per cent flowering (P = 0.0183; G = -0.2715), and shelling percentage (P = 0.0021; G = 1.2577). It exerted negative indirect effect through leaflet length, 100-seed weight, harvest index, number of immature pods per plant, length of main axis, weight of immature pods per plant, days to emergence, number of primary branches and number of fully expanded leaves.

Leaf length exhibited positive indirect effect through leaflet width (P = 0.1261; G = -0.8481), number of mature pods per plant (P = 0.0381; G = 0.1817), length of primary branches (P = 0.0309; G = -0.7033) and days to 50 per cent flowering (P = 0.0148; G = -0.2826). Negative indirect effects were observed through leaflet length, 100-seed weight, number of immature pods per plant, days to emergence, length of main axis, harvest index, number of primary branches per plant, weight of immature pods per plant, number of fully expanded leaves and shelling percentage.

Number of fully expanded leaves exhibited positive indirect effect on pod yield per plant through number of mature pods per plant (P = 0.1182; G = 0.4999), number of primary branches per plant (P = 0.0242; G = 2.2259), days to emergence (P = 0.0167; G = -0.1101), weight of immature pods per plant (P = 0.0134; G = 0.7966), number of immature pods per plant (P = 0.0117; G = 0.1004) and length of primary branches (P = 0.0099; G = -0.2341). Negative indirect effects were found through 100-seed weight, harvest index, days to 50 per cent flowering, leaflet length, shelling percentage, length of main axis, leaflet width and leaf length.

Number of mature pods per plant registered positive indirect effect through leaflet width (P = 0.0595; G = -0.7176), number of primary branches per plant (P = 0.0478; G = 2.9423), length of primary branches (P = 0.0336; G = -0.7272), number of fully expanded leaves (P = 0.0309; G = -0.2244), leaf length (P = 0.0169; G = -0.7178), weight of immature pods per plant (P = 0.0134; G = -0.5388), days to 50 per cent flowering (P = 0.0109; G = -0.1789), number of immature pods per plant (P = 0.0020; G = -0.6911) and days to emergence (P = 0.0018; G = -0.1715). Negative indirect effects were observed through leaflet length, 100-seed weight, length of main axis, shelling percentage and harvest index.

Number of immature pods per plant showed positive indirect effect through leaflet length (P = 0.0686; G = -4.5617), weight of immature

pods per plant (P = 0.0233; G = -0.3058), 100-seed weight (P = 0.0183; G = 0.3426), number of fully expanded leaves per plant (P = 0.0054; G = -0.0344), length of main axis (P = 0.0046; G = -0.5195), number of mature pods per plant (P = 0.0035; G = -0.5276), harvest index (P = 0.0032, G = 0.4613) and length of primary branches (P = 0.0004; G = 0.3353). However, negative indirect effects were observed through leaflet width, days to emergence, leaf length, number of primary branches per plant, days to 50 per cent flowering and shelling percentage.

Weight of immature pods per plant exhibited positive indirect effect through 100-seed weight (P = 0.0806; G = 3.1544), number of mature pods per plant (P = 0.0510; G = -0.1953), number of immature pods per plant (P = 0.0502; G = -0.1452), number of primary branches per plant (P = 0.0492; G = 3.6217), days to emergence (P = 0.0239; G = -0.1812), leaflet length (P = 0.0235; G = -2.3206), harvest index (P = 0.0134; G = 0.4053), number of fully expanded leaves (P = 0.0130; G = -0.1296) and length of main axis (P = 0.0115; G = -0.9778). It exhibited negative indirect effect through leaflet width, shelling percentage, leaf length, length of primary branches and days to 50 per cent flowering.

100-seed weight showed positive indirect effect through leaflet length (P = 0.1101; G = -3.7063), number of primary branches per plant (P = 0.0375; G = 1.0939), days to emergence (P = 0.0373; G = -0.2023),

weight of immature pods per plant (P = 0.0338; G = 1.6599), harvest index (P = 0.0289; G = 0.5930), length of main axis (P = 0.0259; G =- 1.3116) and number of immature pods per plant (P = 0.0165; G = 0.0856). Negative indirect effects were found through leaflet width, number of mature pods per plant, length of primary branches, leaf length, days to 50 per cent flowering, shelling percentage and number of fully expanded leaves.

Shelling percentage exerted positive indirect effect through length of primary branches (P = 0.0153; G = -0.5478), leaflet width (P = 0.0071; G = -0.3295) and days to 50 per cent flowering (P = 0.0063; G = -0.2578). Remaining all characters had negative indirect effects.

Harvest index contributed positive indirect effect through leaflet length (P = 0.1200; G = -3.4019), 100-seed weight (P = 0.0518; G = 1.2093), length of main axis (P = 0.0194; G = 0.9328), weight of immature pods per plant (P = 0.0100; G = 0.4349), number of primary branches per plant (P = 0.0095; G = 0.2230) and number of immature pods per plant (P = 0.0052; G = 0.2351). It showed negative indirect effect through leaflet width, length of primary branches, days to emergence, leaf length, number of fully expanded leaves, days to 50 per cent flowering, number of mature pods per plant and shelling percentage.

4.5.2 Physiological characters

Positive direct contribution to pod yield per plant was found from leaf area duration (LAD) at 54 DAS (P = 0.6489; G = 0.8140), LAD at 90 DAS (P = 0.4201; G = 0.4141), seedling vigour index (P = 0.3722; G = 0.2733), CGR at 54 DAS (P = 0.3349; G = 0.9985), LAI at 72 DAS (P = 0.3157; G = 0.0309), harvest index (P = 0.2687; G = 0.4174), SCMR (P = 0.1895; G = 0.0408), SLA at 18 DAS (P = 0.1804; G = -0.1978), germination percentage (P = 0.0839; G = -0.0116), CGR at 72 DAs (P = 0.0795; G = -0.3264), SLA at 72 DAS (P = 0.0420; G = 0.2840) and NAR at 54 DAS (P = 0.0164; G = 0.5018). Negative direct effect was observed from LAD at 72 DAS, LAI at 36 DAS, SLA at 54 DAS, LAI at 54 DAS, NAR at 36 DAS and SLA at 36 DAS.

Leaf area duration (LAD) at 54 DAS expressed positive indirect effect on pod yield per plant through LAD at 90 DAS (P = 0.3554; G = 0.3623), LAI at 72 DAS (P = 0.2632; G = 0.0266), CGR at 54 DAS (P = 0.1504; G = 0.4676), CGR at 72 DAS (P = 0.0361; G = -0.1524), SLA at 72 DAS (P = 0.0203; G = 0.1592), germination percentage (P = 0.0158; G = -0.0035) and SLA at 18 DAS (P = 0.0014; G = -0.0035). It showed negative indirect effect through LAD at 72 DAS, LAI at 36 DAS, seedling vigour index, harvest index, LAI at 54 DAS, SCMR, SLA at 54 DAS, NAR at 36 DAS, SLA at 36 DAS and NAR at 54 DAS.

LAD at 72 DAS contributed positive indirect effect through LAD at 54 DAS (P = 0.5758; G = 0.7273), LAD at 90 DAS (P = 0.4012;

G = 0.4037), LAI at 72 DAS (P = 0.3093; G = 0.0306), CGR at 54 DAS (P = 0.1394; G = 0.4327), CGR at 72 DAS (P = 0.0362; G = -0.1542), SLA at 72 DAS (P = 0.0224; G = 0.1771) and germination percentage (P = 0.0191; G = 0.0045). It exhibited negative indirect effect through seedling vigour index, LAI at 36 DAS, harvest index, LAI at 54 DAS, SCMR, SLA at 54 DAS, NAR at 36 DAS, NAR at 54 DAS, SLA at 36 DAS and SLA at 18 DAS.

LAD at 90 DAS recorded positive indirect effect through LAD at 54 DAS (P = 0.5490; G = 0.7121), LAI at 72 DAS (P = 0.3017; G = 0.0302), CGR at 54 DAS (P = 0.1489; G = 0.4666), CGR at 72 DAS (P = 0.0412; G = -0.1805), SLA at 72 DAS (P = 0.0238; G = 0.1959) and germination percentage (P = 0.0229; G = -0.0054). It registered negative indirect effect through LAD at 72 DAS, seedling vigour index, LAI at 36 DAS, harvest index, LAI at 54 DAS, SCMR, NAR at 36 DAS, SLA at 54 DAS, SLA at 18 DAS, NAR at 54 DAS and SLA at 36 DAS.

CGR at 54 DAS showed positive indirect effect through LAD at 54 DAS (P = 0.2913; G = 0.3812), LAD at 90 DAS (P = 0.1867; G = 0.1935), LAI at 72 DAS (P = 0.1336; G = 0.0138), SLA at 18 DAS (P = 0.0144; G = -0.0173), CGR at 72 DAS (P = 0.0094; G = -0.0417), SLA at 72 DAS (P = 0.0049; G = 0.0484) and germination percentage (P = 0.0008; G = -0.0008). It exerted negative indirect effect through LAD at 72 DAS, LAI at 36 DAS, harvest index, seedling vigour index, LAI at 54 DAS, NAR at 36 DAS, SLA at 54 DAS, SCMR, NAR at 54 DAS and SLA at 36 DAS.

CGR at 72 DAS recorded positive indirect effect through LAD at 54 DAS (P = 0.2946; G = 0.3801), LAD at 90 DAS (P = 0.2175; G = 0.2290), LAI at 72 DAS (P = 0.1487; G = 0.0155), SLA at 54 DAS (P = 0.0421; G = 0.1766), CGR at 54 DAS (P = 0.0397; G = 0.1277), SLA at 72 DAS (P = 0.0031; G = 0.0315), SLA at 36 DAS (P = 0.0028; G = -0.0768), NAR at 36 DAS (P = 0.0022; G = 0.0342), germination percentage (P = 0.0072; G = -0.0009) and NAR at 54 DAS (P = 0.0011; G = 0.0459). It had negative indirect effect through LAD at 72 DAS, seedling vigour indirect effect through LAD at 72 DAS, seedling vigour index, LAI at 36 DAS, harvest index, SCMR, LAI at 54 DAS and SLA at 18 DAS.

LAI at 36 DAS registered positive indirect effect through LAD at 54 DAS (P = 0.4344; G = 0.6911), LAD at 90 DAS (P = 0.1833; G = 0.2360), LAI at 72 DAS (P = 0.1432; G = 0.0179), CGR at 54 DAS (P = 0.1353; G = 0.5050), CGR at 72 DAS (P = 0.0221; G = -0.1122), germination percentage (P = 0.0086; G = -0.0028), SLA at 72 DAS (P = 0.0067; G = 0.0771), SLA at 18 DAS (P = 0.0023; G = 0.0116) and NAR at 36 DAS (P = 0.0019; G = -0.0849). It exhibited negative indirect effect through LAD at 72 DAS, harvest index, LAI at 54 DAS, seedling vigour index SLA at 54 DAS, SCMR, NAR at 54 DAS and SLA at 36 DAS.

LAI at 54 DAS exerted positive indirect effect through LAD at 54 DAS (P = 0.5231; G = 0.7263), LAD at 90 DAS (p = 0.3383; G = 0.4005), LAI at 72 DAS (P = 0.2713; G = 0.0307), CGR at 54 DAS (P = 0.1148; G = 0.3849), CGR at 72 DAS (P = 0.0307; G = -0.1390), SLA at 72 DAS

(P = 0.0205; G = 0.1805), germination percentage (P = 0.0195; G = -0.0044) and SLA at 18 DAS (P = 0.0142; G = -0.0221). Negative indirect effects were exerted through LAD at 72 DAS, seedling vigour index, LAI at 36 DAS, harvest index, SCMR, SLA at 54 DAS, NAR at 36 DAS, SLA at 36 DAS and NAR at 54 DAS.

LAI at 72 DAS showed positive indirect effect through LAD at 54 DAS (P = 0.5410; G = 0.7003), LAD at 90 DAS (P = 0.4015; G = 0.4044), CGR at 54 DAS (P = 0.1418; G = 0.4446), CGR at 72 DAS (P = 0.0375; G = -0.1631), SLA at 72 DAS (P = 0.0214; G = 0.1730) and germination percentage (P = 0.0195; G = -0.0051) while it exhibited negative indirect effect through LAD at 72 DAS, seedling vigour index, LAI at 36 DAS, harvest index, LAI at 54 DAS, SCMR, NAR at 36 DAS SLA at 54 DAS, SLA at 18 DAS, NAR at 54 DAS and SLA at 36 DAS.

NAR at 36 DAS showed positive indirect effect through LAD at 54 DAS (P = 0.1558; G = 0.2733), LAD at 90 DAS (P = 0.1355; G = 0.1872), LAI at 72 DAS (P = 0.0969; G = 0.0129), CGR at 54 DAS (P = 0.0777; G = 0.3285), LAI at 36 DAS (P = 0.0253; G = -0.0056), seedling vigour index (P = 0.0095; G = -0.0129), LAI at 36 DAS (P = 0.0063; G = -0.0773), SLA at 72 DAS (P = 0.0044; G = 0.1125) and SLA at 54 DAS (P = 0.0020; G = -0.0198). It exerted negative indirect effect through LAD at 72 DAS, harvest index, SCMR, LAI at 54 DAS, SLA at 18 DAS, NAR at 54 DAS, CGR at 72 DAS and SLA at 36 DAS.

NAR at 54 DAS exhibited positive indirect effect through LAD at 72 DAS (P = 0.1135; G = -0.0501), LAI at 36 DAS (P = 0.0747; G = 0.0874), harvest index (P = 0.0418; G = 0.0895), LAI at 54 DAS (P = 0.0189; G = 0.0436), SLA at 54 DAS (P = 0.0168; G = 0.0372), NAR at 36 DAS (P = 0.0146; G = 0.1685), CGR at 72 DAS (P = 0.0055; G = -0.0299), SCMR (P = 0.0046; G = 0.0042) and germination percentage (P = 0.0042; G = 0.0017). It showed negative indirect effect through CGR at 54 DAS, LAD at 90 DAS, LAD at 54 DAS, LAI at 72 DAS, seedling vigour index, SLA at 18 DAS, SLA at 36 DAS and SLA at 72 DAS.

SLA at 18 DAS showed positive indirect effect on pod yield per plant through CGR at 54 DAS (P = 0.0268; G = 0.0874), SCMR (P = 0.0170; G = 0.0007), LAD at 72 DAS (P = 0.0065; G = -0.0013), NAR at 36 DAS (P = 0.0064; G = 0.1392) and LAD at 54 DAS (P = 0.0050; G = 0.0142). It exhibited negative indirect effect through SLA at 54 DAS, LAD at 90 DAS, seedling vigour index, germination percentage, CGR at 72 DAS, harvest index, LAI at 54 DAS, LAI at 72 DAS, SLA at 36 DAS, LAI at 36 DAS, SLA at 72 DAS and NAR at 54 DAS.

SLA at 36 DAS exhibited positive indirect effect through LAD at 54 DAS (P = 0.1141; G = 0.2793), SLA at 18 DAS (P = 0.0606; G = -0.1504), seedling vigour index (P = 0.0441; G = 0.0860), CGR at 54 DAS (P = 0.0430; G = 0.1943), LAD at 90 DAS (P = 0.0425; G = 0.0495), LAI at 72 DAS (P = 0.0201; G = 0.0029), SLA at 72 DAS (P = 0.0080; G =0.1227), NAR at 54 DAS (P = 0.0009; G = 0.0568) and SCMR

(P = 0.0021; G = -0.0222). It exerted negative indirect effect through SLA at 54 DAS, LAI at 36 DAS, LAD at 72 DAS, harvest index, LAI at 54 DAS, CGR at 72 DAS, germination percentage and NAR at 36 DAS.

SLA at 54 DAS showed positive indirect effect through LAD at 54 DAS (P = 0.1478; G = 0.2673), seedling vigour index (P = 0.0904; G = 0.0630), SLA at 18 DAS (P = 0.0594; G = -0.1239), LAD at 90 DAS (P = 0.0453; G = 0.0803), CGR at 54 DAS (P = 0.0382; G = 0.2142), LAI at 72 DAS (P = 0.0362; G = 0.0049), SLA at 72 DAS (P = 0.0109; G = 0.1230), germination percentage (P = 0.0017; G = -0.0031) and NAR at 36 DAS (P = 0.0010; G = -0.0248). Negative indirect effects were exhibited through LAD at 72 DAS, LAI at 36 DAS, harvest index, LAI at 54 DAS, SCMR, CGR at 72 DAS, SLA at 36 DAS and NAR at 54 DAS.

SLA at 72 DAS showed positive indirect effect through LAD at 54 DAS (P = 0.3134; G = 0.4563), LAD at 90 DAS (P = 0.2381; G = 0.2856), LAI at 72 DAS (P = 0.1609; G = 0.0188), CGR at 54 DAS (P = 0.0390; G = 0.1703), germination percentage (P = 0.0186; G = -0.0065) and CGR at 72 DAS (P = 0.0058; G = -0.0361). It showed negative indirect effect through LAD at 72 DAS, seedling vigour index, LAI at 54 DAS, LAI at 36 DAS, SLA at 54 DAS, SCMR, harvest index, NAR at 36 DAS, SLA at 36 DAS, SLA at 18 DAS and NAR at 54 DAS.

SCMR exerted positive indirect effect through LAD at 72 DAS (P = 0.1838; G = -0.0955), seedling vigour index (P = 0.0390; G = 0.0807), LAI at 54 DAs (P = 0.0388, G = 0.1360), LAI at 36 DAS

(P = 0.0357; G = 0.2837), NAR at 36 DAS (P = 0.0236; G = 0.3917), SLA at 54 DAS (P = 0.0205; G = 0.1336), SLA at 18 DAS (P = 0.0161; G = -0.0032), harvest index (P = 0.0156; G = 0.1296) and NAR at 54 DAS (P = 0.0004; G = 0.0515). It had negative indirect effect through LAD at 54 DAS, LAD at 90 DAS, LAI at 72 DAS, CGR at 54 DAS, CGR at 72 DAS, germination index, SLA at 72 DAS and SLA at 36 DAS.

Germination percentage showed positive indirect effect through LAD at 54 DAS (P = 0.1220; G = 0.2441), LAD at 90 DAS (P = 0.1146; G = 0.1930), LAI at 72 DAS (P = 0.0732; G = 0.0135), seedling vigour index (P = 0.0600; G = 0.0133), harvest index (P = 0.0249; G = -0.0567), SLA at 72 DAS (P = 0.0093; G = 0.1586), CGR at 72 DAS (P = 0.0068, G = -0.0239), CGR at 54 DAS (P = 0.0033; G = 0.0657), NAR at 54 DAS (P = 0.0008; G = 0.0740) and SLA at 36 DAS (P = 0.0001; G = 0.0790). Negative indirect effects were through LAD at 72 DAS, SLA at 18 DAS, SCMR, LAI at 36 DAS, LAI at 54 DAS, NAR at 36 DAS and SLA at 54 DAS.

Seedling vigour index registered positive indirect effect through LAD at 72 DAS (P = 0.2822; G = -0.1241), harvest index (P = 0.0802; G = 0.1870), LAI at 54 DAS (P = 0.0466; G = 0.1650), LAI at 36 DAS (P = 0.0342; G = 0.1799), SCMR (P = 0.0199; G = 0.0121) and germination percentage (P = 0.0135; G = -0.0006). Negative indirect effects were observed through LAD at 54 DAS, LAD at 90 DAS, LAI at 72 DAS, CGR at 54 DAS, SLA at 54 DAS, CGR at 72 DAS, SLA at 18 DAS, SLA at 72 DAS, SLA at 36 DAS, NAR at 36 DAS and NAR at 54 DAS.

Harvest index exerted positive indirect effect on pod yield per plant through LAD at 72 DAS (P = 0.2929; G = -0.1011), seedling vigour index (P = 0.1111, G = 0.1224), LAI at 36 DAS (P = 0.1022; G = 0.2508), LAI at 54 DAS (P = 0.0583; G = 0.1298), SLA at 54 DAS (P = 0.0190; G = 0.1009), NAR at 36 DAS (P = 0.0168; G = 0.1840), SCMR (P = 0.0110; G = 0.0127), SLA at 36 DAS (P = 0.0040; G = -0.1055) and NAR at 54 DAS (P = 0.0026; G = 0.1076). It exerted negative indirect effect through LAD at 54 DAS, LAD at 90 DAS, LAI at 72 DAS, CGR at 54 DAS, CGR at 72 DAS, germination percentage, SLA at 18 DAS and SLA at 72 DAS.

Table 3: Analysis of variance for 16 morphological, yield and yield attributes in 29 cultivars of groundnut.

Sl. No.	Character	Replications (df = 2)	Treatments (df = 28)	Error (df = 56)
1	Days to emergence	0.08	1.92**	0.16
2	Number of primary branches per plant	2.22	1.03	0.86
3	Length of main axis	9.01	142.94**	18.01
4	Length of primary branches	3.73	201.55**	28.95
5	Days to 50% flowering	19.87	31.94**	6.42
6	Leaflet length	0.04	0.91**	0.12
7	Leaflet width	0.01	0.19**	0.02
8	Leaf length	0.07	1.00**	0.21
9	Number of fully expanded leaves	69.62	322.01**	87.56
10	Number of mature pods per plant	15.03	29.10	18.12
11	Number of immature pods per plant	12.17	12.42	7.55
12	Weight of immature pods per plant	4.76	5.36**	2.30
13	100-seed weight	17.46	134.42**	18.90
14	Shelling percentage	174.95	119.74**	64.08
15	Harvest index	5.34	172.69**	7.37
16	Pod yield per plant	0.15	19.41**	6.32

** Significant at 1% level

Table 13: Relative contribution of 16 morphological, yield and yield attributes to genetic diversity in 29 groundnut cultivars.

Sl. No.	Character	Times ranked First	Contribution (%)
1	Days to emergence	69	17.00
2	Number of primary branches per plant	1	0.25
3	Length of main axis	35	8.62
4	Length of primary branches	4	0.99
5	Days to 50% flowering	15	3.69
6	Leaflet length	26	6.40
7	Leaflet width	14	3.45
8	Leaf length	19	4.68
9	Number of fully expanded leaves	13	3.20
10	Number of mature pods per plant	0	0.00
11	Number of immature pods per plant	1	0.25
12	Weight of immature pods per plant	18	4.43
13	100-seed weight	24	5.91
14	Shelling percentage	10	2.46
15	Harvest index	136	33.50
16	Pod yield per plant	21	5.17

Table 14: Canonical root values, per cent of variation expected and cumulative variation expected for 29 cultivars of groundnut.

Sl. No.	Values of canonical root	Per cent of variation expected	Cumulative total Variation expected
Z_1	108.89	33.03	33.03
Z_2	61.00	18.50	51.53
Z_3	47.97	14.55	66.08
Z_4	26.93	8.17	74.24
Z_5	23.84	7.23	81.47

Table 9: Analysis of variance for dispersion in 29 cultivars of groundnut for 16 morphological, yield and yield attributes

Source of Variation	Degrees of freedom	Mean sum of squares
Cultivars	28	1.1017E21**
Error	55	9.0838E12
Total	83	3.7165E20

** Significant at 1% level

Table 15: Mean values of canonical vectors in 29 cultivars of groundnut

Sl. No.	Cultivar	'X' Vector	'Y' vector	'Z' vector
1	Tirupati-1	3.98	-3.98	11.42
2	Tirupati-2	4.68	-3.42	11.05
3	Tirupati-3	1.62	0.18	9.41
4	Tirupati-4	3.73	-2.24	12.77
5	Narayani	2.68	-3.18	9.77
6	Kalahasti	3.45	-0.28	11.54
7	Prasuna	2.07	-0.51	14.08
8	Abhaya	4.77	-1.91	13.58
9	TCGS-156	1.82	-2.61	10.96
10	TCGS-653	6.04	-1.75	10.41
11	TIR-23	6.28	-0.75	13.34
12	TCGS-888	9.37	-1.90	11.95
13	TCGS-913	5.43	-2.72	11.39
14	K-134	5.02	-0.96	13.35
15	K-4	5.35	-0.08	12.22
16	K-6	3.82	-1.36	11.58
17	TCGS-717	2.47	0.83	12.04
18	TCGS-722	3.35	-1.52	13.13
19	TCGS-750	5.04	0.29	10.19
20	TG-47	8.64	-0.37	9.87
21	TG-39	6.89	0.68	10.35
22	TCGP-6	6.75	0.09	14.15
23	JL-24	3.28	-1.24	12.69
24	TMV-2	4.48	-5.12	12.22
25	TCGS-645	5.13	-0.28	10.97
26	TCGS-91	4.23	-2.13	11.22
27	JL-501	3.77	-1.47	12.77
28	R_2001-2	8.48	-3.55	12.34
29	TIR-9	5.12	-1.84	10.68

Table 16: Canonical vectors for 16 morphological, yield and yield attributes contributing to genetic divergence in 29 groundnut cultivars

S. No.	Character	Canonical vectors				
		Z_1	Z_2	Z_3	Z_4	Z_5
1	Days to emergence	0.034	0.470	0.613	0.245	0.072
2	Number of primary branches per plant	0.016	0.056	-0.094	0.004	0.245
3	Length of main axis	-0.298	-0.408	0.065	0.232	0.255
4	Length of primary branches	-0.282	-0.276	-0.010	0.028	0.250
5	Days to 50% flowering	0.048	0.207	-0.184	-0.170	-0.087
6	Leaflet length	-0.244	-0.019	0.302	0.125	0.036
7	Leaflet width	-0.211	0.051	0.296	0.159	0.055
8	Leaf length	0.048	-0.194	-0.106	0.404	0.326
9	Number of fully expanded leaves	-0.086	0.239	-0.103	-0.254	0.473
10	Number of mature pods per plant	0.213	0.199	0.159	-0.043	0.054
11	Number of immature pods per plant	0.080	0.130	-0.088	-0.105	0.000
12	Weight of immature pods per plant	0.154	0.128	-0.225	0.412	0.235
13	100-seed weight	0.152	0.295	-0.213	0.554	-0.066
14	Shelling percentage	-0.112	-0.102	0.406	-0.089	-0.069
15	Harvest index	0.775	-0.426	0.286	-0.031	0.142
16	Pod yield per plant	0.056	0.201	0.037	-0.299	0.614

Table 10: Distribution of 29 cultivars of groundnut in different clusters (Tocher's method)

Cluster	Number of cultivars	Cultivars
I	13	TCGS-653, TIR - 9, TCGS-91, Tirupati - 2, K-6, Tirupati – 1, JL - 501, TCGS - 722, Abhaya, K - 134, TCGS-645, Kalahasti, JL – 24
II	1	TMV-2
III	6	TIR - 23, TCGP – 6, K – 4, TCGS – 750, TG – 39, TG – 47
IV	1	TCGS – 156
V	4	TCGS – 888, R - 2001-2, TCGS – 913, Tirupati-4
VI	1	Prasuna
VII	1	TCGS-717
VIII	1	Narayani
IX	1	Tirupati–3

Table 4: Mean performance of 29 cultivars of groundnut for 16 morphological, yield and yield attributes

Sl. No.	Cultivar	Days to emer-gence	Number of primary branches per plant	Length of main axis	Length of primary branches	Days to 50% flower-ing	Leaflet length	Leaflet width	Leaf length	Number of fully expanded leaves	Number of mature pods per plant	Number of immat-ure pods per plant	Weight of imamt-ure pods per plant	100-seed weight	Shelling percentage		Harvest Index	Pod yield per plant
															Trans-formed	Obser-ved		
1	Tirupati-1	***4.00***	5.47	38.39	43.81	***26.33***	5.21	2.10	5.47	50.00	18.07	7.67	1.20	27.67	57.80	71.62	44.69	10.66
2	Tirupati-2	***4.00***	5.73	37.47	42.68	27.00	5.09	2.27	5.61	52.67	18.73	8.07	2.33	31.00	48.56	56.23	49.18	14.20
3	Tirupati-3	4.67	6.00	28.37	47.16	36.00	4.45	1.89	5.09	73.11	19.27	10.07	2.73	30.67	51.94	62.08	***31.70***	14.20
4	Tirupati-4	5.33	6.87	40.64	48.93	27.67	5.17	2.44	6.33	61.66	**24.73**	8.60	2.67	31.33	51.06	60.52	44.84	**18.40**
5	Narayani	***4.00***	5.53	**49.61**	**51.14**	28.33	5.27	2.37	6.47	62.55	19.47	10.87	3.67	36.67	47.98	55.23	42.43	15.66
6	Kalahasti	5.33	5.33	27.48	28.24	29.00	4.55	2.09	4.89	46.55	11.73	9.53	2.47	33.67	49.49	57.84	35.56	9.73
7	Prasuna	**6.67**	5.93	43.09	47.25	35.33	5.13	2.46	5.36	56.22	19.80	10.67	1.67	31.33	54.03	65.52	35.59	14.00
8	Abhaya	5.67	6.00	32.85	39.69	29.00	4.82	2.13	5.53	47.66	20.47	7.73	1.27	33.00	**60.94**	**76.43**	45.01	15.06
9	TCGS-156	***4.00***	5.53	39.51	43.47	30.33	5.51	**2.55**	6.24	50.11	16.87	6.80	***0.80***	34.33	59.15	73.71	38.05	11.13
10	TCGS-653	***4.00***	5.67	25.37	27.99	35.33	4.28	2.05	4.72	49.11	12.93	12.43	1.67	35.33	51.41	61.16	51.34	11.40
11	TIR-23	6.00	5.00	24.77	29.89	36.00	4.69	2.14	5.63	47.22	15.13	8.00	1.27	37.67	55.00	67.67	50.81	13.66
12	TCGS-888	5.33	***4.87***	23.09	23.26	34.33	3.91	***1.59***	4.91	51.66	13.80	8.87	2.00	39.67	52.95	63.78	62.54	11.60
13	TCGS-913	5.00	5.27	32.26	36.11	28.67	4.75	2.10	**6.64**	***39.00***	***11.67***	7.67	2.40	41.67	54.09	65.63	48.42	9.40
14	K-134	6.00	5.60	29.75	35.10	27.00	4.85	2.23	5.53	46.22	17.60	7.13	2.60	35.67	49.02	57.00	44.59	16.13
15	K-4	5.00	6.27	24.27	27.08	29.00	4.07	2.19	***4.53***	64.22	22.13	10.33	2.73	34.00	53.85	65.29	46.79	17.00
16	K-6	4.67	4.93	29.36	32.73	31.00	5.20	2.42	5.66	39.77	13.67	7.00	3.07	36.33	52.18	62.47	42.42	11.86
17	TCGS-717	6.00	6.20	32.58	36.97	32.67	5.55	2.30	5.55	**82.67**	19.27	6.20	4.60	35.67	50.94	60.30	35.85	13.46
18	TCGS-722	5.00	5.53	28.39	32.48	28.00	5.63	2.54	5.81	43.55	17.60	7.40	1.53	30.00	55.80	68.47	39.24	11.60
19	TCGS-750	5.00	5.60	28.00	30.45	**36.67**	4.14	2.03	4.83	59.66	17.93	7.00	1.80	48.33	49.89	58.60	47.43	11.86
20	TG-47	4.67	**7.13**	***20.45***	23.54	33.33	***3.61***	1.63	4.56	55.22	15.53	12.47	**6.20**	48.67	49.14	57.22	58.59	17.00
21	TG-39	5.33	6.93	22.89	***21.69***	35.67	4.76	2.04	6.05	58.77	16.27	10.87	6.00	**49.33**	***43.11***	***46.76***	51.40	15.60
22	TCGP-6	6.67	6.07	28.69	29.21	33.33	4.59	2.24	5.04	51.77	19.73	6.13	4.00	40.67	49.54	57.95	53.45	16.53
23	JL-24	5.33	5.73	33.71	37.54	31.33	5.36	2.42	6.09	75.77	17.93	7.60	1.47	23.33	52.00	62.10	41.42	15.60
24	TMV-2	***4.00***	5.47	42.45	47.03	27.33	5.30	2.36	5.75	42.33	18.33	8.22	1.73	***21.33***	52.36	62.73	50.20	***9.13***
25	TCGS-645	5.00	6.87	27.09	29.61	33.00	4.74	2.22	5.73	53.88	19.13	***4.53***	3.67	39.67	45.97	51.73	47.96	14.53
26	TCGS-91	***4.00***	5.93	33.13	34.55	34.00	**5.86**	**2.55**	6.39	61.78	21.07	8.87	2.33	30.33	50.59	59.71	47.70	14.20
27	JL-501	5.67	5.33	35.53	39.12	33.33	5.30	2.40	5.91	60.33	16.07	7.13	2.33	33.00	53.01	63.80	44.01	9.53
28	R_2001-2	4.67	5.73	30.56	32.54	31.33	4.47	1.92	5.71	60.33	20.93	8.40	1.80	28.00	51.83	61.85	**63.66**	14.20
29	TIR-9	4.33	5.33	28.57	32.96	34.00	4.33	1.94	5.25	55.00	14.53	**12.93**	1.33	32.33	55.80	68.46	46.19	12.53
	G. MEAN	5.01	5.79	31.67	35.59	31.53	4.85	2.19	5.56	55.13	17.60	8.59	2.53	34.85	52.00	62.13	46.24	13.44
	S.ED.	0.23	0.54	2.45	3.11	1.46	0.20	0.09	0.27	5.40	2.46	1.59	0.88	2.51	5.01	--	1.57	2.05
	C.D.(0.05)	0.66	NS	6.94	8.80	4.14	0.57	0.25	0.75	15.31	NS	NS	2.48	7.11	9.86	--	4.44	4.10
	C.D.(0.01)	0.88	NS	9.24	11.71	5.52	0.76	0.33	1.00	20.37	NS	NS	3.30	9.47	10.11	--	5.91	5.46
	C.V.(%)	8.08	16.01	13.40	15.12	8.04	7.19	6.86	8.25	16.97	24.18	31.98	59.96	12.47	13.06	--	5.87	18.69

Table 7: Genetic parameters for 16morphological, yield and yield attributes of 29 groundnut cultivars

Sl. No.	Character	Mean	Range		Variance		Co-efficient of variation		Herita-bility (Broad sense %)	Genetic Advance	Genetic Advance as per cent of mean (%)
			Min.	Max.	Geno-typic	Pheno-typic	Geno-typic (%)	Pheno-typic (%)			
1	Days to emergence	5.01	4.00	6.67	0.58	0.75	15.25	17.26	78.10	1.39	27.76
2	Number of primary branches per plant	5.79	4.87	7.13	0.06	0.92	4.17	16.54	06.34	0.13	2.16
3	Length of main axis	31.67	20.45	49.61	41.64	59.66	20.38	24.39	69.80	11.11	35.07
4	Length of primary branches	35.59	21.69	51.14	57.53	86.48	21.31	26.13	66.53	12.74	35.81
5	Days to 50% flowering	31.53	26.33	36.67	8.51	14.93	9.25	12.25	56.99	4.54	14.39
6	Leaflet length	4.85	3.61	5.86	0.26	0.39	10.59	12.80	68.46	0.88	18.06
7	Leaflet width	2.19	1.59	2.55	0.06	0.08	10.70	12.71	70.85	0.41	18.56
8	Leaf length	5.56	4.53	6.64	0.26	0.47	9.24	12.39	55.60	0.79	14.19
9	Number of fully expanded leaves	55.13	39.00	82.67	78.15	165.71	16.04	23.35	47.16	12.51	22.68
10	Number of mature pods per plant	17.60	11.67	24.73	3.66	21.78	10.87	26.51	16.81	1.62	9.18
11	Number of immature pods per plant	8.59	4.53	12.93	1.62	9.17	14.83	35.25	17.70	1.10	12.85
12	Weight of immature pods per plant	2.53	0.80	6.20	1.02	3.32	39.97	72.06	30.76	1.15	45.66
13	100-seed weight	34.85	21.33	49.33	38.51	57.41	17.81	21.74	67.08	10.47	30.04
14	Shelling percentage	62.13	46.76	76.43	18.55	82.63	6.93	14.63	22.45	4.20	6.77
15	Harvest index	46.24	31.70	63.66	55.10	62.48	16.05	17.09	88.20	14.36	31.06
16	Pod yield per plant	13.45	9.13	18.40	4.36	10.68	15.54	24.31	40.86	2.75	20.46

Table 11: Average Inter and Intra-cluster (diagonal) distance D^2 and D values (Parenthesis) in 29 cultivars of groundnut (Mahalanobis's D^2 statistic)

Cluster	I	II	III	IV	V	VI	VII	VIII	IX
I	12.74 (3.57)	18.66 (4.32)	21.80 (4.67)	***16.24 (4.03)***	24.50 (4.95)	23.71 (4.87)	20.88 (4.57)	24.20 (4.92)	29.48 (5.43)
II		0.00 (0.00)	39.31 (6.27)	18.40 (4.29)	24.70 (4.97)	35.64 (5.97)	45.42 (6.74)	22.10 (4.71)	51.55 (7.18)
III			18.57 (4.31)	38.31 (6.19)	25.90 (5.09)	37.57 (6.13)	30.47 (5.52)	41.08 (6.41)	44.62 (6.68)
IV				0.00 (0.00)	38.93 (6.24)	21.06 (4.59)	22.09 (4.70)	11.02 (3.32)	22.75 (4.77)
V					26.83 (5.18)	45.42 (6.74)	44.89 (6.70)	36.96 (6.08)	**57.76 (7.60)**
VI						0.00 (0.00)	18.40 (4.29)	33.98 (5.83)	32.49 (5.70)
VII							0.00 (0.00)	31.58 (5.62)	18.40 (4.29)
VIII								0.00 (0.00)	30.47 (5.52)
IX									0.00 (0.00)

Table 12: Cluster means for 16 morphological, yield and yield attributes in 29 groundnut cultivars (Mahalanobis's D^2 method)

Cultivar	Days to emer-gence	Number of primary branches per plant	Length of main axis	Length of primary branches	Days to 50% flower-ing	Leaflet length	Leaflet width	Leaf length	Number of fully expanded leaves	Number of mature pods per plant	Number of immat-ure pods per plant	Weight of imamt-ure pods per plant	100-seed weight	Shelling percent-tage	Harvest Index	Pod yield per plant
I	4.85	5.65	31.31	35.12	30.64	5.02	2.26	5.58	52.48	16.89	8.31	2.10	32.41	62.85	44.56	12.85
II	4.00	5.47	42.45	47.03	27.33	5.30	2.36	5.75	42.33	18.33	8.22	1.73	21.33	62.73	50.20	9.13
III	5.44	6.17	24.85	26.98	34.00	4.31	2.04	5.11	56.14	17.79	9.13	3.67	43.11	58.91	51.41	15.28
IV	4.00	5.53	39.51	43.47	30.33	5.51	2.55	6.24	50.11	16.87	6.80	0.80	34.33	73.71	38.05	11.13
V	5.08	5.68	31.64	35.21	30.50	4.58	2.01	5.90	53.16	17.78	8.38	2.22	35.17	62.95	54.87	13.40
VI	6.67	5.93	43.09	47.25	35.33	5.13	2.46	5.36	56.22	19.80	10.67	1.67	31.33	65.52	35.59	14.00
VII	6.00	6.20	32.58	36.97	32.67	5.55	2.30	5.55	82.67	19.27	6.20	4.60	35.67	60.30	35.85	13.47
VIII	4.00	5.53	49.61	51.14	28.33	5.27	2.37	6.47	62.55	19.47	10.87	3.67	36.67	55.23	42.43	15.67
IX	4.67	6.00	28.37	47.16	36.00	4.45	1.89	5.09	73.11	19.27	10.07	2.73	30.67	62.08	31.70	14.20

Table 27: Phenotypic (r_p) and genotypic (r_g) correlation coefficients among 16 morphological, yield and yield attributes of 29 groundnut cultivars

Character		Number of primary branches per plant	Length of main axis	Length of primary branches	Days to 50% flowering	Leaflet length	Leaflet width	Leaf length	Number of fully expanded leaves	Number of mature pods per plant	Number of immature pods per plant	Weight of immature pods per plant	100-seed weight	Shelling percent-age	Harvest Index	Pod yield per plant
Days to emergence	r_p	0.0905	-0.1517	-0.1409	0.2226*	-0.0973	-0.0141	-0.1479	0.0865	0.0091	-0.2072	0.1236	0.1928	-0.0873	-0.1125	0.1960
	r_g	0.2370	-0.2251	-0.2228	0.2802	-0.0685	0.0567	-0.1465	0.1389	0.2163	-0.4171	0.2285	0.2552	-0.0048	-0.0992	0.3591
Number of primary branches/ plant	r_p		-0.0469	-0.0565	0.0922	-0.0493	-0.0146	-0.0619	0.1362	0.2694*	-0.0430	0.2776*	0.2118*	-0.3476**	0.0535	0.3197**
	r_g		-0.4506	-0.2573	0.1721	-0.4181	-0.2145	-0.0724	1.3410	1.7726	0.9351	2.1819	0.6591	-1.0223	0.1344	2.0384
Length of main axis	r_p			0.7454**	-0.3576**	0.5615**	0.5062**	0.4361**	0.0683	0.3092**	-0.0788	-0.1989	-0.4477**	0.0932	-0.3359**	-0.0272
	r_g			1.0249	-0.5579	0.7357	0.6948	0.6950	0.0716	0.5702	-0.2295	-0.4320	-0.5795	0.3213	-0.4121	-0.1533
Length of primary branches	r_p				-0.3283**	0.4749**	0.4029**	0.3321**	0.1064	0.3610**	0.0048	-0.1229	-0.4483**	0.1644	-0.4537**	0.0273
	r_g				-0.4848	0.6625	0.5913	0.6036	0.2009	0.6242	-0.2878	-0.6131	-0.6986	0.4702	-0.5724	-0.1029
Days to 50% flowering	r_p					-0.2887**	-0.2668**	-0.2167*	0.1658	-0.1592	0.0786	0.1227	0.3416**	-0.0924	0.1423	0.0333
	r_g					-0.4284	-0.3925	-0.4086	0.4646	-0.2586	0.5194	0.2688	0.5353	-0.3728	0.1290	0.0412
Leaflet length	r_p						0.8461**	0.7118**	0.0310	0.2520*	-0.2593*	-0.0888	-0.4164**	0.0469	-0.4540**	-0.0792
	r_g						0.8993	0.7779	0.1124	0.3615	-0.7487	-0.3809	-0.6083	0.2972	-0.5584	-0.2472
Leaflet width	r_p							0.5830**	-0.0161	0.2753**	-0.2611*	-0.1509	-0.3633**	0.0330	-0.4669**	0.0006
	r_g							0.6166	0.0257	0.5217	-0.6815	-0.3648	-0.5065	0.2395	-0.5938	-0.0557
Leaf length	r_p								-0.0161	0.1251	-0.1997	-0.0974	-0.1884	-0.0032	-0.1381	-0.0028
	r_g								-0.0093	0.2585	-0.5572	-0.0964	-0.2786	0.0199	-0.1990	-0.0995
Number of fully expanded leaves	r_p									0.3878**	0.0676	0.1633	-0.1071	-0.0786	-0.1713	0.2006
	rg									0.7111	0.1090	0.4108	-0.0774	-0.4975	-0.2882	0.7033
Number of mature pods per plant	r_p										0.0116	0.1673	-0.2075	-0.0492	-0.0276	0.3913**
	r_g										-0.7505	-0.2779	-0.5197	0.0347	-0.1631	1.1435
Number of immature pods per plant	r_p											0.2905**	0.0957	-0.0385	0.0299	0.1612
	r_g											-0.1577	0.0930	-0.1345	0.2553	0.1317
Weight of immature pods per plant	r_p												0.4221**	-0.4944**	0.1253	0.2999**
	r_g												0.8560	-1.1741	0.2243	0.6758
100-seed weight	r_p													-0.1910	0.2712*	0.2283*
	r_g													-0.7753	0.3282	0.1405
Shelling percentage	r_p														-0.1318	-0.1236
	r_g														-0.3029	-0.7190
Harvest Index	r_p															0.0990
	r_g															0.1648

* - Significant at 5% level ** - Significant at 1% level

Table 29: Phenotypic (P) and Genotypic (G) path coefficients for pod yield and different morphological and yield attributes in 29 groundnut cultivars.

Characters		Days to emer-gence	Number of primary branches per plant	Length of main axis	Length of primary branches	Days to 50% flower-ing	Leaflet length	Leaflet width	Leaf length	Number of fully expanded leaves	Number of mature pods per plant	Number of immature pods per plant	Weight of immature pods per plant	100-seed weight	Shelling percent-age	Harvest Index	Correlation with Pod yield per plant
Days to emergence	P	**0.1937**	0.0161	0.0088	-0.0131	-0.0152	0.0257	-0.0031	-0.0199	0.0069	0.0028	-0.0358	0.0099	0.0368	-0.0054	-0.0120	0.1960
	G	**-0.7929**	0.3933	-0.5095	0.2595	0.1938	-0.4171	-0.0780	0.4069	-0.0438	0.1521	-0.3841	0.4432	0.9403	-0.0253	-0.1792	0.3591
Number of primary branches per plant	P	0.0175	**0.1773**	0.0027	-0.0053	-0.0063	0.0130	-0.0032	-0.0083	0.0108	0.0821	-0.0074	0.0222	0.0404	-0.0217	0.0057	0.3197**
	G	-0.1879	**1.6598**	-1.0200	0.2998	0.1190	-2.5474	0.2950	0.2010	-0.4232	1.2462	0.8611	4.2311	2.4286	-5.3677	0.2428	2.0384
Length of main axis	P	-0.0294	-0.0083	**-0.0578**	0.0694	0.0245	-0.1484	0.1095	0.0588	0.0054	0.0942	-0.0136	-0.0159	-0.0855	0.0058	-0.0359	-0.0272
	G	0.1785	-0.7480	**2.2635**	-1.1941	-0.3859	4.4822	-0.9557	-1.9299	-0.0226	0.4008	-0.2113	-0.8377	-2.1353	1.6870	-0.7448	-0.1533
Length of primary branches	P	-0.0273	-0.0100	-0.0431	**0.0931**	0.0225	-0.1255	0.0871	0.0447	0.0085	0.1100	0.0008	-0.0098	-0.0856	0.0103	-0.0484	0.0273
	G	0.1766	-0.4272	2.3199	**-1.1651**	-0.3353	4.0365	-0.8134	-1.6763	-0.0634	0.4388	-0.2650	-1.1889	-2.5744	2.4685	-1.0344	-0.1029
Days to 50% flowering	P	0.0431	0.0164	0.0207	-0.0306	**-0.0684**	0.0763	-0.0577	-0.0292	0.0132	-0.0485	0.0136	0.0098	0.0652	-0.0058	0.0152	0.0333
	G	-0.2222	0.2857	-1.2629	0.5648	**0.6917**	-2.6101	0.5399	1.1347	-0.1466	-0.1818	0.4783	0.5212	1.9727	-1.9573	0.2331	0.0412
Leaflet length	P	-0.0189	-0.0087	-0.0325	0.0442	0.0198	**-0.2643**	0.1830	0.0959	0.0025	0.0768	-0.0448	-0.0071	-0.0795	0.0029	-0.0484	-0.0792
	G	0.0543	-0.6940	1.6651	-0.7719	-0.2963	**6.0927**	-1.2370	-2.1603	-0.0355	0.2541	-0.6895	-0.7386	-2.2416	1.5602	-1.0091	-0.2472
Leaflet width	P	-0.0027	-0.0026	-0.0293	0.0375	0.0183	-0.2236	**0.2162**	0.0786	-0.0013	0.0839	-0.0451	-0.0121	-0.0694	0.0021	-0.0498	0.0006
	G	-0.0450	-0.3560	1.5726	-0.6890	-0.2715	5.4792	**-1.3755**	-1.7123	-0.0081	0.3668	-0.6276	-0.7074	-1.8666	1.2577	-1.0730	-0.0557
Leaf length	P	-0.0286	-0.0110	-0.0252	0.0309	0.0148	-0.1881	0.1261	**0.1347**	-0.0013	0.0381	-0.0345	-0.0078	-0.0360	-0.0002	-0.0147	-0.0028
	G	0.1162	-0.1201	1.5730	-0.7033	-0.2826	4.7396	-0.8481	**-2.7770**	0.0029	0.1817	-0.5132	-0.1870	-1.0266	0.1047	-0.3597	-0.0995
Number of fully expanded leaves	P	0.0167	0.0242	-0.0039	0.0099	-0.0113	-0.0082	-0.0035	-0.0022	**0.0796**	0.1182	0.0117	0.0131	-0.0204	-0.0049	-0.0183	0.2006
	G	-0.1101	2.2259	0.1621	-0.2341	0.3214	0.6847	-0.0353	0.0257	**-0.3156**	0.4999	0.1004	0.7966	-0.2851	-2.6122	-0.5209	0.7033
Number of mature pods per plant	P	0.0018	0.0478	-0.0179	0.0336	0.0109	-0.0666	0.0595	0.0169	0.0309	**0.3047**	0.0020	0.0134	-0.0396	-0.0031	-0.0029	0.3913**
	G	-0.1715	2.9423	1.2906	-0.7272	-0.1789	2.2024	-0.7176	-0.7178	-0.2244	**0.7030**	-0.6911	-0.5388	-1.9151	0.1823	-0.2948	1.1435
Number of immature pods per plant	P	-0.0401	-0.0076	0.0046	0.0004	-0.0054	0.0686	-0.0565	-0.0269	0.0054	0.0035	**0.1729**	0.0233	0.0183	-0.0024	0.0032	0.1612
	G	0.3307	1.5521	-0.5195	0.3353	0.3592	-4.5617	0.9375	1.5475	-0.0344	-0.5276	**0.9209**	-0.3058	0.3426	-0.7064	0.4613	0.1317
Weight of immature pods per plant	P	0.0239	0.0492	0.0115	-0.0114	-0.0084	0.0235	-0.0326	-0.0131	0.0130	0.0510	0.0502	**0.0801**	0.0806	-0.0309	0.0134	0.2999**
	G	-0.1812	3.6217	-0.9778	0.7143	0.1859	-2.3206	0.5018	0.2677	-0.1296	-0.1953	-0.1452	**1.9392**	3.1544	-6.1647	0.4053	0.6758
100-seed weight	P	0.0373	0.0375	0.0259	-0.0418	-0.0234	0.1101	-0.0786	-0.0254	-0.0085	-0.0632	0.0165	0.0338	**0.1910**	-0.0119	0.0289	0.2283
	G	-0.2023	1.0939	-1.3116	0.8139	0.3703	-3.7063	0.6968	0.7736	0.0244	-0.3654	0.0856	1.6599	**3.6850**	-4.0705	0.5930	0.1405
Shelling percent-age	P	-0.0169	-0.0616	-0.0054	0.0153	0.0063	-0.0124	0.0071	-0.0004	-0.0063	-0.0150	-0.0067	-0.0396	-0.0365	**0.0624**	-0.0141	-0.1236
	G	0.0038	-1.6969	0.7273	-0.5478	-0.2578	1.8105	-0.3295	-0.0554	0.1570	0.0244	-0.1239	-2.2769	-2.8569	**5.2504**	-0.5474	-0.7190
Harvest Index	P	-0.0218	0.0095	0.0194	-0.0423	-0.0097	0.1200	-0.1010	-0.0186	-0.0136	-0.0084	0.0052	0.0100	0.0518	-0.0082	**0.1067**	0.0990
	G	0.0786	0.2230	-0.9328	0.6668	0.0892	-3.4019	0.8167	0.5527	0.0910	-0.1147	0.2351	0.4349	1.2093	-1.5904	**1.8072**	0.1648

Residual effect (Phenotypic) 0.8060
Residual effect (Genotypic) 0.4520

Bold : Direct effects
Normal: Indirect effects

** Significant at 1% level
* Significant at 5% level

Table 25: List of random primers along with their nucleotide sequence selected for PCR amplification in groundnut

Sl. No.	Primer code	Nucleotide sequence (5' – 3')	Total number of bands	Polymorphic bands
1	OPA – 3	AGTCAGCCAC	10	9
2	OPA – 19	CAAACGTCGG	7	6
3	OPH-7	CTGCATCGTG	10	8
4	OPH-20	GGGAGACATC	8	5
5	OPJ-1	CCCGGCATAA	7	6
6	OPJ-4	CCGAACACGG	5	5
7	OPJ-6	TCGTTCCGCA	11	9
		Total bands	58	48

Table 26: Similarity matrix of 12 groundnut cultivars using Jaccard's coefficient of similarity

Sl. No.	Cultivars	1	2	3	4	5	6	7	8	9	10	11	12
1	Tirupati-3	1											
2	Tirupati-4	0.410	1										
3	Narayani	0.500	0.424	1									
4	Kalahasti	0.500	0.489	0.929	1								
5	Prasuna	0.537	0.487	0.756	0.705	1							
6	Abhaya	0.468	0.488	0.814	0.761	0.800	1						
7	TCGS-653	0.533	0.488	0.773	0.800	0.674	0.733	1					
8	TCGS-888	0.526	0.432	0.675	0.628	0.694	0.634	0.718	1				
9	TCGS-913	0.477	0.429	0.805	0.750	0.700	0.762	0.721	0.750	1			
10	TCGS-750	0.522	0.444	0.756	0.783	0.738	0.795	0.756	0.659	0.786	1		
11	TG-47	0.488	0.475	0.825	0.767	0.763	0.825	0.780	0.771	0.865	0.850	1	
12	TCGS-645	0.500	0.326	0.596	0.592	0.438	0.563	0.596	0.488	0.578	0.583	0.591	1

Table 5: Analysis of Variance for 10 physiological characters in 29 cultivars of groundnut

Sl. No.	Character	Source of Variation		
		Replications (df = 2)	Treatments (df = 28)	Error (df = 56)
1	LAD at 54 DAS	51.9138	4563.3452**	25.5314
2	LAD at 72 DAS	21.8362	8404.2080**	40.3750
3	LAD at 90 DAS	123.8448	6752.6069**	111.0859
4	CGR at 54 DAS	0.0540	19.4759**	0.4121
5	CGR at 72 DAS	1.2145	56.8400**	0.9267
6	LAI at 36 DAS	0.5228	1.3154**	0.2205
7	LAI at 54 DAS	0.1988	3.2883**	0.2236
8	LAI at 72 DAS	0.0175	2.5419**	0.0362
9	NAR at 36 DAS	0.0001	0.0004**	0.0001
10	NAR at 54 DAS	0.0000	0.0001**	0.0000
11	SLA at 18 DAS	31.7931	2571.8572**	468.3913
12	SLA at 36 DAS	141.7759	904.0714**	342.7536
13	SLA at 54 DAS	32.9009	1100.3541**	334.7149
14	SLA at 72 DAS	186.3103	1560.3810**	162.1399
15	SCMR	7.7233	13.3469**	5.1166
16	Germination %	24.7243	78.8281**	32.7546
17	Seedling vigour index	52297.5156	113602.3828**	24492.3262
18	Harvest index	5.3400	172.6855**	7.3727
19	Pod yield per plant	0.1500	19.4109**	6.3174

** Significant at 1% level

Table 21: Relative contribution of 10 physiological characters to genetic diversity in 29 groundnut cultivars.

Sl. No.	Character	Times ranked first	Contribution (%)
1	LAD at 54 DAS	140	34.48
2	LAD at 72 DAS	52	12.81
3	LAD at 90 DAS	1	0.25
4	CGR at 54 DAS	34	8.37
5	CGR at 72 DAS	50	12.32
6	LAI at 36 DAS	0	0.00
7	LAI at 54 DAS	1	0.25
8	LAI at 72 DAS	82	20.20
9	NAR at 36 DAS	0	0.00
10	NAR at 54 DAS	2	0.49
11	SLA at 18 DAS	2	0.49
12	SLA at 36 DAS	0	0.00
13	SLA at 54 DAS	0	0.00
14	SLA at 72 DAS	13	3.20
15	SCMR	1	0.25
16	Germination %	0	0.00
17	Seedling vigour index	9	2.22
18	Harvest index	19	4.68
19	Pod yield per plant	0	0.00

Table 22: Canonical root values, per cent of variation expected and cumulative variation expected for 29 cultivars of groundnut.

Sl. No.	Values of canonical root	Per cent of variation expected	Cumulative total Variation expected
Z_1	1373.54	50.84	50.84
Z_2	743.82	27.53	78.38
Z_3	214.76	7.95	86.32
Z_4	129.26	4.78	91.11

Table 17: Analysis of variance for dispersion in 29 cultivars of groundnut for 10 physiological characters

Source of Variation	Degrees of freedom	Mean sum of squares
Genotypes	28	9.0564E27
Error	55	9.1068E15
Total	83	3.0552E27

** Significant at 1% level

Table 23: Mean values of canonical vectors in 29 cultivars of groundnut

Sl. No.	Cultivar	'X' Vector	'Y' vector	'Z' vector
1	Tirupati-1	44.345	9.028	-6.876
2	Tirupati-2	47.258	8.724	-2.489
3	Tirupati-3	48.132	16.496	-1.263
4	Tirupati-4	52.456	4.912	-9.755
5	Narayani	38.909	15.419	-4.307
6	Kalahasti	39.149	11.183	0.444
7	Prasuna	39.943	10.191	-3.199
8	Abhaya	36.576	11.53	-6.386
9	TCGS-156	41.348	8.369	-0.336
10	TCGS-653	33.77	9.319	-2.083
11	TIR -23	38.273	11.617	-2.272
12	TCGS-888	36.641	8.78	-3.227
13	TCGS-913	30.886	3.508	-5.614
14	K-134	52.557	10.494	-6.221
15	K-4	43.91	8.953	-1.32
16	K-6	39.746	17.723	-6.242
17	TCGS-717	50.243	4.106	-0.153
18	TCGS-722	41.837	17.648	-9.744
19	TCGS-750	33.541	4.516	-3.385
20	TG-47	35.096	21.757	-1.402
21	TG-39	37.629	12.286	-2.802
22	TCGP – 6	32.804	12.379	-3.498
23	JL-24	51.565	18.528	-1.494
24	TMV-2	38.185	14.011	-6.266
25	TCGS-645	28.711	20.128	-5.507
26	TCGS-91	32.81	4.476	-1.176
27	JL-501	36.889	4.73	-8.273
28	R-2001-2	30.491	14.009	-4.358
29	TIR-9	29.114	5.242	-4.696

Table 24: Canonical vectors for 10 physiological characters 6 morphological contributing to genetic divergence in 29 groundnut cultivars.

Sl. No.	Character	Canonical Vectors			
		Z_1	Z_2	Z_3	Z_5
1	LAD at 54 DAS	0.567	0.355	0.184	0.178
2	LAD at 72 DAS	0.451	-0.231	0.209	0.128
3	LAD at 90 DAS	0.176	0.127	-0.052	-0.095
4	CGR at 54 DAS	0.161	0.093	0.283	-0.830
5	CGR at 72 DAS	0.297	-0.038	-0.714	-0.170
6	LAI at 36 DAS	0.013	0.061	0.051	0.084
7	LAI at 54 DAS	0.336	-0.038	0.085	0.133
8	LAI at 72 DAS	-0.039	0.639	-0.161	-0.085
9	NAR at 36 DAS	-0.209	-0.051	0.083	0.050
10	NAR at 54 DAS	0.144	0.199	-0.005	0.220
11	SLA at 18 DAS	0.106	0.177	-0.027	0.089
12	SLA at 36 DAS	0.071	-0.224	0.261	0.152
13	SLA at 54 DAS	-0.110	0.050	-0.042	-0.179
14	SLA at 72 DAS	0.140	-0.310	0.119	-0.216
15	SCMR	0.130	-0.155	-0.261	-0.046
16	Germination %	0.057	0.122	0.279	-0.103
17	Seedling vigour index	-0.266	0.301	0.235	0.076
18	Harvest index	0.053	0.161	-0.001	0.066
19	Pod yield per plant	0.097	0.053	0.037	-0.098

Table 18: Distribution of 29 cultivars of groundnut in different clusters (Tocher's method)

Cluster	Number of cultivars	Cultivars
I	11	TCGS - 913, TIR - 9, TCGS-91, TCGS - 750, TCGS-653, TCGS-888, TCGP - 6, TG - 39, TIR – 23, Abhaya, JL - 501
II	11	Narayani, K-6, TMV-2, TCGS-722, Kalahasti, Prasuna, TCGS-156, K-4, Tirupati-1, Tirupati-2, Tirupati-3
III	1	R-2001-2
IV	1	JL-24
V	1	TCGS-717
VI	2	Tirupati-4, K-134
VII	1	TCGS-645
VIII	1	TG-47

Table 6: Mean performance of 29 cultivars of groundnut for 10 physiological characters.

Sl. No	Cultivar	LAD at			CGR at		LAI at			NAR at		SLA at				SCMR	Germination (%)		Seedling Vigour Index	Harvest Index	Pod yield/ plant
		54 DAS	72 DAS	90 DAS	54 DAS	72 DAS	36 DAS	54 DAS	72 DAS	36 DAS	54 DAS	18 DAS	36 DAS	54 DAS	72 DAS		T	O			
1	Tirupati-1	181.54	259.83	307.82	***5.50***	25.55	1.81	4.29	4.96	0.05	0.03	232.33	207.83	195.03	173.15	40.37	90.00	100.00	678.00	44.69	10.67
2	Tirupati-2	181.73	284.17	331.20	14.51	22.94	2.15	4.53	5.72	0.04	0.02	221.47	211.73	201.22	164.98	40.87	90.00	100.00	766.00	49.18	14.20
3	Tirupati-3	221.55	302.45	331.34	13.66	20.79	3.02	5.24	5.92	0.05	0.03	225.19	209.57	196.96	159.24	44.77	90.00	100.00	790.21	***31.70***	14.20
4	Tirupati-4	192.37	303.26	352.28	11.10	**33.18**	1.60	4.89	5.91	0.05	0.03	194.77	186.67	173.93	160.11	43.17	90.00	100.00	602.33	44.84	**18.40**
5	Narayani	166.75	215.39	266.87	11.53	22.36	2.25	3.37	4.31	0.05	0.03	250.44	221.17	196.06	141.28	42.23	90.00	100.00	880.67	42.43	15.67
6	Kalahasti	169.43	239.53	268.67	10.06	16.75	1.83	4.23	4.54	0.06	0.04	264.34	**254.52**	**225.87**	141.69	42.83	90.00	100.00	1046.33	35.56	9.73
7	Prasuna	152.04	216.38	270.62	**16.40**	22.20	2.81	3.69	4.39	0.05	0.02	238.90	208.45	197.01	129.98	43.97	90.00	100.00	790.67	35.59	14.00
8	Abhaya	123.15	199.92	264.69	10.11	22.36	1.73	3.16	4.60	0.04	0.04	259.25	192.55	170.58	125.14	44.00	90.00	100.00	698.67	45.01	15.07
9	TCGS-156	169.14	259.65	290.48	11.06	16.93	1.88	4.54	5.07	0.06	0.02	214.15	187.27	174.29	127.71	43.07	90.00	100.00	800.00	38.05	11.13
10	TCGS-653	131.24	189.93	245.03	9.62	***15.31***	1.53	2.82	3.87	0.05	0.03	193.98	196.37	184.98	167.20	46.10	71.56	90.00	891.23	51.34	11.40
11	TIR - 23	147.73	216.63	283.15	11.92	18.36	1.95	3.44	4.51	0.04	0.02	229.50	224.85	178.94	147.86	45.10	90.00	100.00	905.67	50.81	13.67
12	TCGS-888	134.51	210.30	242.39	10.46	19.10	1.46	3.56	4.27	0.06	0.04	233.31	***171.27***	***150.21***	118.11	41.57	77.34	95.23	608.11	62.54	11.60
13	TCGS-913	92.65	161.73	213.83	6.42	19.34	***0.81***	2.38	3.37	0.04	0.04	205.53	190.15	173.48	121.78	46.77	90.00	100.00	899.00	48.42	9.40
14	K-134	217.49	321.85	348.40	10.48	28.73	2.02	**5.71**	6.14	0.06	0.04	233.43	210.75	179.47	137.45	45.03	90.00	100.00	664.67	44.59	16.13
15	K-4	171.07	261.67	297.48	11.79	18.80	1.76	4.74	5.15	0.05	0.03	271.24	216.19	198.77	**180.46**	44.13	75.35	93.60	***593.48***	46.79	17.00
16	K-6	176.96	224.71	274.14	10.72	24.71	2.67	3.78	4.53	0.05	0.03	230.43	205.73	194.84	100.72	40.53	75.00	93.33	829.60	42.42	11.87
17	TCGS-717	192.07	316.92	**358.67**	14.72	21.80	1.64	5.70	6.17	**0.10**	0.02	240.73	222.33	188.21	160.12	***39.40***	90.00	100.00	818.67	35.85	13.47
18	TCGS-722	188.81	225.99	268.98	11.27	29.87	3.01	3.75	4.44	0.04	0.03	203.21	198.66	151.18	109.60	42.33	65.88	83.33	687.50	39.24	11.60
19	TCGS-750	108.80	186.95	215.25	10.93	18.33	0.95	2.93	3.85	***0.03***	0.02	**325.11**	208.08	195.28	***93.14***	**47.23**	61.07	76.67	784.50	47.43	11.87
20	TG-47	174.63	212.02	249.28	9.30	15.61	2.74	3.24	4.38	0.06	0.03	222.22	202.80	196.17	127.70	45.57	90.00	100.00	1106.67	58.59	17.00
21	TG-39	148.14	215.68	245.20	12.22	19.59	1.61	3.59	4.42	0.04	0.04	245.08	216.21	187.39	124.29	45.00	71.56	90.00	869.63	51.40	15.60
22	TCGP-6	129.08	176.53	218.86	12.08	19.85	1.77	2.66	3.64	0.05	0.03	203.36	188.34	155.54	110.19	44.40	90.00	100.00	1293.67	53.45	16.53
23	JL-24	**242.95**	**323.34**	347.56	15.72	23.82	**3.14**	5.20	**6.18**	0.05	0.03	235.02	215.51	213.49	149.54	40.67	90.00	100.00	743.33	41.42	15.60
24	TMV-2	153.01	214.41	246.58	7.38	23.74	2.31	4.41	4.57	0.05	0.03	264.21	226.87	181.93	144.91	40.97	90.00	100.00	851.67	50.20	***9.13***
25	TCGS-645	124.50	***123.11***	***202.28***	12.13	19.74	1.10	***1.89***	***2.66***	0.05	0.04	247.35	225.09	189.86	126.86	43.70	75.00	93.33	875.53	47.96	14.53
26	TCGS-91	111.53	185.71	219.60	8.78	16.40	1.00	3.44	3.68	0.05	0.03	220.47	220.14	205.31	118.28	40.60	90.00	100.00	1018.00	47.70	14.20
27	JL-501	110.28	197.43	260.60	11.16	26.19	1.23	2.78	4.46	0.06	0.03	***177.15***	185.02	156.75	109.88	42.43	90.00	100.00	795.33	44.01	9.53
28	R_2001-2	117.65	158.36	213.38	9.53	19.52	1.36	2.29	3.47	0.04	0.03	246.09	220.87	217.74	123.73	43.03	79.37	96.67	**1420.33**	**63.66**	14.20
29	TIR-9	***87.80***	156.35	208.97	7.43	17.64	0.96	2.29	3.49	0.04	0.03	200.65	185.85	166.69	110.52	45.87	75.00	93.33	1098.20	46.19	12.53
	G. MEAN	155.81	226.21	270.47	10.97	21.36	1.87	3.74	4.57	0.05	0.03	232.03	207.27	186.11	134.68	43.30	79.53	96.74	855.44	46.24	13.45
	S.Ed.	4.12	5.18	8.60	0.52	0.78	0.38	0.38	0.15	0.01	0.00	17.67	15.11	14.93	10.39	1.84	3.86	--	127.78	2.21	2.05
	C.D.(0.05)	8.27	10.40	17.24	1.05	1.57	0.77	0.77	0.31	0.02	0.01	35.40	30.28	29.92	20.83	3.70	8.86	--	255.98	4.44	4.11
	C.D.(0.01)	11.01	13.85	22.95	1.40	2.10	1.02	1.03	0.41	0.02	0.01	47.12	40.31	39.83	27.72	4.92	11.66	--	340.74	5.91	5.47
	C.V.(%)	3.24	2.81	3.90	5.85	4.51	25.17	12.63	4.16	21.55	18.09	9.33	8.93	9.83	9.46	5.22	6.02	--	18.29	5.87	18.69

Table 8: Genetic parameters for 10 physiological characters of 29 groundnut cultivars.

Sl. No.	Character	Mean	Range		Variance		Co-efficient of variation		Herita-bility (Broad sense %)	Genetic Advance	Genetic Advance as per cent of mean (%)
			Min.	Max.	Geno-typic	Pheno-typic	Geno-typic (%)	Pheno-typic (%)			
1	LAD at 54 DAS	155.81	87.80	242.95	1512.60	1538.14	24.96	25.17	98.34	79.45	50.99
2	LAD at 72 DAS	226.21	123.11	323.34	2821.28	2861.65	23.48	23.65	98.59	108.64	48.03
3	LAD at 90 DAS	270.47	202.28	358.67	2213.84	2324.93	17.40	17.83	95.22	94.58	34.97
4	CGR at 54 DAS	10.97	5.50	16.40	6.35	6.77	22.99	23.72	93.91	5.03	45.89
5	CGR at 72 DAS	21.36	15.31	33.18	18.64	19.56	20.21	20.71	95.26	8.68	40.63
6	LAI at 36 DAS	1.87	0.81	3.14	0.37	0.59	32.38	41.01	62.34	0.98	52.67
7	LAI at 54 DAS	3.74	1.89	5.71	1.02	1.25	27.00	29.81	82.04	1.89	50.38
8	LAI at 72 DAS	4.57	2.66	6.18	0.84	0.87	19.98	20.41	95.85	1.84	40.29
9	NAR at 36 DAS	0.05	0.03	0.10	0.00	0.00	20.04	29.43	46.38	0.01	28.12
10	NAR at 54 DAS	0.03	0.02	0.04	0.00	0.00	18.69	26.01	51.61	0.01	27.65
11	SLA at 18 DAS	232.03	177.15	325.11	701.16	1169.55	11.41	14.74	59.95	42.24	18.20
12	SLA at 36 DAS	207.27	171.27	254.52	187.11	529.86	6.60	11.11	35.31	16.74	8.08
13	SLA at 54 DAS	186.11	150.21	225.87	255.21	589.93	8.58	13.05	43.26	21.65	11.63
14	SLA at 72 DAS	134.68	93.14	180.46	466.08	628.22	16.03	18.61	74.19	38.31	28.44
15	SCMR	43.30	39.40	47.23	2.74	7.86	3.83	6.47	34.90	2.02	4.66
16	Germination %	96.74	76.67	100.00	21.36	56.12	4.78	7.74	38.06	5.87	6.07
17	Seedling vigour index	855.44	593.48	1420.33	29703.35	54195.68	20.15	27.21	54.81	262.84	30.73
18	Harvest index	46.24	31.70	63.66	55.10	62.48	16.05	17.09	88.20	14.36	31.06
19	Pod yield per plant	13.45	9.13	18.40	4.36	10.68	15.54	24.31	40.86	2.75	20.46

Table 19: Average Inter and Intra-cluster (diagonal) distance D^2 and D values (Parenthesis) in 29 cultivars of groundnut (Mahalanobis's D^2 statistic)

Cluster	I	II	III	IV	V	VI	VII	VIII
I	75.69 (8.70)	162.05 (12.73)	100.60 (10.03)	446.89 (21.14)	326.88 (18.08)	396.80 (19.92)	235.31 (15.34)	244.92 (15.65)
II		102.41 (10.12)	205.34 (14.33)	185.50 (13.62)	207.93 (14.42)	221.41 (14.88)	303.45 (17.42)	207.07 (14.39)
III			0.00 (0.00)	488.85 (22.11)	534.53 (23.12)	564.53 (23.76)	***78.49 (8.86)***	111.93 (10.58)
IV				0.00 (0.00)	230.12 (15.17)	185.50 (13.62)	560.74 (23.68)	309.05 (17.58)
V					0.00 (0.00)	119.46 (10.93)	760.10 (27.57)	583.22 (24.15)
VI						61.77 (7.86)	**772.28 (27.79)**	567.86 (23.83)
VII							0.00 (0.00)	119.90 (10.95)
VIII								0.00 (0.00)

Table 20: Cluster means for 10 physiological characters in 29 groundnut cultivars (Mahalanobis's D^2 method)

Cultivar	LAD at			CGR at		LAI at			NAR at		SLA at				SCMR	Germination percentage	Seedling vigour index	Harvest index	Pod yield per plant
	54 DAS	72 DAS	90 DAS	54 DAS	72 DAS	36 DAS	54 DAS	72 DAS	36 DAS	54 DAS	18 DAS	36 DAS	54 DAS	72 DAS					
I	120.45	190.65	237.96	10.10	19.32	1.36	3.01	4.01	0.05	0.03	226.67	198.08	175.01	122.40	44.46	95.02	896.55	49.85	12.85
II	175.64	245.83	286.74	11.26	22.24	2.32	4.23	4.87	0.05	0.03	237.81	213.45	192.11	143.07	42.37	97.30	792.19	41.44	12.65
III	117.65	158.36	213.38	9.53	19.52	1.36	2.29	3.47	0.04	0.03	246.09	220.87	217.74	123.73	43.03	96.67	1420.33	63.66	14.20
IV	242.95	323.34	347.56	15.72	23.82	3.14	5.20	6.18	0.05	0.03	235.02	215.51	213.49	149.54	40.67	100.00	743.33	41.42	15.60
V	192.07	316.92	358.67	14.72	21.80	1.64	5.70	6.17	0.10	0.02	240.73	222.33	188.21	160.12	39.40	100.00	818.67	35.85	13.47
VI	204.93	312.55	350.34	10.79	30.96	1.81	5.30	6.02	0.05	0.04	214.10	198.71	176.70	148.78	44.10	100.00	633.50	44.72	17.27
VII	124.50	123.11	202.28	12.13	19.74	1.10	1.89	2.66	0.05	0.04	247.35	225.09	189.86	126.86	43.70	93.33	875.53	47.96	14.53
VIII	174.63	212.02	249.28	9.30	15.61	2.74	3.24	4.38	0.06	0.03	222.22	202.80	196.17	127.70	45.57	100.00	1106.67	58.59	17.00

Table 28: Phenotypic (r_p) and genotypic (r_g) correlation coefficients among 10 physiological characters in 29 groundnut cultivars.

Character		LAD at 72 DAS	LAD at 90 DAS	CGR at 54 DAS	CGR at 72 DAS	LAI at 36 DAS	LAI at 54 DAS	LAI at 72 DAS	NAR at 36 DAS	NAR at 54 DAS	SLA at 18 DAS	SLA at 36 DAS	SLA at 54 DAS	SLA at 72 DAS	SCMR	Germi-nation%	S.vigour Index	Harvest index	Pod Yield/ plant
LAD at 54 DAS	r_p	0.8875**	0.8460**	0.4490**	0.4540**	0.6695**	0.8062**	0.8338**	0.2401*	-0.1065	0.0077	0.1759	0.2278*	0.4830**	-0.2976**	0.1881	-0.3522**	-0.4413**	0.2529**
	r_g	0.8934	0.8748	0.4683	0.4669	0.8490	0.8923	0.8603	0.3357	-0.1302	0.0175	0.3431	0.3284	0.5605	-0.4916	0.2999	-0.4918	-0.4648	0.4086
LAD at 72 DAS	r_p		0.9552**	0.4163**	0.4548**	0.4578**	0.8975**	0.9795**	0.3179	-0.1813	-0.0104	0.0817	0.1604	0.5320**	-0.2936**	0.2273*	-0.4506**	-0.4677**	0.2094
	r_g		0.9749	0.4333	0.4724	0.5867	1.0043	0.9883	0.4367	-0.2489	-0.0062	0.1725	0.2237	0.6235	-0.4743	0.3877	-0.6161	-0.502	0.3269
LAD at 90 DAS	r_p			0.4445**	0.5178**	0.4364**	0.8054**	0.9558**	0.3227*	-0.2124**	-0.0759	0.1011	0.1079	0.5667	-0.2784	0.2729	-0.4808	-0.479**	0.2449*
	r_g			0.4673	0.5529	0.5698	0.9670	0.9765	.4521	-0.2639	-0.099	0.1196	0.1938	0.6897	-0.5219	0.4660	-0.6408	-0.528	0.3393
CGR at 54 DAS	r_p				0.1186	0.4041**	0.3428**	0.4233**	0.2320*	-0.3180**	0.0799	0.1284	0.1140	0.1165	-0.0981	0.0098	-0.1659	-0.3586**	0.3208**
	r_g				0.1279	0.5057	0.3854	0.4453	0.3290	-0.4564	0.0875	0.1946	0.2145	0.1706	-0.2277	0.0658	-0.2244	-0.3753	0.5282
CGR at 72 DAS	r_p					0.2777**	0.3860**	0.4711**	-0.0238	0.0696	-0.191	-0.1204	-0.2253	0.0731	-0.2937**	0.0857	-0.3852**	-0.2712*	0.1142
	r_g					0.3439	0.4257	0.4997	-0.0501	0.0915	-0.2399	-0.2108	-0.3241	0.1107	-0.4296	0.0734	-0.6047	-0.2948	0.1556
LAI at 36 DAS	r_p						0.4490**	0.4535**	-0.0206	-0.2430*	0.0126	0.1672	0.1236	0.1603	-0.1161	0.1029	-0.1113	-0.3327**	0.1043
	r_g						0.5665	0.5799	0.1245	-0.1408	-0.0589	0.1769	0.2285	0.2716	-0.4569	0.2450	-0.2897	-0.4039	0.3007
LAI at 54 DAS	r_p							0.8595**	0.2970**	-0.1522	0.0787	0.1543	0.2043	0.4886**	-0.3124**	0.2324*	-0.3747**	-0.4692**	0.1115
	r_g							0.9918	0.517	-0.1786	0.1119	0.3030	0.2251	0.6356	-0.5569	0.3751	-0.6758	-0.532	0.2795
LAI at 72 DAS	r_p								0.3071**	-0.1875	-0.0249	0.0636	0.1148	0.5098**	-0.2861**	0.2318*	-0.4647**	-0.4336**	0.2159*
	r_g								0.4160	-0.2627	-0.0174	0.0931	0.1599	0.6091	-0.4646	0.4375	-0.6222	-0.481	0.3267
NAR at 36 DAS	r_p									-0.1558	-0.0686	0.0007	-0.0107	0.105	-0.2521*	0.3019**	0.0256	-0.1800	0.0711
	r_g									-0.2470	-0.2042	0.2426	0.0364	0.3960	-0.5743	0.4799	-0.0474	-0.2698	-0.0366
NAR at 54 DAS	r_p										-0.0075	0.0558	-0.0897	-0.0184	0.0242	0.0502	-0.1076	0.1554	-0.0565
	r_g										0.0683	0.1133	-0.0683	-0.2206	0.1026	0.1475	-0.0087	0.2144	0.1339
SLA at 18 DAS	r_p											0.3361**	0.3294**	-0.0045	0.0895	-0.2865**	-0.0834	-0.0402	0.0380
	r_g											0.7600	0.6262	-0.0171	0.0161	-0.4127	-0.1046	0.0225	0.0392
LA at 36 DAS	r_p												0.4666**	0.1914	0.011	-0.0051	0.1186	-0.1719	0.0473
	r_g												1.1575	0.4320	-0.5446	0.2168	0.3147	-0.2895	-0.0165
SLA at 54 DAS	r_p													0.2582*	-0.1096	0.0208	0.2429*	-0.1014	0.0020
	r_g													0.4333	-0.2453	0.2628	0.2304	-0.1852	0.3102
SLA at 72 DAS	r_p														-0.2259*	0.2213*	-0.3019**	-0.1529	0.1148
	r_g														-0.2200	0.5584	-0.3632	-0.2142	0.3204
SCMR	r_p															-0.2005	0.1049	0.0582	0.0800
	r_g															-0.5521	0.2954	0.3105	0.1766
Germi-nation%	r_p																0.1612	-0.0928	0.1246
	r_g																0.0486	-0.136	0.1719
Seedling vigour index	r_p																	0.2986**	0.1053
	r_g																	0.4481	-0.0845
Harvest Index	r_p																		0.0990
	r_g																		0.1648

** - Significant at 1% level * - Significant at 5% level

Table 30: Phenotypic (P) and Genotypic (G) path coefficients for pod yield and different physiological characters in 29 groundnut cultivars.

Character		LAD at 54 DAS	LAD at 72 DAS	LAD at 90 DAS	CGR at 54 DAS	CGR at 72 DAS	LAI at 36 DAS	LAI at 54 DAS	LAI at 72 DAS	NAR at 36 DAS	NAR at 54 DAS	SLA at 18 DAS	SLA at 36 DAS	SLA at 54 DAS	SLA at 72 DAS	SCMR	Germi-nation%	S.vigour Index	Harvest index	'r' with pod yield/pl
LAD at 54 DAS	P	**0.6489**	-0.5557	0.3554	0.1504	0.0361	-0.2058	-0.1002	0.2632	-0.0225	-0.0017	0.0014	-0.0040	-0.0426	0.0203	-0.0564	0.0158	-0.1311	-0.1186	0.2529*
	G	**0.8140**	0.1800	0.3623	0.4676	-0.1524	-0.5272	-0.2178	0.0266	-0.2290	-0.0653	-0.0035	0.1250	-0.1789	0.1592	-0.0201	-0.0035	-0.1344	-0.1940	0.4086
LAD at 72 DAS	P	0.5758	**-0.6262**	0.4012	0.1394	0.0362	-0.1407	-0.1115	0.3093	-0.0297	-0.0030	-0.0019	-0.0019	-0.0300	0.0224	-0.0556	0.0191	-0.1677	-0.1257	0.2094
	G	0.7273	**0.2014**	0.4037	0.4327	-0.1542	-0.3643	-0.2452	0.0306	-0.2978	-0.1249	0.0012	0.0628	-0.1219	0.1771	-0.0194	-0.0045	-0.1684	-0.2094	0.3269
LAD at 90 DAS	P	0.5490	-0.5981	**0.4201**	0.1489	0.0412	-0.1341	-0.1001	0.3017	-0.0302	-0.0035	-0.0137	-0.0023	-0.0202	0.0238	-0.0528	0.0229	-0.1789	-0.1287	0.2449*
	G	0.7121	0.1964	**0.4141**	0.4666	-0.1805	-0.3538	-0.2361	0.0302	-0.3084	-0.1324	0.0196	0.0436	-0.1056	0.1959	-0.0213	-0.0054	-0.1751	-0.2205	0.3393
CGR at 54 DAS	P	0.2913	-0.2606	0.1867	**0.3349**	0.0094	-0.1242	-0.0426	0.1336	-0.0217	-0.0052	0.0144	-0.0030	-0.0213	0.0049	-0.0186	0.0008	-0.0618	-0.0964	0.3208**
	G	0.3812	0.0873	0.1935	**0.9985**	-0.0417	-0.3140	-0.0941	0.0138	-0.2244	-0.2290	-0.0173	0.0709	-0.1169	0.0484	-0.0093	-0.0008	-0.0613	-0.1567	0.5282
CGR at 72 DAS	P	0.2946	-0.2848	0.2175	0.0397	**0.0795**	-0.0853	-0.0480	0.1487	0.0022	0.0011	-0.0345	0.0028	0.0421	0.0031	-0.0557	0.0072	-0.1434	-0.0729	0.1142
	G	0.3801	0.0951	0.2290	0.1277	**-0.3264**	-0.2135	-0.1039	0.0155	0.0342	0.0459	0.0475	-0.0768	0.1766	0.0315	-0.0175	-0.0009	-0.1652	-0.1231	0.1556
LAI at 36 DAS	P	0.4344	-0.2867	0.1833	0.1353	0.0221	**-0.3073**	-0.0558	0.1432	0.0019	-0.0040	0.0023	-0.0038	-0.0231	0.0067	-0.0220	0.0086	-0.0414	-0.0894	0.1043
	G	0.6911	0.1182	0.2360	0.5050	-0.1122	**-0.6210**	-0.1383	0.0179	-0.0849	-0.0706	0.0116	0.0644	-0.1245	0.0771	-0.0186	-0.0028	-0.0792	-0.1686	0.3007
LAI at 54 DAS	P	0.5231	-0.5620	0.3383	0.1148	0.0307	-0.1380	**-0.1242**	0.2713	-0.0278	-0.0025	0.0142	-0.0036	-0.0382	0.0205	-0.0592	0.0195	-0.1395	-0.1261	0.1115
	G	0.7263	0.2023	0.4005	0.3849	-0.1390	-0.3518	**-0.2441**	0.0307	-0.3530	-0.0896	-0.0221	0.1104	-0.1226	0.1805	-0.0227	-0.0044	-0.1847	-0.2220	0.2795
LAI at 72 DAS	P	0.5410	-0.6134	0.4015	0.1418	0.0375	-0.1394	-0.1068	**0.3157**	-0.0287	-0.0031	-0.0045	-0.0015	-0.0215	0.0214	-0.0542	0.0195	-0.1729	-0.1165	0.2159*
	G	0.7003	0.1991	0.4044	0.4446	-0.1631	-0.3601	-0.2421	**0.0309**	-0.2837	-0.1318	0.0034	0.0339	-0.0871	0.1730	-0.0190	-0.0051	-0.1700	-0.2009	0.3267
NAR at 36 DAS	P	0.1558	-0.1991	0.1355	0.0777	-0.0019	0.0063	-0.0369	0.0969	**-0.0935**	-0.0026	-0.0124	0.0000	0.0020	0.0044	-0.0478	0.0253	0.0095	-0.0484	0.0711
	G	0.2733	0.0880	0.1872	0.3285	0.0164	-0.0773	-0.1263	0.0129	**-0.6820**	-0.1240	0.0404	0.0884	-0.0198	0.1125	-0.0234	-0.0056	-0.0129	-0.1126	-0.0366
NAR at 54 DAS	P	-0.0691	0.1135	-0.0892	-0.1065	0.0055	0.0747	0.0189	-0.0592	0.0146	**0.0164**	-0.0014	-0.0013	0.0168	-0.0008	0.0046	0.0042	-0.0401	0.0418	-0.0565
	G	-0.1060	-0.0501	-0.1093	-0.4558	-0.0299	0.0874	0.0436	-0.0081	0.1685	**0.5018**	-0.0135	0.0413	0.0372	-0.0626	0.0042	-0.0017	-0.0024	0.0895	0.1339
SLA at 18 DAS	P	0.0050	0.0065	-0.0319	0.0268	-0.0152	-0.0039	-0.0098	-0.0079	0.0064	-0.0001	**0.1804**	-0.0077	-0.0616	-0.0002	0.0170	-0.0240	-0.0310	-0.0108	0.0380
	G	0.0142	-0.0013	-0.0410	0.0874	0.0783	0.0366	-0.0273	-0.0005	0.1392	0.0343	**-0.1978**	0.2769	-0.3412	-0.0049	0.0007	0.0048	-0.0286	0.0094	0.0392
SLA at 36 DAS	P	0.1141	-0.0512	0.0425	0.0430	-0.0096	-0.0514	-0.0192	0.0201	-0.0001	0.0009	0.0606	**-0.0230**	-0.0872	0.0080	0.0021	-0.0004	0.0441	-0.0462	0.0473
	G	0.2793	0.0348	0.0495	0.1943	0.0688	-0.1098	-0.0740	0.0029	-0.1655	0.0568	-0.1504	**0.3643**	-0.6306	0.1227	-0.0222	-0.0025	0.0860	-0.1208	-0.0165
SLA at 54 DAS	P	0.1478	-0.1005	0.0453	0.0382	-0.0179	-0.0380	-0.0254	0.0362	0.0010	-0.0015	0.0594	-0.0107	**-0.1869**	0.0109	-0.0208	0.0017	0.0904	-0.0273	0.0020
	G	0.2673	0.0451	0.0803	0.2142	0.1058	-0.1419	-0.0549	0.0049	-0.0248	-0.0343	-0.1239	0.4216	**-0.5448**	0.1230	-0.0100	-0.0031	0.0630	-0.0773	0.3102
SLA at 72 DAS	P	0.3134	-0.3331	0.2381	0.0390	0.0058	-0.0493	-0.0607	0.1609	-0.0098	-0.0003	-0.0008	-0.0044	-0.0483	**0.0420**	-0.0428	0.0186	-0.1124	-0.0411	0.1148
	G	0.4563	0.1256	0.2856	0.1703	-0.0361	-0.1687	-0.1552	0.0188	-0.2701	-0.1107	0.0034	0.1574	-0.2361	**0.2840**	-0.0090	-0.0065	-0.0993	-0.0894	0.3204
SCMR	P	-0.1931	0.1838	-0.1169	-0.0329	-0.0234	0.0357	0.0388	-0.0903	0.0236	0.0004	0.0161	-0.0003	0.0205	-0.0095	**0.1895**	-0.0168	0.0390	0.0156	0.0800
	G	-0.4002	-0.0955	-0.2161	-0.2274	0.1402	0.2837	0.1360	-0.0144	0.3917	0.0515	-0.0032	-0.1984	0.1336	-0.0625	**0.0408**	0.0064	0.0807	0.1296	0.1766
Germi-nation%	P	0.1220	-0.1424	0.1146	0.0033	0.0068	-0.0316	-0.0289	0.0732	-0.0282	0.0008	-0.0517	0.0001	-0.0039	0.0093	-0.0380	**0.0839**	0.0600	-0.0249	0.1246
	G	0.2441	0.0781	0.1930	0.0657	-0.0239	-0.1521	-0.0916	0.0135	-0.3273	0.0740	0.0816	0.0790	-0.1432	0.1586	-0.0225	**-0.0116**	0.0133	-0.0567	0.1719
Seedling vigour index	P	-0.2285	0.2822	-0.2020	-0.0556	-0.0306	0.0342	0.0466	-0.1467	-0.0024	-0.0018	-0.0150	-0.0027	-0.0454	-0.0127	0.0199	0.0135	**0.3722**	0.0802	0.1053
	G	-0.4004	-0.1241	-0.2654	-0.2240	0.1974	0.1799	0.1650	-0.0192	0.0323	-0.0043	0.0207	0.1146	-0.1256	-0.1031	0.0121	-0.0006	**0.2733**	0.1870	-0.0845
Harvest Index	P	-0.2863	0.2929	-0.2012	-0.1201	-0.0216	0.1022	0.0583	-0.1369	0.0168	0.0026	-0.0072	0.0040	0.0190	-0.0064	0.0110	-0.0078	0.1111	**0.2687**	0.0990
	G	-0.3784	-0.1011	-0.2188	-0.3748	0.0962	0.2508	0.1298	-0.0149	0.1840	0.1076	-0.0044	-0.1055	0.1009	-0.0608	0.0127	0.0016	0.1224	**0.4174**	0.1648

Residual effect (Phenotypic) = 0.7950 Bold : Direct Effects **: Significant at 1% level
Residual effect (Genotypic) = 0.4420 Normal : Indirect Effects *: Significant at 5% level

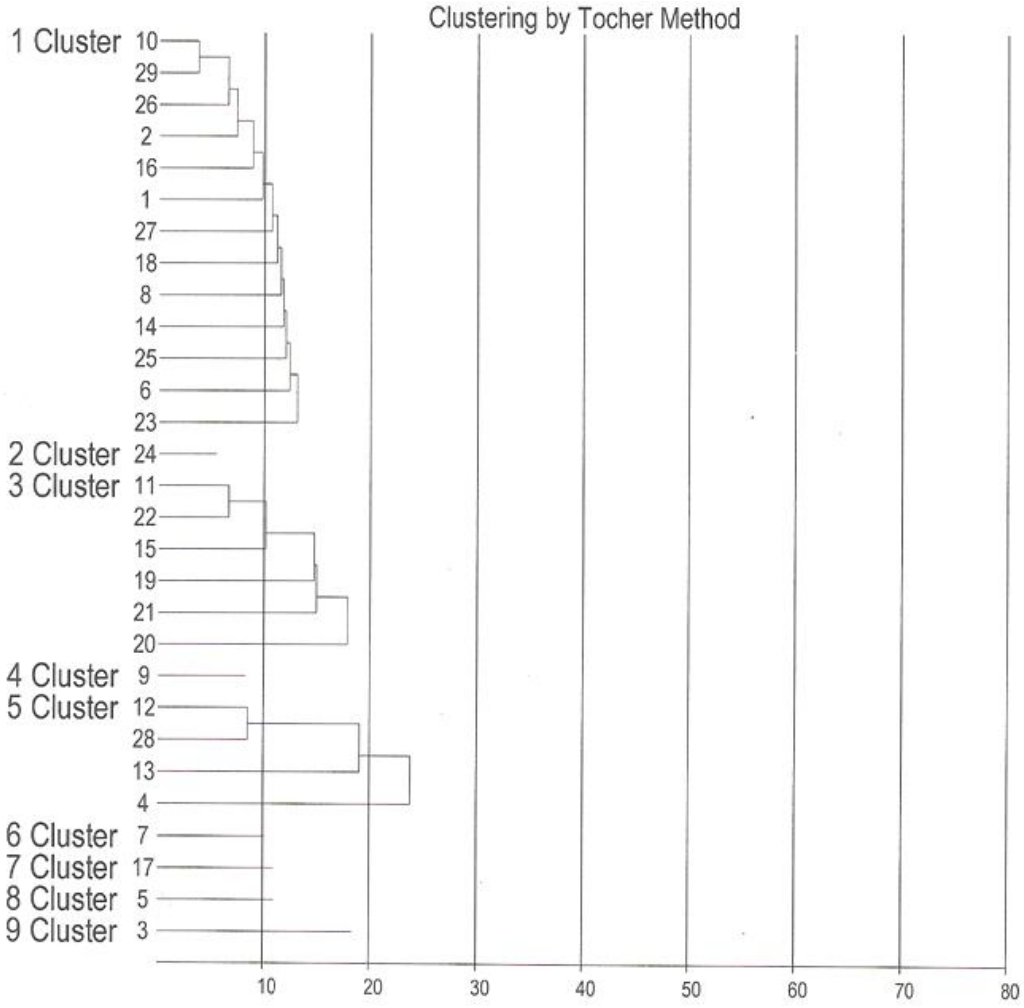
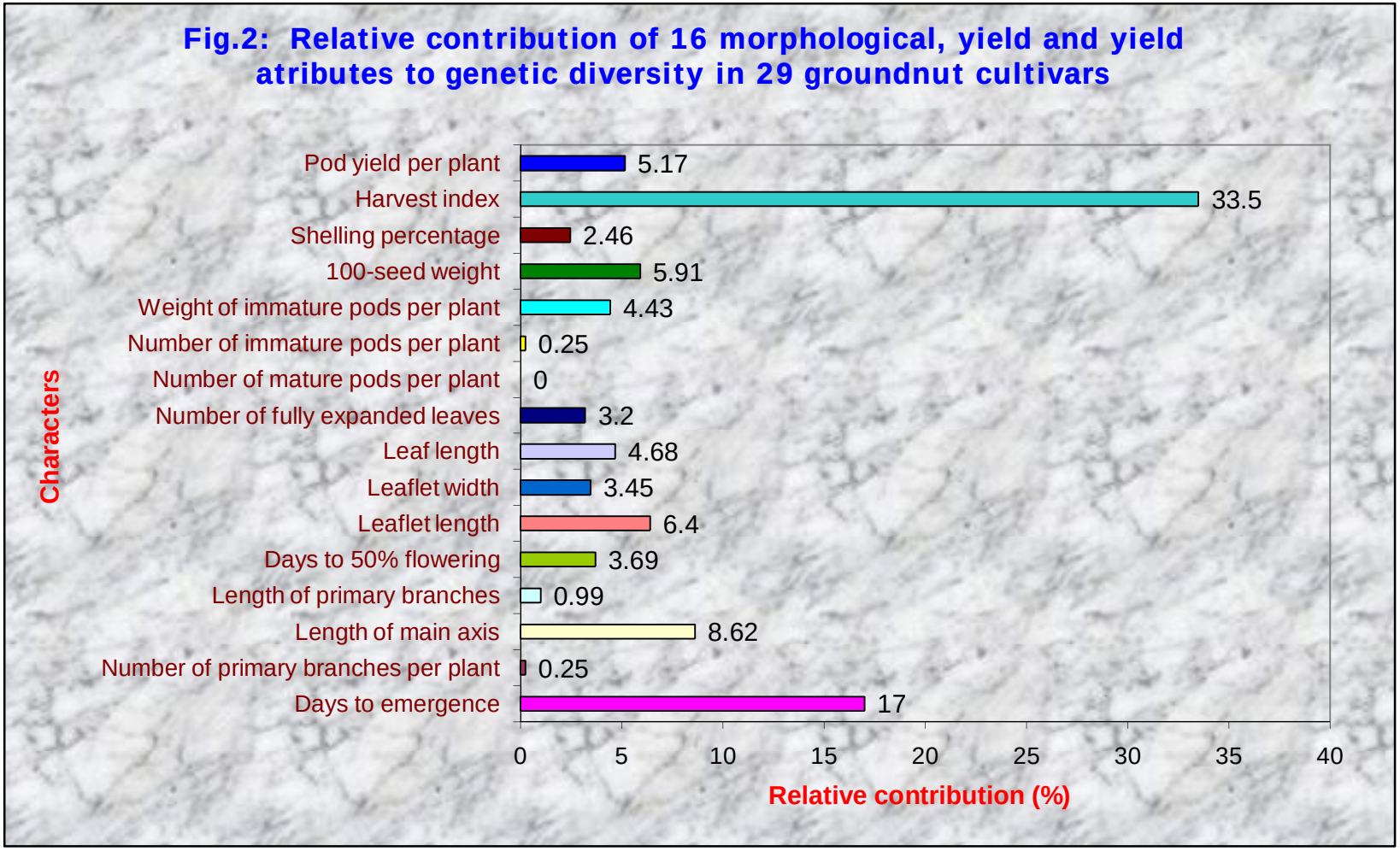


Fig.1: Dendogram of 29 groundnut cultivars obtained through Tocher method of classification based on morphological data.

Fig.2: Relative contribution of 16 morphological, yield and yield atributes to genetic diversity in 29 groundnut cultivars



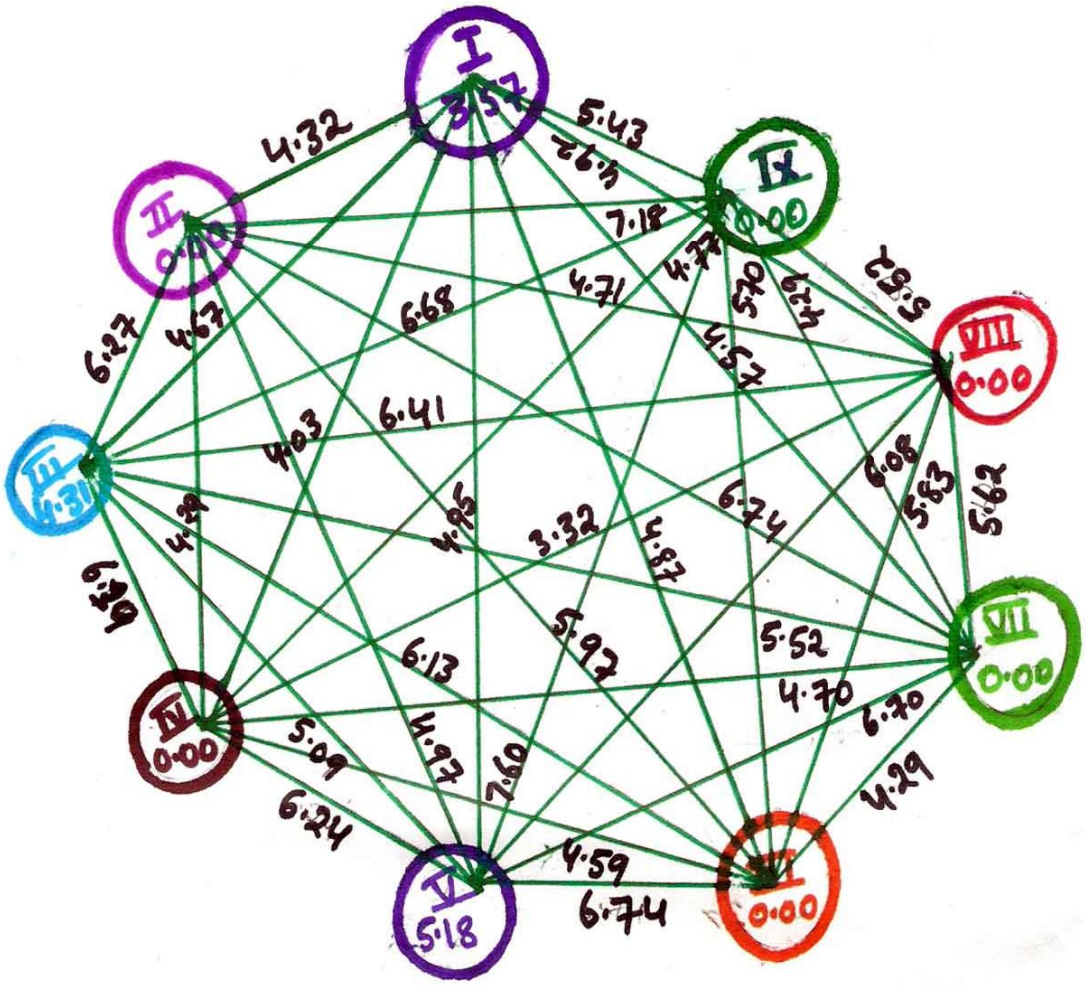


Fig.3: Statistical inter-cluster (D) distance among 9 clusters of groundnut based on morphological data

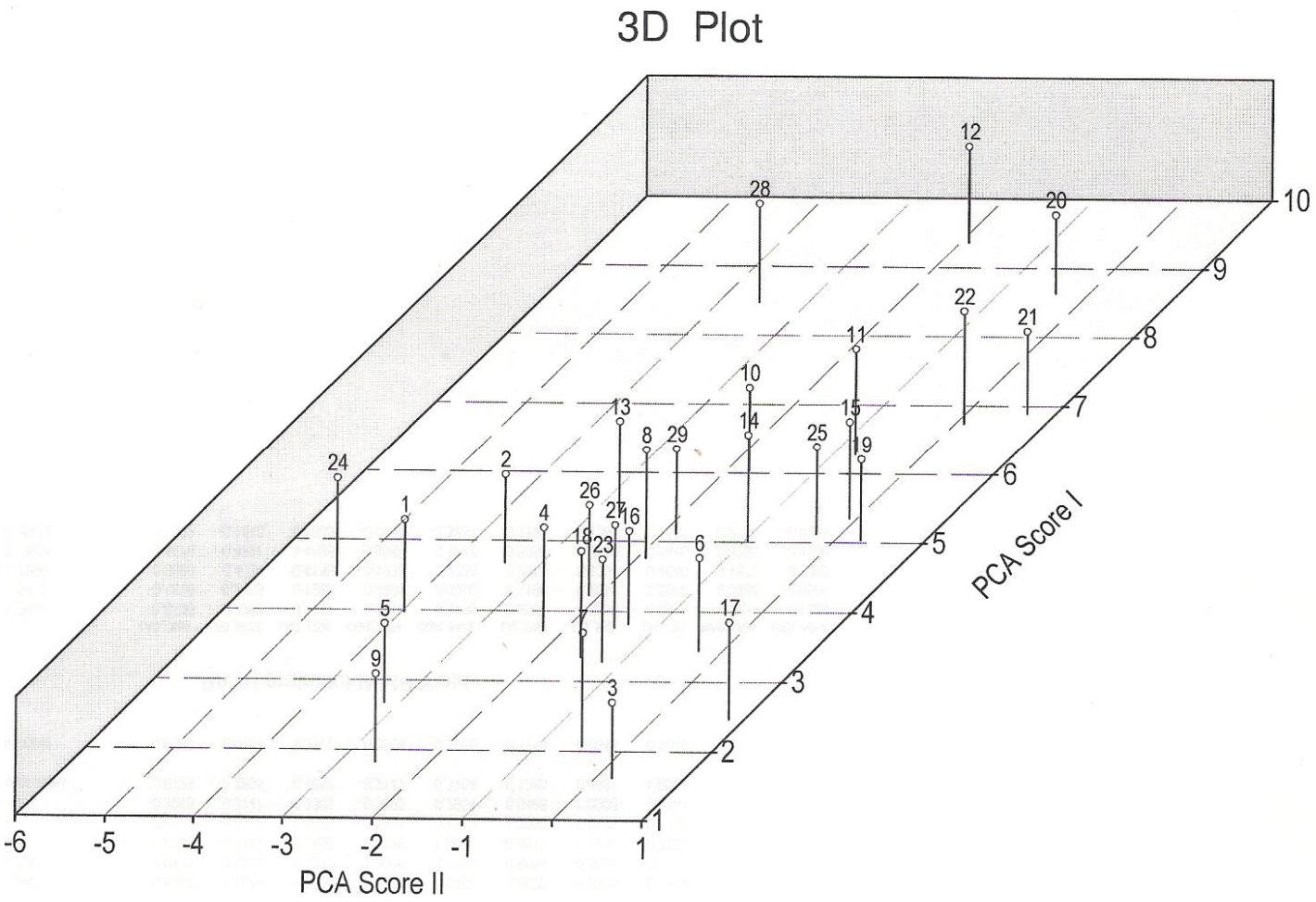


Fig.4: Principal component analysis (PCA) of 29 groundnut cultivars as revealed by Canonical analysis

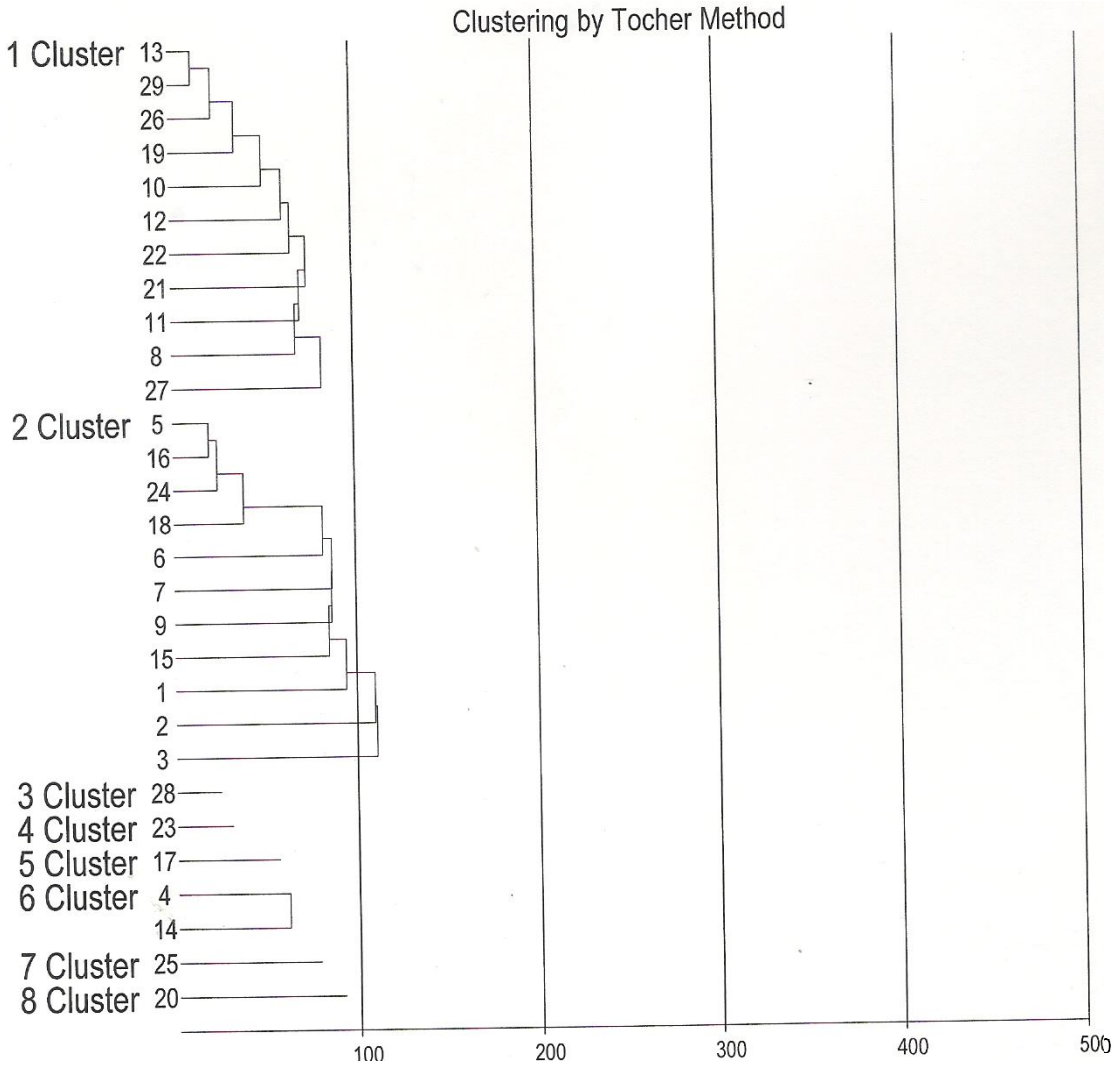
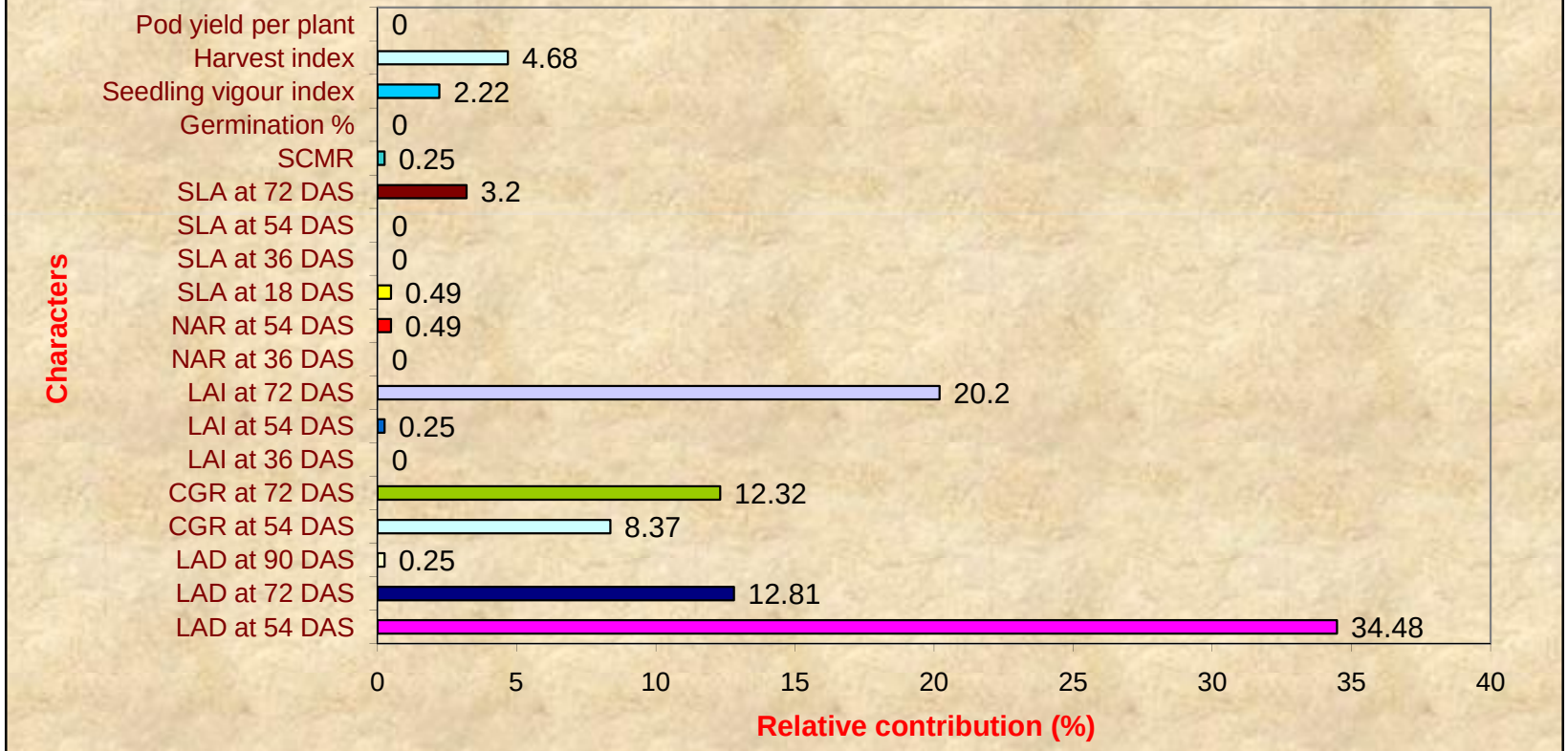


Fig.5: Dendogram of 29 groundnut cultivars obtained through Tocher method of classification based on physiological data.

Fig.6: Relative contribution of 10 physiological characters to genetic diversity in 29 groundnut cultivars



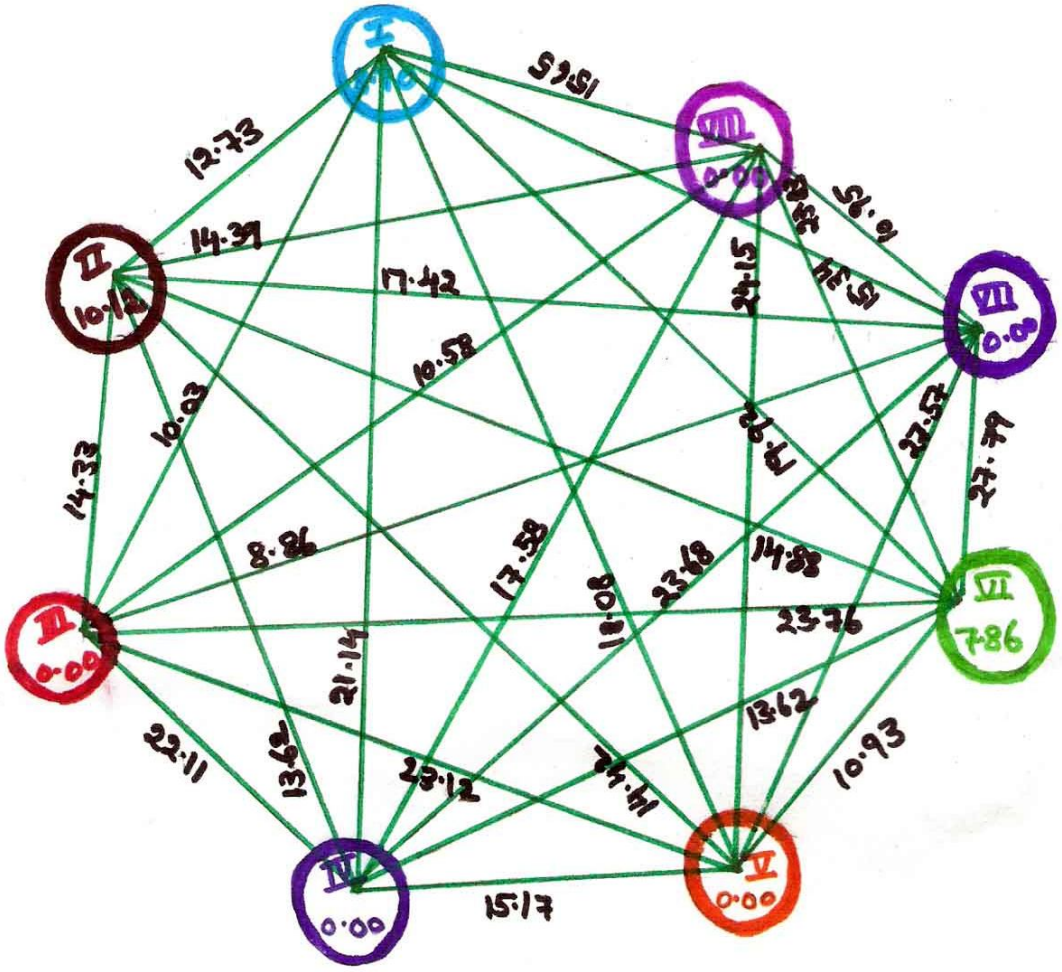


Fig.7: Statistical inter-cluster (D) distance among 8 clusters of groundnut based on physiological data

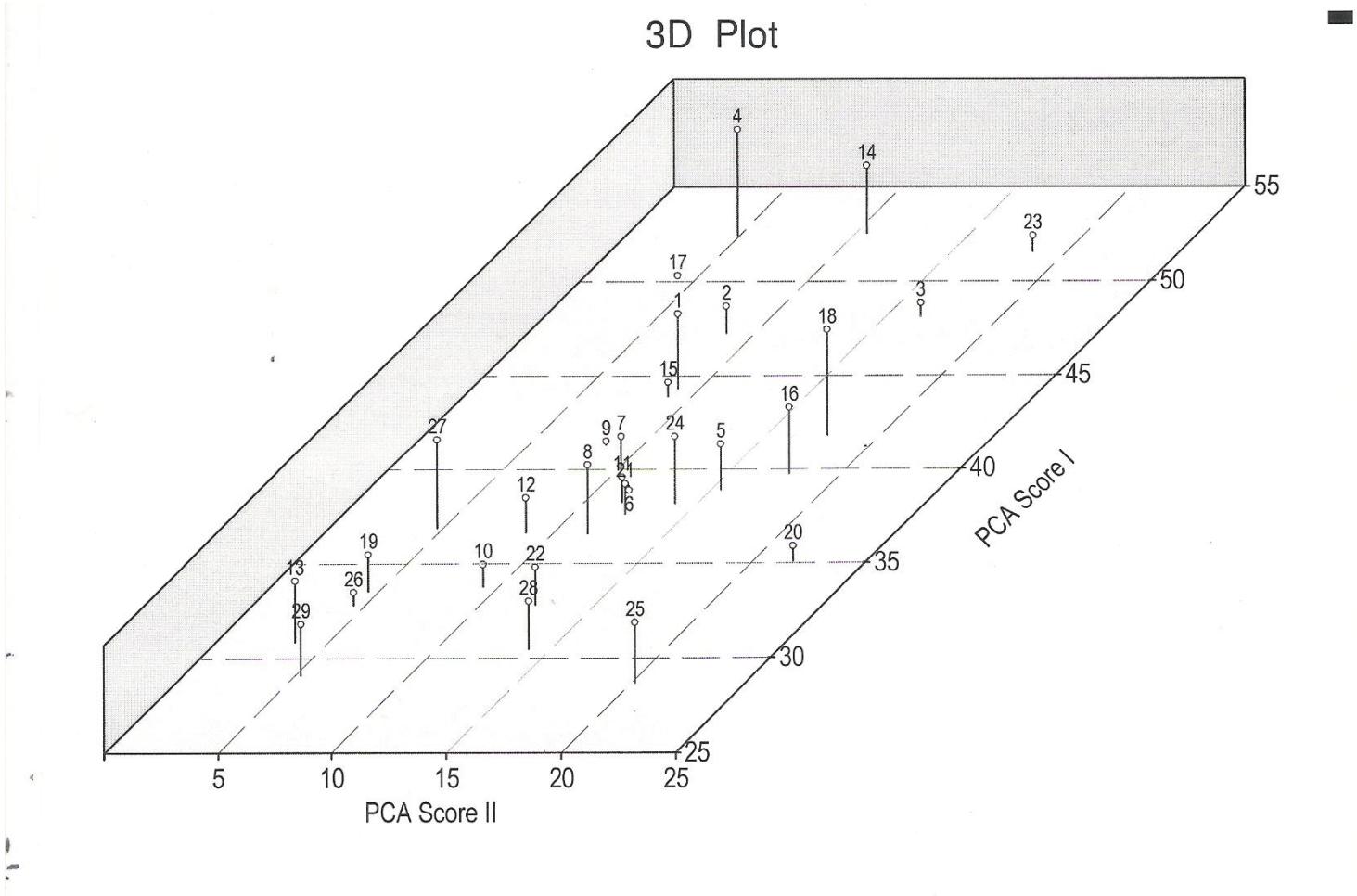


Fig.8: Principal component analysis (PCA) of 29 groundnut cultivars as revealed by Canonical analysis

Fig.9: RAPD gel profile of 12 groundnut cultivars using OPA-3 primer

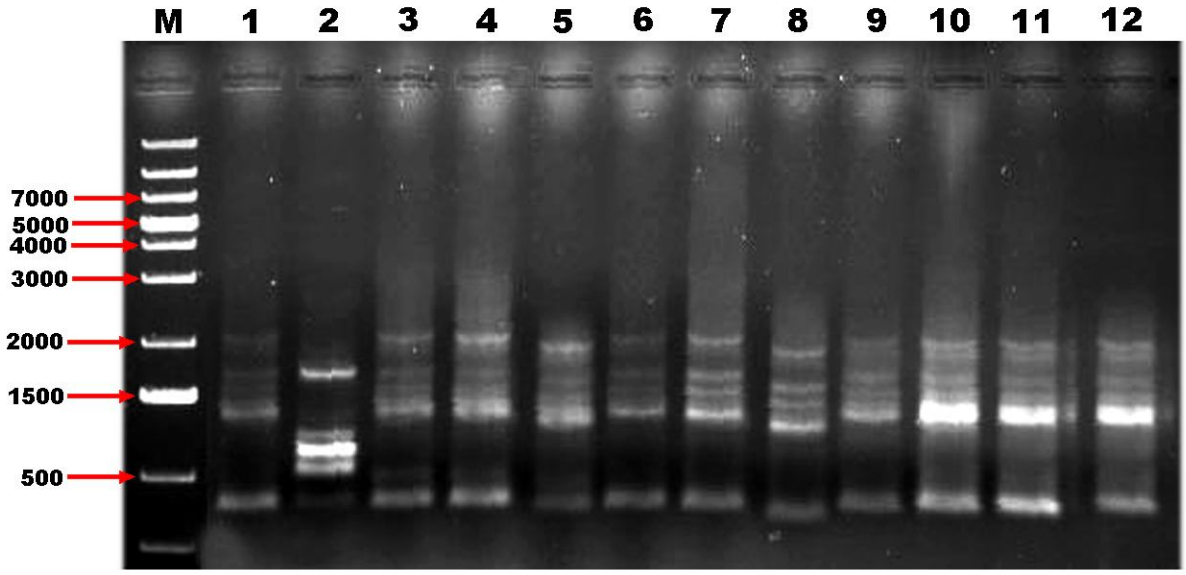
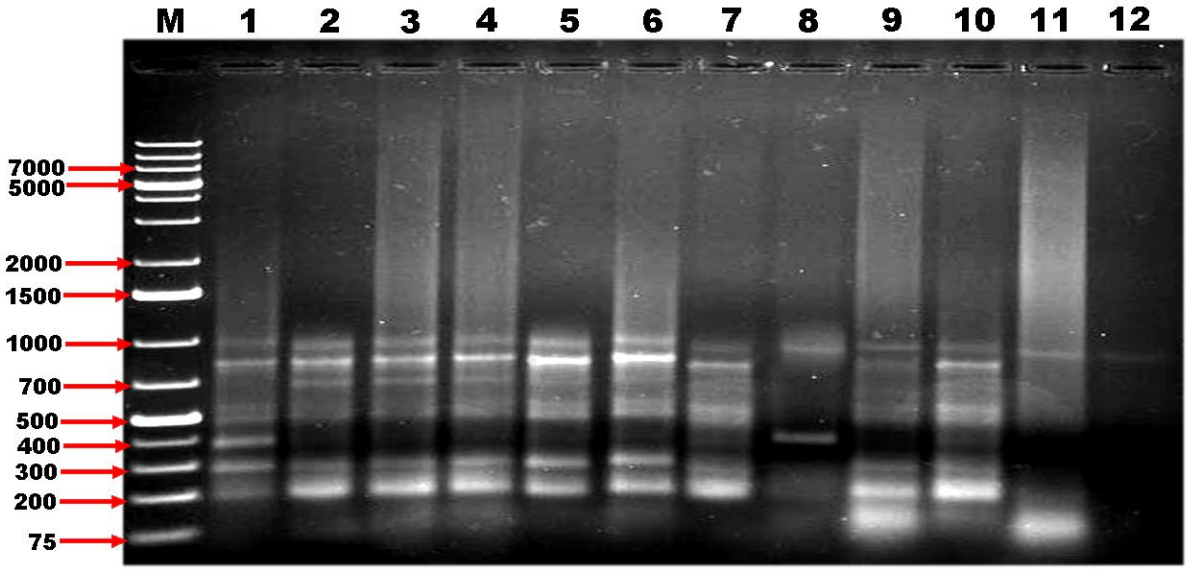


Fig.10: RAPD gel profile of 12 groundnut cultivars using OPA-19 primer



Lane M = Marker

1. Tirupati-3
2. Tirupati-4
3. Narayani
4. Kalahasti
5. Prasuna
6. Abhaya
7. TCGS-653
8. TCGS-888
9. TCGS-913
10. TCGS-750
11. TG-47
12. TCGS-645

Fig.11: RAPD gel profile of 12 groundnut cultivars using OPH-7 primer

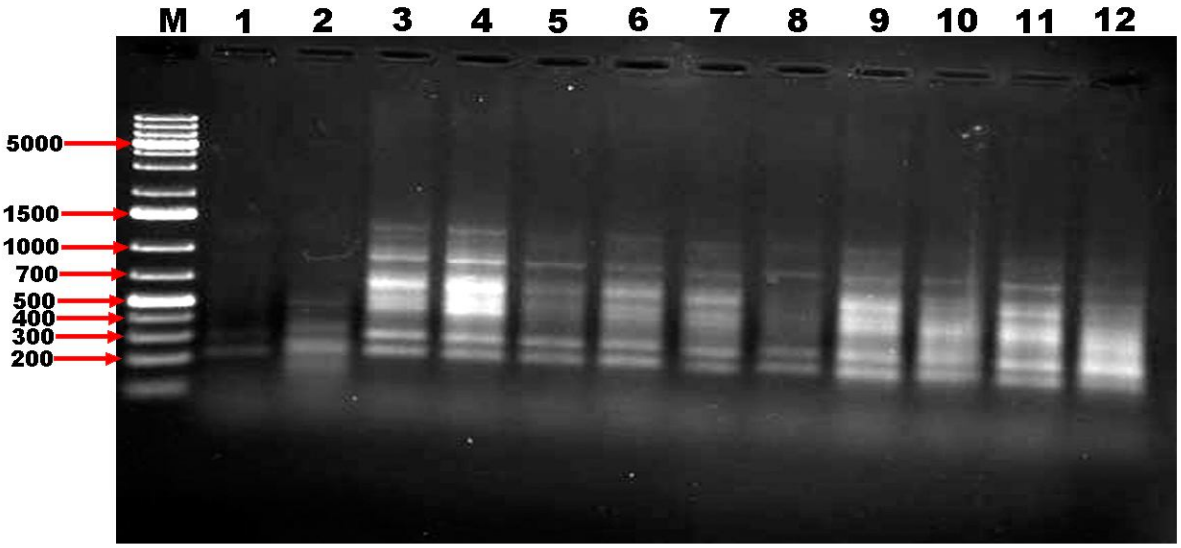
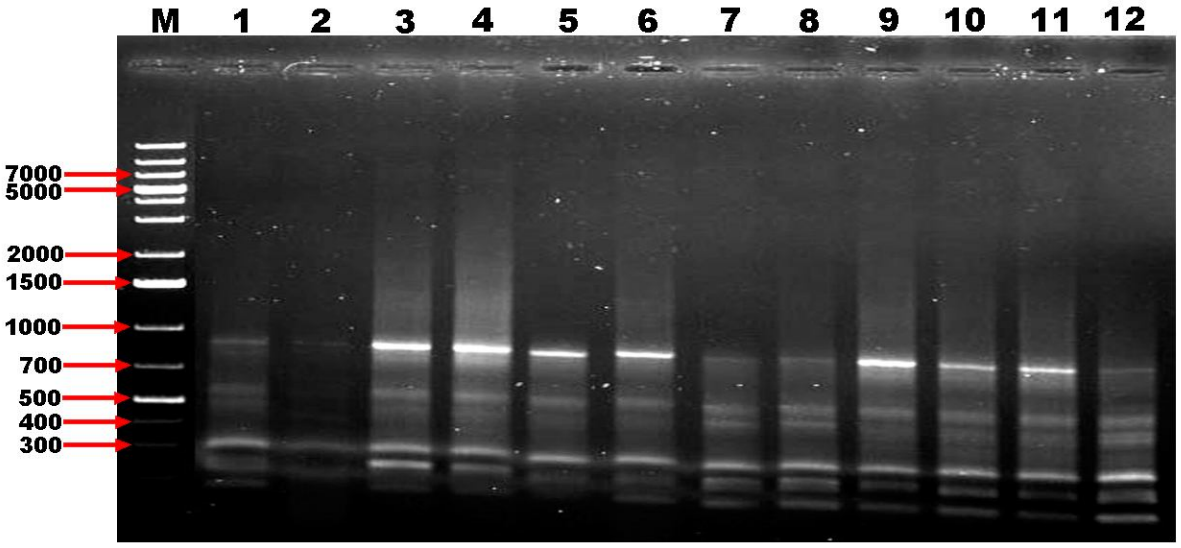


Fig.12: RAPD gel profile of 12 groundnut cultivars using OPH-20 primer



Lane M = Marker

1. Tirupati-3
2. Tirupati-4
3. Narayani
4. Kalahasti
5. Prasuna
6. Abhaya
7. TCGS-653
8. TCGS-888
9. TCGS-913
10. TCGS-750
11. TG-47
12. TCGS-645

Fig.13: RAPD gel profile of 12 groundnut cultivars using OPJ-1 primer

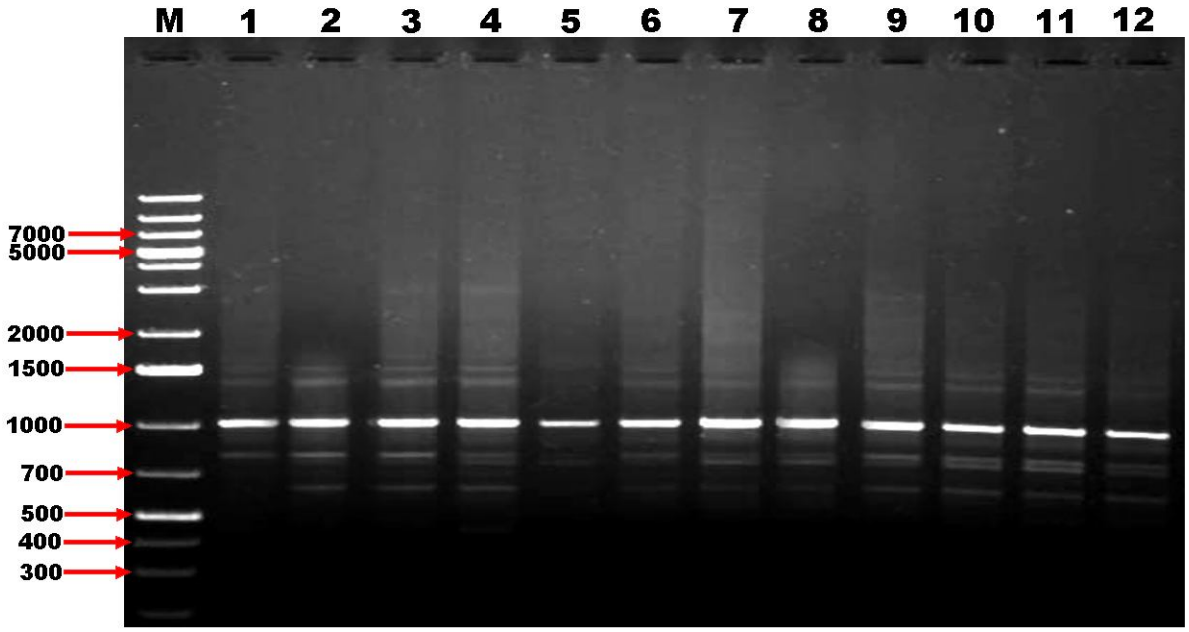
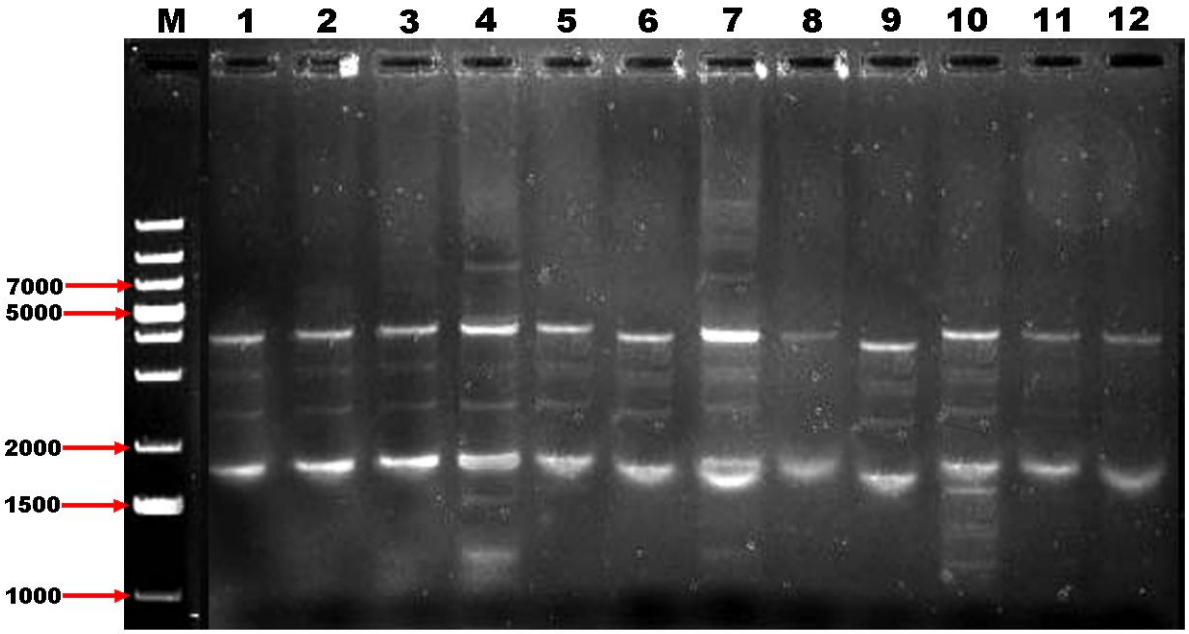
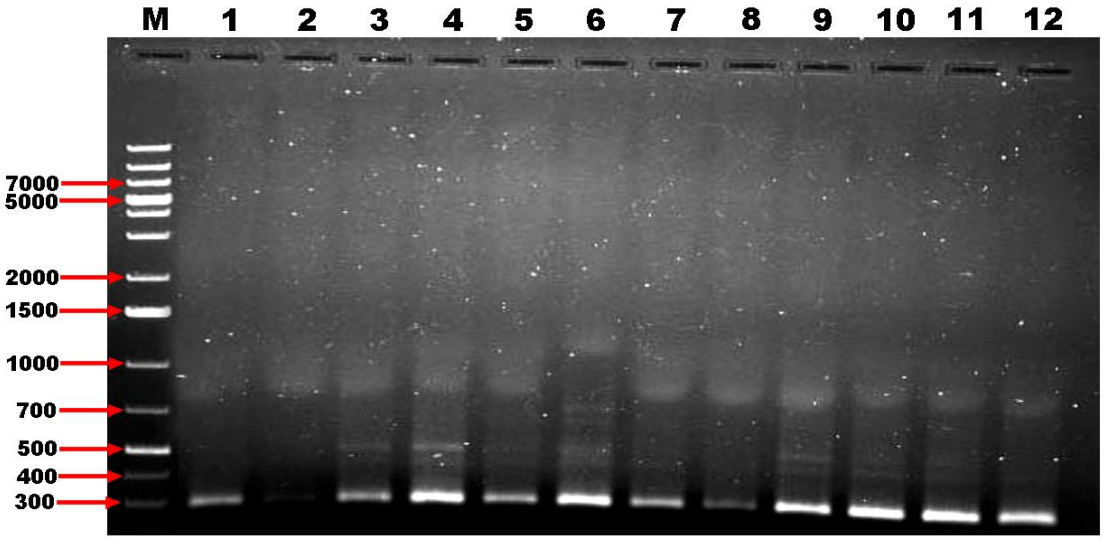


Fig.14: RAPD gel profile of 12 groundnut cultivars using OPJ-6 primer



1. Tirupati-3
2. Tirupati-4
3. Narayani
4. Kalahasti
5. Prasuna
6. Abhaya
7. TCGS-653
8. TCGS-888
9. TCGS-913
10. TCGS-750
11. TG-47
12. TCGS-645

Fig.15: RAPD gel profile of 12 groundnut cultivars using OPJ-4 primer



Lane M = Marker

1. Tirupati-3
2. Tirupati-4
3. Narayani
4. Kalahasti
5. Prasuna
6. Abhaya
7. TCGS-653
8. TCGS-888
9. TCGS-913
10. TCGS-750
11. TG-47
12. TCGS-645

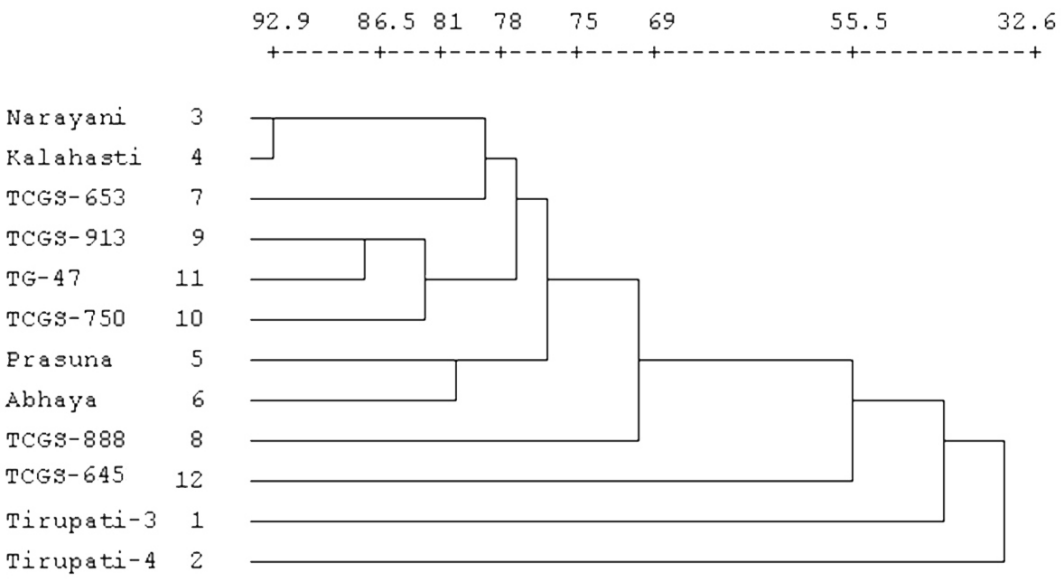


Fig. 16: Dendrogram generated using UPGMA analysis showing relationship between cultivars of groundnut using RAPD markers

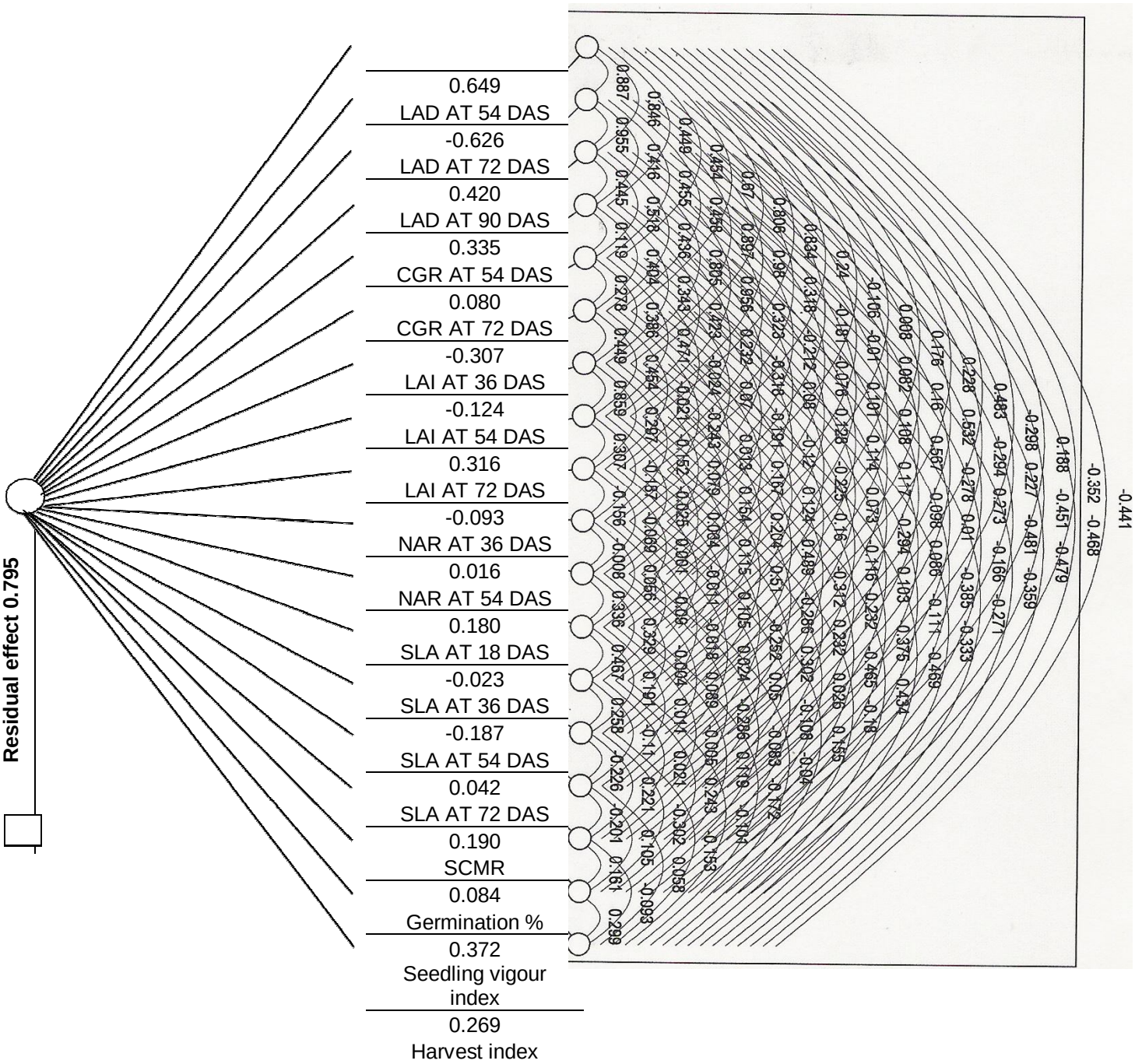


Fig.19: Phenotypic path diagram of pod yield per plant and different physiological characters in 29 groundnut cultivars.

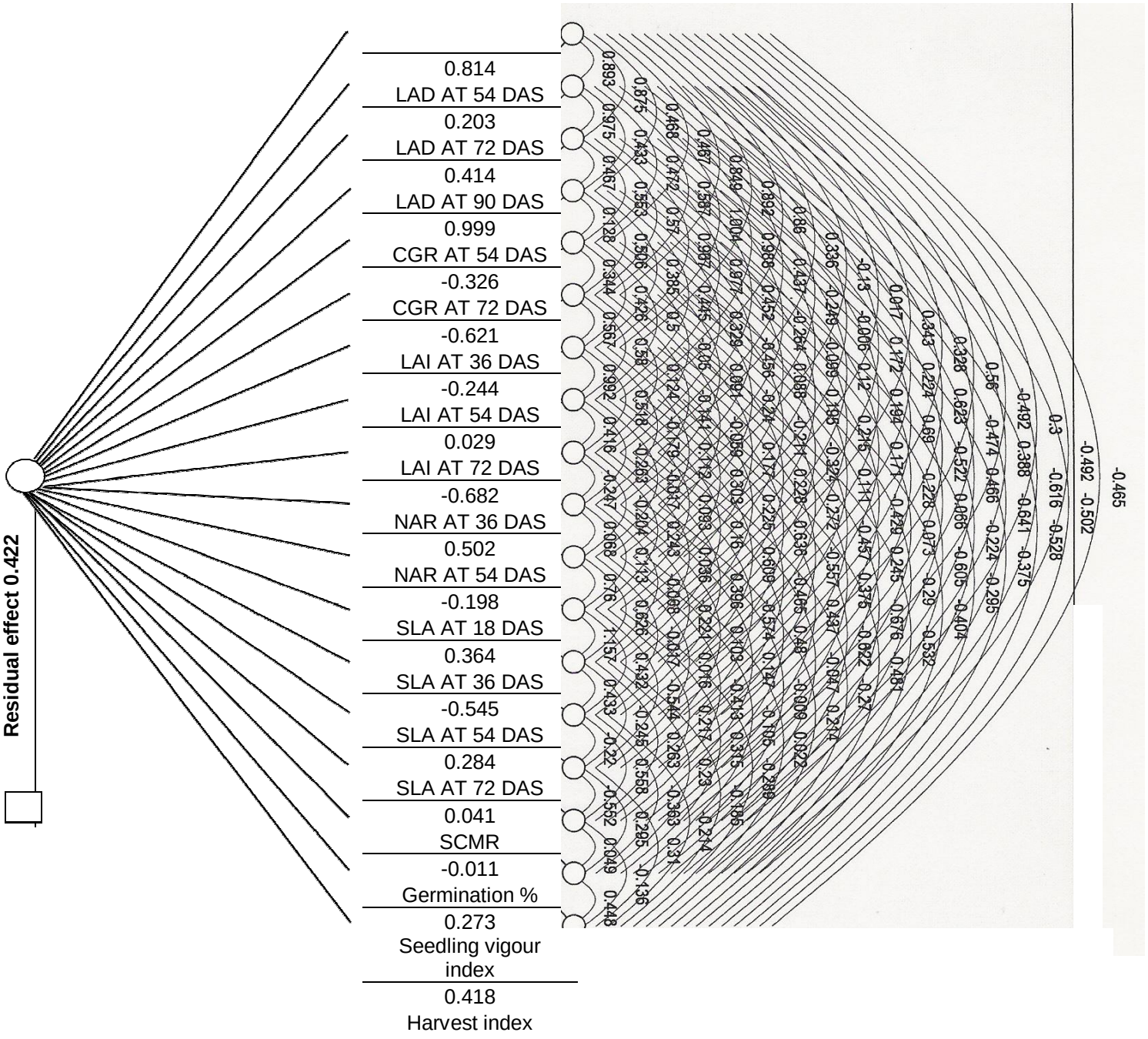


Fig.20: Genotypic path diagram of pod yield per plant and different physiological characters in 29 groundnut cultivars.

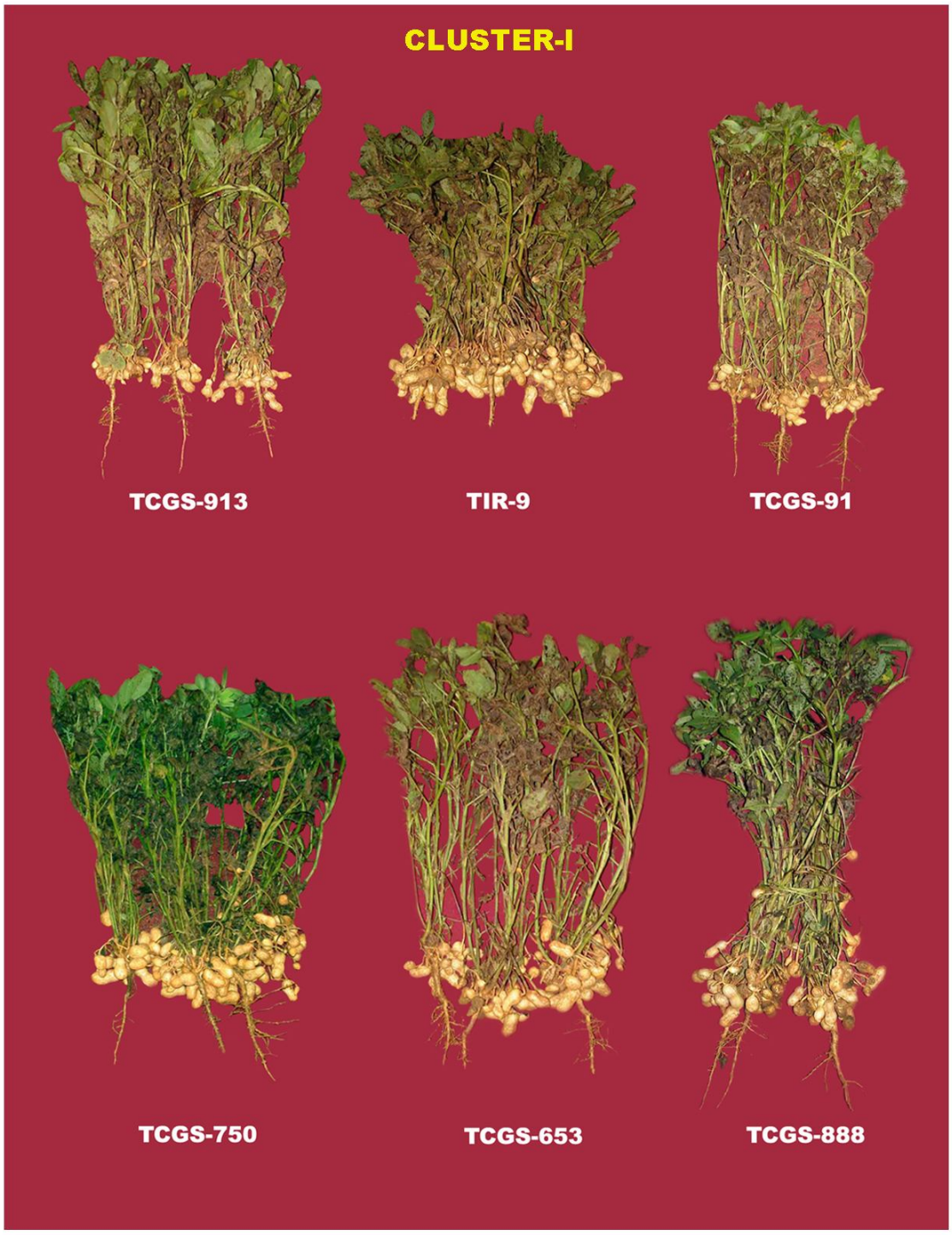


Plate 1: Distribution of 29 cultivars of groundnut in different clusters (Tocher's Method) based on physiological data



Plate 2: Distribution of 29 cultivars of groundnut in different clusters (Tocher's Method) based on physiological data



Plate 3: Distribution of 29 cultivars of groundnut in different clusters (Tocher's Method) based on physiological data



Plate 4: Distribution of 29 cultivars of groundnut in different clusters (Tocher's Method) based on physiological data



Plate 5: Distribution of 29 cultivars of groundnut in different clusters (Tocher's Method) based on physiological data

CHAPTER-V

DISCUSSION

Groundnut is an important oilseed and food crop of Andhra Pradesh. It is cultivated in an area of 16 lakh hectares in *Kharif* season under rainfed conditions. Moisture stress is the most important abiotic stress factor followed by excess rainfall due to erratic distribution of rainfall. Cloudy weather restricts photosynthetic activity and promotes diseases mainly late leaf spot during the season. During *rabi* season, a soil borne nematode problem called as 'Kalahasti malady' is a serious problem in some pockets. Therefore, development of groundnut varieties suitable for *kharif* and *rabi* seasons keeping in view the constraints in production has been taken and eight groundnut varieties i.e., Tirupati-1, Tirupati-2, Tirupati-3, Tirupati-4, Narayani, Kalahasti, Prasuna and Abhaya were released from Regional Agricultural Research Station, Tirupati and another six varieties have been released from Agricultural Research Station, Kadiri for the benefit of farming community. The present study has been planned with the objective of assessing the genetic divergence at morphological, physiological and molecular level among the released varieties and pre-release cultures. The knowledge of genetic divergence helps in making choice of parents to be used in hybridization programme to get good recombinants for desired characters. Correlation studies indicate the relationship between yield, its component morpho-physiological attributes while path co-efficient

analysis further partitions correlation coefficients into direct and indirect effects. Variability and heritability studies further are helpful in formulating effective selection procedures. The results obtained are discussed here under.

5.1 MEAN PERFORMANCE

5.1.1 Morphological, yield and yield attributes

The cultivar, Tirupati-4 recorded the highest pod yield per plant (18.40 g) followed by TG-47 (17.00 g), K-4 (17.00 g) and K-134 (16.13 g) in decreasing order. The increased pod yield per plant in Tirupati-4 may be attributed to its superiority for number of mature pods per plant, shelling percentage, leaflet length, leaflet width, leaf length, length of primary branches, length of main axis and early emergence. The cultivar, TG-47 also recorded high pod yield per plant (17.00 g) as it had relatively more harvest index, 100-seed weight and number of primary branches per plant. Similarly, K-134 showed fairly high pod yield per plant (16.13 g), number of mature pods per plant (17.60) leaf length (5.53 cm), leaflet width (2.23 cm), leaflet length (4.85 cm), early flowering (27.00 days) and early germination (6.00 days). Pod yield per plant was found to be highly related to the number of mature pods per plant, 100-seed weight, length of main axis and number of primary branches per plant (Labana *et al.,* 1980). Contribution of 100-seed weight to pod yield was identified and reported by several workers.

In addition to above cultivars, Narayani (15.66 g) and TG-39 (15.60 g) also registered fairly high pod yield per plant which might be due to their superiority in traits *i.e.* 100-seed weight, number of mature pods per plant, leaflet length, leaflet width, leaf length and number of primary branches per plant.

The cultivar, R-2001-2 had the highest harvest index (63.66), Abhaya had the maximum shelling percentage (60.94). The cultivar, TG-39 showed the highest 100-seed weight (49.33 g) whereas TCGS-717 reported higher number of fully expanded leaves (82.67). Tirupati-1 was early in flowering (26.33). Narayani exhibited maximum length of primary branches (51.14 cm) and length of main axis (49.61 cm). TCGS-156 showed lowest weight of immature pods per plant (0.80 g) and TCGS-645 recorded least number of immature pods per plant (4.53). The above cultivars are worthy of utilization in improvement of the respective characters.

5.1.2 Physiological characters

Significant differences were observed in LAD values from 54 to 90 DAS. The cultivars JL-24, Tirupati-3, Tirupati-4, K-134 and TCGS-717 maintained consistently higher LAD values throughout the crop period from 54 DAS to 90 DAS. In some cultivars *i.e.* TCGS-645 (79.28), TIR-23 (66.53), Abhaya (64.78), JL-501 (63.16), R-2001-2 (55.01), TCGS-653 (55.01), Prasuna (54.25), TIR-9 (52.62) and TCGS-913 (52.09) the rate of increase in LAD from 72 DAS to 90 DAS was very high that ranged from

52.09 to 79.28. The increase in LAD in these cultivars coincides with pod filling phase. The maintenance of high LAD values during pod filling phase helps in sustained production of photosynthates and is a desirable attribute. Studies of Enyi (1977) on growth aspect of two varieties of groundnut, a sequential branching type, Natal common and an alternate type, 'Domodo Edible' indicated greater grain to leaf ratio (grain weight at harvest/LAD between pod initiation and final sampling) in spreading types than bunch types. In the present study, the cultivars, that showed high LAD values during pod filling phase were mostly derivatives of infra-specific crosses.

Crop growth rate (CGR) is the increase in dry matter per unit land area per unit time. It is the integration of intercepted radiation and radiation use efficiency and is the major determinant of final yield. Significant differences were observed in CGR at 54 and 72 DAS. In the present study, CGR has shown steady increase in all the cultivars from 54 to 72 DAS. The marked increase in CGR at later part of the growing season could be due to a combination of decreased leaf area and increased leaf weight (Siva Kumar and Shaw, 1978). The cultivar, Prasuna reported high CGR at 54 DAS (16.40) whereas Tirupati-4 exhibited high CGR at 72 DAS (33.18). Vindhiya Varman *et al.* (1996) also reported an increase in CGR upto 50 to 70 DAS. Other than Tirupati-4 and Prasuna, the cultivar, TCGS-722 also showed fairly high CGR in both the stages.

Significant differences were found in the values of LAI from 36 to 72 DAS. Leaf area index (LAI) describes the size of assimilatory apparatus of a crop or the crop canopy expansion. LAI increased from 36 to 72 DAS. Duncan *et al.* (1978) reported that maximum light interception occurred when the LAI was three. In the present study, LAI values greater than three were observed in all the cultivars at 72 DAS. The cultivar, JL-24 showed maximum LAI at both 36 and 72 DAS. It showed fairly high LAI at 54 DAS also. The cultivar, K-134 showed maximum LAI at 54 DAS and also at 36 and 72 DAS. Hence, the cultivars, JL-24 and K-134 can be selected to improve the LAI. As per Williams (1976) it is important to maintain high leaf area during pod filling period since sinks seemed to be not limiting. Maintenance of high LAI is advantageous especially in *Kharif* season due to low photosynthetic rate under low light conditions.

Significant differences among the cultivars in NAR values were observed at 36 DAS and 54 DAS. Higher NAR values were maintained from 36 to 54 DAS in cultivars, Tirupati-4, Nararyani, Kalahasti, Abhaya, TCGS-888, K-134, TCGS-717, TG-47, TCGP-6, TCGS-645, TCGS-91 and JL-501. No significant differences were observed in NAR values of cultivars at 18, 72 and 90 DAS. NAR decreased from 36 to 54 DAS in almost all the cultivars. Similar results were also observed by Janamatti (1979) in NAR amongst the 4 bunch groundnut cultivars during the vegetative phase (0-25 days). In all, NAR decreased during

flower initiation (25-40 days), pod initiation and pod development (40-70 days) stages. There was decrease in NAR during the peak pod filling period.

Significant differences were observed in SLA from 18 to 72 DAS while differences were not significant at 90 DAS. Genotypes with lower SLA (thicker leaves) were known to have more photosynthetic machinery *i.e.* more chlorophyll content (Wright *et al.,* 1994). Arjunan *et al.* (1997) opined that more leaf area inturn higher dry matter production results in accumulation of photosynthates for high pod yield. SLA values decreased from 18 DAS to 72 DAS in all cultivars. Low SLA is desirable as it is highly correlated with higher water use efficiency. Hemanth Kumar (2004) also observed a decreasing trend in the SLA from 30 DAS to 60 DAS. The cultivar, JL-501 showed lowest SLA value at 18 DAS whereas TCGS-888 reported lowest SLA values at 36 and 54 DAS and TCGS-750 showed lowest value at 72 DAS. These cultivars showed considerably low SLA values at all growth stages and can be selected to increase water use efficiency in groundnut. Incidentally, JL-501 and TCGS-888 maintained higher NAR at grand growth phase *i.e.* 36-54 DAS. These two cultivars bearing the traits of low SLA and high photosynthetic efficiency at grand growth phase can be explored in developing drought tolerant groundnut genotypes. The cultivar TCGS-750 showed highest SLA value at 18 DAS while Kalahasti recorded highest SLA at 36 and 54 DAS and K-4 showed higher SLA value at 72

DAS. The performance of these cultivars with high SLA values would be better where availability of water and sunlight is not a limiting factor *i.e.* during *rabi* season.

Crop physiologists have identified a number of physiological attributes that confer water use efficiency. Many of the traits like transpiration efficiency and SLA are difficult to measure in large segregating generations and in screening large number of genotypes. A portable hand-held SPAD chlorophyll meter has been developed which measures leaf transmittance and whose readings are highly correlated with specific leaf area and specific leaf nitrogen, important traits that contribute for WUE. Bindu Madhava *et al.* (2003) observed a strong positive relationship of SCMR with WUE suggesting that SCMR could be a potential physiological trait to employ as a surrogate for selection for water use efficiency (WUE) in groundnut. The cultivar, TCGS-750 recorded highest SCMR value followed by TCGS-913, TCGS-653, Tiruapti-3, Abhaya, TIR-23, K-134, K-4, TG-47, TG-39, TCGP-6 and TIR-9 which showed SCMR values above 44.0. These cultivars also showed lower SLA values which ranged from 170-195. The observation of high SCMR and low SLA in some of the cultivars further confirms that SCMR could be used as a physiological tool for screening for water use efficiency.

In the present study, almost all the cultivars showed 90 per cent germination except TCGS-653, TCGS-888, K-4, K-6, TCGS-722, TCGS-

750, TG-39, TCGS-645, R-2001-2 and TIR-9 in 10 days. The effect of dormancy on reducing germination percentage can be ruled out as the material sown was of four months old. High seedling vigour index is advantageous as it helps in attaining early ground coverage *i.e.* achievement of high LAI early in growth of the crop. High seedling vigour index values were observed in cultivars, R-2001-2, TCGP-6, TG-47, TIR-9, TCGS-91 and Kalahasti which also exhibited 90% germination in 10 days except R-2001-2 and TIR-9 which showed 79.37% and 75.00% germination respectively in 10 days.

Harvest index indicates the extent of drymatter partitioning into economic products *i.e.* pods, seeds and oil in groundnut. The cultivar, R-2001-2 exhibited highest harvest index (63.66%%) followed by TCGS-888 (62.54%0, TG-47 (58.59%) and TCGP-6 (53.45%) respectively. Duncan *et al.* (1978) stated that most of the yield variation among the five groundnut cultivars grown in Florida was due to differences in the partitioning of assimilates between vegetative and reproductive parts, the length of grain-filling period and rate of fruit establishment. Estimates of partitioning to fruit ranged from 41% in the first cultivar released in US to 98% in the latest cultivar though CGR did not vary much among different cultivars. In the present study, harvest index values ranged from 31.70% in Tirupati-3 to 66.66% in R-2001-2 during rainy season. In a set of 11 genotypes which consisted of released varieties and

advanced breeding lines, Vasanthi *et al.* (2003) observed a range of 41% (TCGS-647) to 53% (JL-24) in harvest index in post-rainy season.

5.2 GENETIC PARAMTERS

The amount of variability present for different characters in a population and its efficient management decides the success of any breeding programme. The co-efficient of variation is useful in measuring the range of variability in characters. However, it is not possible to assess the extent of heritable variation with genetic co-efficient of variation alone. Genotypic co-efficient of variation (GCV) along with heritability estimates would provide a better picture of the amount of genetic advance to be expected by phenotypic selection (Burton, 1952). Further, the estimates of heritability alone will not be of much value for selection based on phenotypic performance and suggested that genetic gain should be considered in conjunction with heritability estimates (Johnson *et al.,* 1955).

In the present study, the estimates of PCV for all the characters were higher than the estimates of GCV, indicating the interaction of cultivars with the environment (Table 7). The results obtained are discussed here under.

High GCV, PCV values were observed for weight of immature pods per plant, length of primary branches and length of main axis in decreasing order. High variability estimates were also reported by earlier

workers (Seethala Devi, 2004 and Vasanthi *et al.,* 2003) for length of main axis and Balaiah and Reddy (1975) for length of primary branches. Moderate GCV and high PCV values were found for number of fully expanded leaves, number of mature pods per plant, number of immature pods per plant, 100-seed weight and pod yield per plant. The results were in accordance with the results of Vasanthi *et al.* (2003) for number of mature pods per plant, number of immature pods per plant and pod yield per plant. Ravi Kumar (2005) reported high PCV values for 100-seed weight and Vasanthi and Raja Reddy (2002) for number of fully expanded leaves.

Moderate PCV and moderate to low GCV values were found for days to emergence, number of primary branches per plant, days to 50% flowering, leaflet length, leaflet width, leaf length, shelling percentage and harvest index indicating little scope for selection to improve these characters. The results were in agreement with the results of Sandhu and Khehra (1983) for leaflet length and leaflet width, Naik *et al.* (2000) for number of primary branches per plant and 100-seed weight, Ravi Kumar (2005) for shelling percentage, harvest index and days to 50% flowering and Swamy Rao *et al.* (1988) for leaf length.

Johnson *et al.* (1955) suggested that heritability along with genetic advance is more useful than heritability estimates alone in predicting the resultant effect for selecting the best individuals. In the present study, high heritability coupled with high genetic advance as per cent of mean

was observed for days to emergence, length of main axis, length of primary branches, 100-seed weight and harvest index, indicating the role of additive gene action in the inheritance of these traits and hence, phenotypic selection would be very effective in their improvement. These results were in accordance with the reports of Ravi Kumar (2005) for 100-seed weight, harvest index and length of main axis. Moderate heritability coupled with high genetic advance as per cent of mean was observed for number of fully expanded leaves, weight of immature pods per plant and pod yield per plant. Similar results were also observed by Naik *et al.* (2000) for pod yield per plant and Rostini *et al.* (2000) for number of fully expanded leaves indicating the action of additive and non-additive gene action. So, phenotypic selection would be effective for the improvement of these characters also.

Moderate to high heritability coupled with moderate genetic advance as per cent of mean was obtained for leaflet length, leaflet width, days to 50% flowering and leaf length. Similar results were also noticed by Ravi Kumar (2005) for days to 50% flowering indicating the involvement of both additive and non-additive gene action. Hence, phenotypic selection would result in moderate genetic gain for these characters.

On contrary, the characters, number of primary branches per plant, number of mature pods per plant and shelling percentage exhibited low heritability coupled with low GAM. Number of immature

pods per plant recorded low heritability with moderate genetic advance as per cent of mean. These results indicated that these characters were highly influenced by environmental effects and simple phenotypic selection would not be that effective for improvement of these characters. These results were in agreement with the reports of Rami Reddy *et al.* (1991) for number of immature pods per plant and shelling percentage and Vijayasekhar (2002) for number of primary branches per plant and number of mature pods per plant.

From the above discussion, it can be concluded that the characters, length of main axis, length of primary branches recorded high GCV, PCV, heritability and GAM indicating that these characters were governed by additive gene action and simple phenotypic selection could be followed for their improvement. On the other hand, the characters, days to emergence, number of fully expanded leaves, weight of immature pods per plant, 100-seed weight, harvest index and pod yield per plant had moderate to high GCV, PCV, heritability and high GAM. These characters were also governed by additive gene action and simple phenotypic selection would be effective for the improvement of these characters. Moderate to low GCV, PCV, heritability and GAM was observed for number of primary branches per plant, days to 50 per cent flowering, leaf length, number of mature and immature pods per plant, and shelling percentage. The characters, leaflet length and leaflet width exhibited moderate GCV, PCV, GAM and high heritability indicating that

the above characters were under the control of non additive gene action and phenotypic selection would not be that effective to improve these characters in early segregating generations and selection for these traits has to be postponed to later generations.

Genetic parameters, GCV, heritability and genetic advance as per cent of mean were estimated for physiological attributes (Table 8). Leaf area duration (LAD) at 54, 72 and 90 DAS showed high to moderate GCV, PCV, high heritability and high genetic advance as per cent of mean (GAM). Crop growth rate (CGR) at 54 and 72 DAS also exhibited high GCV, PCV, heritability and GAM. These results were in agreement with the reports of Sharma *et al.* (2000) for CGR at 54 and 72 DAS. LAI at 36, 54 and 72 DAS registered high GCV, PCV, heritability and GAM. These results corroborate well with the reports of Vindhiyavarman *et al.* (1996) and Desai *et al.* (1999). NAR at 36 and 54 DAS also recorded moderate to high GCV, PCV, moderate heritability and high GAM. The results indicate that these characters were under the control of additive gene action, hence simple phenotypic selection would be effective for their improvement.

On the other hand, the character, SLA at 18, 36 and 54 DAS showed low genetic variability with moderate to high heritability and moderate genetic gain except at 36 DAS. SLA at 72 DAS showed moderate GCV coupled with high heritability and high GAM. From the results, it can be inferred that SLA at 72 DAS was least influenced by

environment compared to other stages in the crop growth and was governed by additive gene action. Thus, selection for water-use efficiency using SLA as surrogate could be most effectively done at 72 DAS of crop growth.

The other characters, seedling vigour index, harvest index and pod yield per plant recorded moderate to high GCV, heritability and high GAM indicating the role of additive gene action in the inheritance of these characters. Hence, they also can be improved by simple phenotypic selection. Similar results were also obtained by Vijayasekhar (2002) for harvest index and Vasanthi *et al.* (2002) for pod yield per plant.

On contrary, low GCV, moderate heritability and low GAM were observed for SCMR and germination percentage indicating that these characters were under the control of non-additive gene action. Hence, selection would be more effective in advanced generations when the non-additive gene effects particularly due to epistasis get fixed. These results corroborated well with the reports of Vasanthi *et al.* (2003) and Seethala Devi (2004) for SCMR and Rajora *et al.* (1999) for germination percentage.

From the results discussed it can be concluded that the characters, LAD, CGR, LAI, NAR, SLA at 72 DAS, seedling vigour index, harvest index and pod yield per plant were under the control of additive gene action and hence they can be improved by simple phenotypic

selection, while the traits like SCMR and germination percentage were governed by non-additive gene action and selection has to be done in advanced generations.

5.3 GENETIC DIVERGENCE

Studies of genetic divergence among cultivars is essential in an efficient and successful hybridization programme since the cross involving genetically diverse parents is likely to produce high heterotic effects and also more variability in the segregating generations. By using advanced biometric techniques such as multivariate analysis based on Mahalanobis's D^2 statistic it has now become possible to quantify the degree of genetic divergence amongst biological populations and to assess relative contribution of various attributes to total divergence. Evaluation of genotypes for phenotypic characters based on morphological variation along with DNA characterization helps in documentation and deployment of the available genetic variability. Though a range of plant characters are currently available for distinguishing closely related individuals, their sensitivity to environment and scanty genome coverage limits their further usage in breeding. DNA based molecular markers are in abundance and clearly allow the comparison of genetic material avoiding any environmental influence on gene expression. Randomly amplified polymorphic DNA (RAPD), a PCR based DNA marker technology, offers advantages in speed, technical simplicity, random coverage of the genome and

relatively higher level of polymorphism (Newburry and Lloyd, 1993). In the present study, genetic divergence analysis was attempted to study divergence among 29 cultivars of groundnut considering 16 morphological, yield and yield attributes and 10 physiological characters along with RAPD marker studies.

5.3.1 Mahalanobis's D^2 analysis

Divergence was studied taking 26 characters into consideration. For the sake of convenience for statistical analysis, divergence based on morphological yield and yield attributes and divergence based on physiological attributes and yield was computed separately. Wilk's 'V' criterion test was highly significant when all the characters were considered simultaneously. The magnitude of D^2 values suggested that there was considerable diversity in the released and pre-release groundnut cultures. The range of variation allowed for grouping of 29 cultivars into 9 clusters based on data of morphological, yield and yield attributes and 8 clusters based on data of physiological characters.

The 29 cultivars were grouped into 9 clusters based on data of morphological, yield and yield contributing characters and the clustering was done following Tocher's method. Out of 9 clusters formed, cluster I contained maximum number of 13 cultivars, (TCGS-653, TCGS-91, TCGS-722, TCGS-645, Tirupati-1, Tirupati-2, TIR-9, K-6, JL-501, Abhaya, K-134, Kalahasti and JL-24) whereas cluster II had single cultivar (TMV-2). Cluster III contained 6 cultivars (TIR-23, TCGP-6, K-4,

TCGS-750, TG-39 and TG-47), cluster IV had one cultivar (TCGS-156) and cluster V had 4 cultivars (TCGS-888, R-2001-2, TCGS-913 and Tirupati-4) whereas cluster VI (Prasuna), VII (TCGS-717), VIII (Narayani) and IX (Tirupati-3) had single cultivar each (Table 10). The formation of largest cluster I comprising 13 cultivars might be due to free flow (or) exchange of breeding material from one place to another or/and the unidirectional selection practiced by breeders of different locations. Six cultivars were not included with any other cluster as they maintained separate identity from all others. They were grouped into different clusters II, IV, VI, VII, VIII and IX each exhibiting high genetic diversity with most of the others clusters. Dispersion pattern of cultivars over a large number of clusters with a maximum of 13 cultivars in cluster I to single cultivar in clusters II, IV, VI, VII, VIII and IX indicates the presence of maximum degree of divergence and genetic heterogenity among cultivars.

Similarly, the range of D^2 values allowed the constellation of 29 cultivars into 8 clusters based on data of physiological characters (Table 18). The minimum number of cultivars were present in the cluster VI (Tirupati-4, K-134) and maximum (11) number of cultivars (TCGS-913, TIR-9, TCGS-91, TCGS-750, TCGS-653, TCGS-888, TCGP-6, TG-39, TIR-23, Abhaya and JL-501) were present in clusters I and II (Narayani, K-6, TMV-2, TCGS-722, TCGS-156, Kalahasti, Prasuna, K-4, Tirupati-1, 2 and 3) respectively. Single cultivars formed separate clusters III

(R-2001-2), IV (JL-24), V (TCGS-717), VII (TCGS-645) and VIII (TG47) and each cultivar in these clusters was distinctly different from cultivars of other clusters.

Constellation of cultivars into different clusters based on morphological, yield and yield attributes and physiological characters was at random and independent of each other. Clustering pattern of genotypes into different clusters did not show any relationship with respect to their pedigrees and place of breeding. Similar observations were made earlier by Chowdhary *et al.* (1998), John Joel and Mylsamy (1998) and Nayak and Patra (1997). Inter-cluster distances were greater in magnitude when both the groups of characters were employed confirming the presence of diversity among clusters. The maximum inter-cluster distance for morphological characters was observed between clusters V and IX (57.76) followed by II and IX (51.55) indicating wide diversity among these clusters. Hence, cultivars from these clusters may be utilized as parents for hybridization which would result in high heterotic expression for yield components and wider segregation in filial generations. By using such cultivars as parents in hybridization programme, superior recombinants can be obtained. Similar inferences were also suggested by Golakia and Makne (1991), Vijayasekhar (2002) in groundnut.

The minimum inter-cluster distance between clusters IV and VIII (11.02) indicated that most of the characters had similar values in these

clusters. Maximum intra-cluster distance was observed in clusters V, III and I and selection of cultivars from cluster I having maximum number of cultivars (13) might be fruitful to produce good recombinants.

In the clustering based on physiological characters, maximum inter cluster distance was found between the clusters VI and VII (772.28) and between V and VII (760.10) indicating the greater diversity between these clusters. In contrast the minimum intercluster distance between III and VII (78.49) indicates the close relationship between the clusters. On the other hand, maximum intra cluster distance was observed in clusters II (102.41), I (75.69) and VI (61.77). As the clusters I and II comprised maximum number of cultivars (11), parents for hybridization can be selected from these clusters.

Major emphasis has been given on cluster means for selecting the best parents for crossing programme. Means for morphological characters indicated that the cultivars of cluster III recorded high 100-seed weight (43.11g), the cultivars of cluster IV registered higher leaflet width (2.55) and shelling percentage (73.71). The cultivars in Cluster V showed high harvest index (54.87) while the cultivars of cluster VI were late emerging ones (6.67) and produced more number of mature pods per plant (19.80). Similarly the cultivars in cluster VII possessed higher number of primary branches per plant (6.20), high leaflet length (5.55), more number of fully expanded leaves (82.67) and higher weight of immature pods per plant (4.60) whereas the cultivars of cluster VIII

showed the highest values for length of main axis (49.61), length of primary branches (51.14), leaf length (6.47), number of immature pods per plant (10.87) and pod yield per plant (15.67) and cluster IX consisted of cultivars that flowered late (36 days to reach 50% flowering). Inter-crossing of the cultivars from these clusters would be useful to generate a wide range of variability for effective selection.

The relative contribution of different plant characters to the total genetic divergence estimated by D^2 analysis indicated that harvest index contributed more (33.50%) towards the divergence followed by days to emergence (17%) and length of main axis (8.62%) (Table 13 and Fig.2). Cluster means together with information on the traits that contribute maximum towards divergence would help in selection of parents. The highest contribution of harvest index towards divergence was also earlier reported by Venkateswarlu (1988) and Vijayasekhar (2002). Dashora and Nagda (2004) studied divergence among 52 genotypes taking 12 characters which were grouped into 11 clusters. Maximum contribution was from haulms yield per plant followed by dry pod yield per plant and hundred kernel weight.

Cluster means for different physiological characters showed considerable difference among the clusters for all the characters. The cultivars of cluster III showed high SLA at 54 DAS (217.74), seedling vigour index (1420.33) and harvest index (63.66). The cultivars of cluster IV exhibited higher LAD at 54 DAS (242.95), LAD at 72 DAS

(323.34), higher CGR at 54 DAS (15.72), higher LAI at 36 DAS (3.14) and at 72 DAS (6.18) and germination percentage (100.00). Cluster V consisted of genotypes with high LAD at 90 DAS (358.67), higher LAI at 54 DAS (5.70), higher NAR at 36 DAS (0.10) and higher SLA at 72 DAS (160.12). The cultivars of cluster VI showed higher values of CGR at 72 DAS (30.96), NAR at 54 DAS (0.04) and pod yield per plant (17.27). The cultivars of cluster VII had high SLA at 18 DAS (247.35) and at 36 DAS (225.09). Cultivars of cluster VIII exhibited higher SCMR (45.57). Inter-crossing the elite cultivars from these clusters could be suggested to generate wide range of variability.

It was observed that LAD at 54 DAS (34.48%), LAI at 72 DAS (20.20%), LAD at 72 DAS (12.81%) and CGR at 72 DAS (12.32%) contributed more towards divergence (Table 21 and Fig.6). The considerable contribution of CGR towards divergence was also earlier reported by Hemanth Kumar (2004).

5.3.2 Canonical root analysis

The group constellations formulated on the basis of Mahalanobis's D^2 statistic were confirmed by canonical root analysis. The five canonical roots were responsible for 81.47 per cent of total variance of uncorrelated (y) variables for 16 morphological, yield and yield attributes which indicated that differentiation of these traits was nearly complete in these cultivars in 5 phases (Table.14). The relative distribution of

cultivars reflected existence of parallelism between grouping obtained by D^2 analysis and canonical vector analysis.

The 5 vectors as a whole contributed 81.47 per cent towards genetic divergence because of which discernible overlapping was observed in group constellation of canonical vectors. The character, harvest index in the first vector, days to emergence in the second and third vector, 100-seed weight in the fourth vector and pod yield per plant in the fifth vector contributed the maximum towards divergence. This was in accordance with the relative contribution of characters as observed through D^2 analysis. Hence, harvest index, days to emergence, 100-seed weight and pod yield per plant were important traits contributing towards genetic divergence in groundnut.

The canonical root analysis for physiological characters showed that the four vectors contributed 91.11 per cent towards genetic divergence (Table 22). The character, LAD at 54 DAS in the first vector, LAI at 72 DAS in the second vector, CGR at 54 DAS in the third vector and NAR at 54 DAS in the fourth vector contributed more towards divergence. This was in accordance with the relative contribution of characters as observed through D^2 analysis. Hence, LAD at 54 DAS, LAI at 72 DAS, CGR at 54 DAS and NAR at 54 DAS were important physiological characters contributing towards genetic divergence in groundnut.

From the above discussion, it is clear that the morphological characters *viz.,* harvest index, days to emergence, 100-seed weight, pod yield per plant and length of main axis and physiological characters, leaf area duration, leaf area index, crop growth rate and net assimilation rate contributed more towards the divergence in the set of 29 cultivars involved in the present study. The cultivars *viz.,* TCGS-888, TCGS-913, R-2001-2, Tirupati-4, Prasuna and Narayani would be the promising cultivars to select as parents in the hybridization programmes to improve harvest index, days to emergence, 100-seed weight and pod yield per plant whereas the cultivars, K-134, TCGS-717, Tirupati-4, JL-24 and TCGS-645 could be selected as effective parents to improve the physiological characters *viz.,* leaf area duration, leaf area index, crop growth rate and net assimilation rate.

5.3.3 Assessment of molecular diversity using RAPD markers

The molecular tools such as DNA markers are becoming increasingly important as effective tools in crop breeding programmes but their application in genetic enhancement of groundnut is lagging behind due to limited knowledge of the genome. Wide variation for morphological and physiological characteristics exists in both wild and cultivated groundnut (Halward *et al.,* 1993), but low DNA polymorphism has been observed in cultivated species (Kochert *et al.,* 1991 and Halward *et al.,* 1993) though a large variation for phenotypic characteristics exists. Studies using RAPD, SSR, RFLP and AFLP

techniques have revealed the presence of DNA polymorphism in cultivated groundnuts (Dwivedi and Gurtu, 2002). The observed polymorphism may be useful for developing molecular markers helpful for screening various traits in groundnut improvement programmes.

In the present study, 12 groundnut cultivars selected based on morphological variation and D^2 clustering pattern were analysed for studies on genetic diversity using RAPD technique. Out of 60 primers screened, seven primers were found to be polymorphic and were used to detect the variation among the cultivars which gave on an average 7-8 bands with fragment size varying from 100-7000 bp. A total of 58 bands were obtained among which 48 bands were polymorphic (82.75%) (Table 25). Polymoprhism was found to be high with the primers OPJ-6 (11 bands), OPA-3 and OPH-7 (10 bands) indicating a wide range of diversity.

The 12 cultivars showed different banding pattern with seven primers used. The cultivar, Tirupati-4 showed an unique band of molecular weight, 300 bp with primer OPA-3. This band is absent in other cultivars. Thus, the banding pattern in Tirupati-4 with OPA-3 primer is genotype specific and can be used for identification of the genotype. Similarly, the cultivar, TCGS-888 also showed a specific band of 200 bp molecular weight with OPA-3 primer. This cultivar also produced a thick specific band of 400 bp with OPA-19 primer. The primers, OPA-19 and OPA-3 could be used to differentiate TCGS-888

from others. The cultivars, Tirupati-3 (400 bp), TG-47 (75-100 bp) and TCGS-913 (75-100 bp) also produced unique low molecular weighted bands with OPA-19 primer. The cultivars, Tirupati-3 and Prasuna failed to produce a band of 500-600 bp which is present in other cultivars. OPA-19 is also useful to differentiate Tirupati-3 and Prasuna from others. All the cultivars, except Tirupati-4 exhibited a common band of 75 bp band with OPJ-4 primer. The profile with OPJ-4 could be used to distinguish Tirupati-4 from other cultivars. The cultivar, Abhaya exhibited two specific light bands with OPJ-4 primer. With primer OPJ-6, the cultivars, Kalahasti (7000 bp) and TCGS-750 (500 bp) produced unique bands which can be used as markers to identify these cultivars. Thus genotype specific banding patterns observed with specific primers would help in the identification of the cultivars.

Genetic relationships among 12 cultivars were estimated using Jaccard's similarity co-efficients. The similarity index values ranged from 32.6%to 92.9% indicating the presence of wide range of genetic diversity at molecular level among the 12 cultivars (Table 26) of groundnut. Dwivedi *et al.* (2001) and Nalini Mallikarjuna *et al.* (2005) also reported a high level of genetic variation in groundnut using RAPD technique.

In a similar study involving twelve released cultivars, Radhakrishnan *et al.* (2004) reported wide genetic diversity among released cultivars *i.e.* within cultivated groundnut in contrast to earlier

reports and concluded that with RAPD technique, sufficient polymorphism can be detected in cultivated groundnut which would help in genetic mapping.

The clustering pattern using RAPD data resulted in 6 major groups (Fig.16). The dendrogram of similarity co-efficients indicated that the cultivars, Narayani of group I and Tirupati-4 of group VI were clustered at the two extremes. Though they share the same pedigree *i.e.* they are derived from JL-24 x Ah316/s. They exhibited only 52.4 per cent of similarity indicating that the diversity might have arisen because of differential contribution from the two parents and also might be due to limited coverage of the genome by the primers used. It is also possible that the primers might have amplified the most dissimilar portion of the genome in these two varieties. The cultivar, Narayani was genetically similar (92.90%) to Kalahasti and TCGS-913 was similar (86.50%) to TG-47 though they have different pedigrees. This indicates that the grouping of cultivars was irrespective of their parentage.

The first group comprising of two sub-clusters (1a and 1b) had a minimum similarity of 77.3% and maximum of 92.9%. The cultivars Narayani and Kalahasti of sub-cluster 1a were closely related having 92.9% similarity. These two cultivars possess red seed coat colour, while group 1b comprised Narayani and TCGS-653 with a similarity of 77.3%. Group 2 included 2 sub-clusters within which the maximum similarity (86.5%) was observed between TCGS-913 and TG-47 of sub

group 2a and minimum of 78.6% between TCGS-913 and TCGS-750 of sub group 2b. Group 3 also included 2 sub clusters with a maximum similarity of 80% between Prasuna and Abhaya of sub-group 3a. These two cultivars possess 3-seeded pods in more number while 3b included only one cultivar TCGS-888, whereas the clusters IV (TCGS-645), V (Tirupati-3) and VI (Tirupati-4) included only one cultivar each indicating wide diversity among them. Sub-clustering pattern indicated low variation within the cluster and high variation between the clusters.

From the foregone discussion, it is evident that there was a considerable variation among the groundnut cultivars at molecular level. Hence, the utilization of available local germplasm resources in hybridization programme would still be efficient to evolve high yielding groundnut cultivars. It is also evident that RAPD markers could be employed for characterization of cultivars, assessment of molecular genetic divergence and relatedness among groundnut cultivars as they are easy to use and do not need sequence data.

Based on both Mahalanobis's D^2 analysis and RAPD marker analysis it is to conclude that the cultivars, Tirupati-4, TCGS-645, Prasuna and Narayani were found to be more diverse compared to other cultivars. The cultivar, Tirupati-4 can be used to improve the pod yield in groundnut. The clustering pattern was different in different methods used. Genotypes with dissimilar pedigrees were grouped into the same cluster while genotypes with same pedigrees are further apart. Likewise

certain genotypes were grouped together in either of the ways i.e. grouping through morphological/RAPD data of physiological/RAPD data or morphological/physiological data. Narayani and Kalahasti were grouped in one cluster, while TCGS-913 and TCGS-750 were also grouped in one cluster when grouping of genotypes was done in both ways *i.e.* based on physiological characters influencing pod yield and RAPD based analysis. Similarly Kalahasti and TCGS-653 appeared together in one cluster while Tirupati-3 alone formed a separate cluster when grouping was carried out based on morphological and yield attributes and RAPD based analysis. Some of the genotypes *i.e.* TIR-9, TCGS-91, Abhaya and JL-501 formed a cluster when grouping was done based on morphological, yield and yield attributes data and based on physiological attributes influencing yield. The information through RAPD data clearly indicates that it has a lot of scope as a tool to distinguish cultivars in groundnut as sufficient polymorphism was observed among cultivated groundnut varieties.

5.4 CHARACTER ASSOCIATION

Correlation studies provide reliable information on nature and extent of relationship between different characters. The information on the association between traits of economic worth is of great value to plant breeders as it will help in assessing the scope of simultaneous improvement of two or more characters. Yield is a highly complex character and polygenic in nature which is influenced by the

environment. Hence, the study of inter-association is essential to understand the relationship of simple traits with complex yield contributing traits. These relationships may be positive or negative. Negative associations are limiting factors in selection for higher yield. The study of genetic correlations gives an idea about the extent to which the characters are under the control of same set of genes. Pleiotropy assumes importance if the correlation is high whereas the independent inheritance of traits may be perceived if the correlation is low.

In the present study, the genotypic correlation co-efficients were observed to be higher than the phenotypic correlation co-efficients, indicating that though there exists an intrinsic association between the characters studied, the environment and cultivar x environment interaction played a major role in determining these associations between the characters (Table 27 and 28).

The results of correlation co-efficients obtained between different morphological, yield and yield attributes and physiological characters are discussed here under.

5.4.1 Correlation studies of morphological, yield and yield attributes

The characters, number of primary branches per plant, number of mature pods per plant, weight of immature pods per plant and 100-seed weight recorded highly significant positive association with pod yield per

plant indicating the positive linear relationship of these characters with pod yield. The results indicate that with the improvement in these characters, improvement in pod yield can be achieved. Similar kind of positive significant association of pod yield with number of primary branches per plant was also reported by Balaiah *et al.* (1980), Vaddoria and Patel (1992) and Nagabhushanam *et al.* (1982). Positive association of pod yield per plant with number of mature pods per plant and 100-seed weight was earlier reported by Nagabhushanam *et al.* (1982), Vaddoria and Patel (1992) and Moinuddin (1997). Jaswal and Gupta (1966) found that number of mature pods and branch length influenced yield in a study using 59 Spanish cultivars.

Sangha and Sandhu (1970) and Khangura and Sandhu (1975) reported that pod yield in 30 Virginia cultivars was strongly associated with the number of primary and secondary branches, the length of primary and secondary branches, the number of mature pods and shelling percentage.

Positive non significant association with pod yield per plant was observed by days to emergence, length of primary branches, days to 50 per cent flowering, leaflet width, number of fully expanded leaves, number of immature pods per plant and harvest index. Similar kind of positive association of pod yield per plant with length of primary branches was also observed by Balaiah *et al.* (1980). Singh and Singh (1999) and Lakshmidevamma *et al.* (2004) reported positive association

of pod yield per plant with days to 50 per cent flowering. Swamy Rao *et al.* (1988) reported positive association of pod yield per plant with leaflet width. Ursal *et al.* (1995) noticed positive association of number of fully expanded leaves with pod yield per plant. The positive association of number of immature pods per plant with pod yield per plant observed in present study was in agreement with the reports of Sharma and Varshney (1990) and Pushkaran and Nair (1993) and for harvest index with Vaddoria and Patel (1992).

Altogether, four characters exhibited positive significant correlation with pod yield per plant. The *inter se* correlations among these characters were also found to be significant and positive to a greater extent. Number of primary branches per plant recorded positive significant association with number of mature pods per plant, weight of immature pods per plant and 100-seed weight indicating the importance of these yield contributing characters to improve the pod yield in groundnut. Similar positive significant association of primary branches per plant with 100-seed weight was also observed by Ramakrishna Raju *et al.* (1981). The positive association of number of primary branches per plant with number of mature pods per plant obtained in the present study corroborate well with the results of Suneetha *et al.* (2005) and Sirisha (2005).

Number of mature pods per plant exhibited positive but non significant association with weight of immature pods and negative non

significant association with 100-seed weight indicating that the increase in pod number resulted in decrease in seed weight. These results were in accordance with the reports of Ramakrishna Raju *et al.* (1981). On the contrary, weight of immature pods showed positive significant association with 100-seed weight.

In contrast, the characters, length of main axis, leaflet length, leaf length and shelling percentage showed negative non significant association with pod yield per plant. These results were in agreement with the reports of Ramakrishna Raju (1981), Vindhiyavarman *et al.* (1996) and Suneetha (2005) for length of main axis. The results were in contrast with the results of Seethala Devi (2004) for leaflet length and Swamy Rao *et al.* (1981) with leaf length, who observed positive association of the respective characters with pod yield per plant. Shettar (1974) and Moinuddin (1997) also reported negative association of shelling percentage with pod yield per plant.

From the discussion, we could infer that the characters, number of primary branches per plant, number of mature pods per plant and 100-seed weight displayed positive significant association with pod yield per plant and among themselves. Hence, these characters could be given importance in formulating selection criteria for improvement of pod yield in groundnut. Other than these characters, days to 50 per cent flowering and length of primary branches also could be considered to improve the pod yield in groundnut as these characters associated

positively with pod yield and also with many other yield contributing characters.

5.4.2 Correlation studies of physiological characters

The characters, LAD at 54 DAS, LAD at 90 DAS, CGR at 54 DAS and LAI at 72 DAS exhibited positive significant association with pod yield per plant indicating that improvement in these characters can bring about increase in pod yield in groundnut which might be due to improved combined effect of growth, assimilation and partitioning of dry matter. Similar kind of positive significant association of CGR was observed by Sreedevi *et al.* (2004) in greengram. Patra *et al.* (1995) and Madhavi *et al.* (1988) identified positive significant association of LAI at 72 DAS with pod yield per plant. They concluded that LAI at 70 DAS and dry matter accumulation at 70 DAS were key growth variables positively influencing pod yield and could be employed as selection criteria to select productive cultivars in groundnut breeding.

The *inter se* correlations among these characters were also positive and significant. LAD at 54 DAS had positive significant association with LAD at 90 DAS, CGR at 54 DAS and LAI at 72 DAS. The character, LAD at 90 DAS showed similar kind of positive association with CGR at 54 DAS and LAI at 72 DAS. The character, CGR at 54 DAS also exhibited positive significant association with LAI at 72 DAS. These results were in agreement with the results of Antony *et al.* (2000) and Sreedevi *et al.* (2004) for CGR at 54 DAS and LAI at 72 DAS. CGR at 72 DAS also

expressed positive significant association with LAI at 36, 54 and 72 DAS. Williams *et al.* (1975) reported that kernel growth rate early in the reproductive phase of groundnut was influenced by CGR. Hence, CGR at maturity stage would be the most important physiological character that contributes for yield in groundnut. Similar conclusions were drawn by earlier workers Reddy and Murthy (1994), Anuradha (1995), Sanjeev Kumar *et al.* (2000) and Hemanth Kumar (2004).

On the other hand, the remaining characters LAD at 72 DAS, CGR at 72 DAS, LAI at 36 DAS, LAI at 54 DAS, NAR at 36 DAS, SLA at 18, 36, 54 and 72 DAS, SCMR, germination percentage, seedling vigour index and harvest index showed positive non significant association with pod yield per plant indicating that these characters could also be considered for the improvement of pod yield in groundnut. Only NAR at 54 DAS showed negative association with pod yield per plant. Similar results were also reported by Madhavi (1988) for LAI at early stages of crop growth. Sanjeev Kumar *et al.* (2000) reported that CGR increased as crop growth progressed and was highest between 60 and 90 DAS. Positive association of NAR was also observed by Sharma *et al.* (2000). Arjunan *et al.* (1997) reported positive non significant association of SLA with pod yield per plant whereas Seethala Devi (2004) observed positive non significant association of SCMR with pod yield per plant. Rajora *et al.* (1999) reported positive and significant association of germination percentage with seed yield per plant, while the positive association of

harvest index with pod yield per plant was observed by Hemanth Kumar (2004). Negative association of NAR with yield was earlier reported by Sreedevi *et al.* (2004).

In the present study, SCMR exhibited negative association with SLA at 54 and 72 DAS. SCMR, which was strongly linked with mesophyll efficiency controlling transpiration, was also proved to be linked with transpiration efficiency in correlation studies of Bindu Madhava *et al.* (2003). An inverse relationship between SLA and SCMR indicated that SCMR was a potential physiological trait to employ as a surrogate for transpiration efficiency (Reddy *et al.*, 2003). The cultivars having low SLA and high SCMR were found to be efficient transpiration controllers. Nageswara Rao *et al.* (2001) suggested that SCMR could be used as a rapid, low-cost, non-destructive technique to screen large breeding populations in place of SLA.

Harvest index showed negative correlation with SLA. Similar results were also reported by Wright *et al.* (1994). They concluded that both SLA and harvest index can be improved in the advanced generations and selection for low SLA in parents may be appropriate in water limited systems, where both pod yield for human consumption and vegetative yield for animal fodder need to be maximized.

From the discussion, we can conclude that the parameters, leaf area duration, leaf area index, crop growth rate, SLA, SCMR and harvest

index are important to improve the pod yield in groundnut as they associated positively with pod yield per plant.

5.5 PATH CO-EFFICIENT ANALYSIS

The association of various component characters among themselves and with pod yield is quite important for devising efficient selection criteria for pod yield. The correlation co-efficients measure the relationship between pairs of characters. But a dependent character is an interaction product of many mutually associated component characters and change in any one component disturbs the entire relationship of cause and effect system. When many characters are affecting a given character, splitting the total correlation into direct and indirect effects of cause as devised by Wright (1921) would give more meaningful interpretation to the causes of association between the dependent and independent variables. This kind of information will help in rationalizing the basis of selection more meaningfully in a breeding programme. Hence, in the present study, path co-efficient analysis of pod yield was carried out based on various morphological, yield and yield attributes and physiological characters.

5.5.1 Path co-efficient analysis of morphological and yield attributes on pod yield per plant

A perusal of path co-efficients (Table 29) revealed that number of mature pods per plant had maximum direct effect on pod yield per plant followed by leaflet width, days to emergence, 100-seed weight and

number of primary branches per plant. These results corroborate well with the reports of Badwal and Singh (1973) for mature pods per plant, Vasanthi *et al.* (1998) and Chaitanya Varma (2004) for 100-seed weight and Johar Singh and Mohinder Singh (2001), Ursal *et al.* (1995) and Suneetha *et al.* (2005) for number of primary branches per plant. Seethala Devi (2004) reported positive direct effect of leaflet width on pod yield per plant.

High positive indirect effect of number of mature pods per plant on pod yield per plant was exerted through leaflet width and number of primary branches per plant. Through days to emergence, it exhibited low positive indirect effect on pod yield per plant. On contrary, through 100-seed weight, it exerted negative indirect effect on pod yield per plant. But all these characters expressed positive significant association with pod yield per plant. Days to emergence, number of primary branches per plant and 100-seed weight exerted positive indirect effects among themselves. So these characters could be given importance for the selection to increase the pod yield in groundnut.

On the other hand, leaflet length exhibited highest negative direct effect on pod yield per plant. However, this character exerted high positive indirect effect through number of mature pods per plant which nullified the negative direct effect of leaflet length. But it showed negative association with pod yield per plant. The characters, length of primary branches, leaf length, number of fully expanded leaves, number of immature pods per plant, weight of immature pods per plant, shelling

percentage and harvest index also exhibited positive direct effects of lower magnitude on pod yield per plant. The results are in agreement with the reports of Durga Rani *et al.* (1987) for shelling percentage, Johar Singh *et al.* (2001) and Suneetha *et al.* (2005) for harvest index and number of immature pods per plant respectively.

From the above discussion, it is evident that number of mature pods per plant, number of primary branches per plant, 100-seed weight and days to emergence are the major yield contributing characters in groundnut. Therefore, due emphasis should be given to these characters in formulating selection criteria to evolve high yielding cultivars of groundnut.

5.5.2 Path co-efficient analysis of physiological characters on pod yield per plant

The results of path co-efficient analysis (Table 30) revealed that the characters, LAD at 54 DAS showed highest positive direct effect on pod yield per plant followed by LAD at 90 DAS, seedling vigour index, CGR at 54 DAS, LAI at 72 DAS, harvest index and SCMR. Similar results were earlier reported by Hemanth Kumar (2004) for CGR at 54 DAS and harvest index, Seethala Devi (2004) for SCMR, Patra *et al.* (1995) and Sree Devi *et al.* (2004) for LAI at 72 DAS. High positive indirect effects of LAD at 54 DAS was exhibited through LAD at 90 DAS, while LAD at 90 DAS, CGR at 54 DAS, LAI at 72 DAS contributed through LAD at 54 DAS. In addition, these four characters also expressed positive significant association with pod yield per plant.

Hence, selection based on these characters would be fruitful in bringing improvement in pod yield.

On contrary, LAD at 72 DAS and LAI at 36 DAS showed high negative direct effect on pod yield per plant. However, these characters exerted high positive indirect effects through LAD at 54 DAS which nullified the negative direct effects of LAD at 72 DAS and LAI at 36 DAS which resulted in positive correlation with pod yield per plant. Hence, these characters could also be considered to improve the pod yield in groundnut. Other than these, the characters, CGR at 72 DAS, germination percentage and SLA at 72 DAS were also found to exert positive direct effects of lower magnitude on pod yield per plant. But it is interesting to note that all these three characters exerted their positive indirect effects through LAD at 54 DAS on pod yield per plant. Similar results were obtained by Sree Devi *et al.* (2004) for CGR at 72 DAS and Rajora *et al.* (1999) for germination percentage. Reports of Hemanth Kumar (2004) for SLA did not corroborate with the results in the present study.

From the above discussion, it could be suggested that LAD, CGR, LAI at 36 and 72 DAS, germination percentage and SLA at 72 DAS are the important physiological traits influencing yield. Therefore, these characters could be given importance in formulating selection criteria in breeding programmes to develop high yielding cultivars of groundnut.

CHAPTER-VI

SUMMARY

The present investigation “Morphological and RAPD based gene diversity studies among released cultivars and pre-release cultures of groundnut (*Arachis hypogaea* L.)” was taken up in 29 released and pre-release cultures of groundnut to study genetic diversity based on morphological, yield, yield attributes, physiological and RAPD data to estimate variability and heritability, to study character association and work out path co-efficients among yield, yield attributes and physiological traits. The experiment was laid out in a randomized block design with three replications at Regional Agricultural Research Station, Tirupati.

The data were recorded on five randomly selected plants for the morphological, yield and yield attributes *viz.,* number of primary branches per plant, length of main axis, length of primary branches, days to 50% flowering, leaflet length, leaflet width, leaf length, number of fully expanded leaves, number of mature pods per plant, number of immature pods per plant, weight of immature pods per plant, 100-seed weight, shelling percentage, harvest index and pod yield per plant. The time taken for more than 90% of the sown seeds to emerge from the soil was recorded as days to emergence.

The data for physiological characters *viz.,* leaf area duration (LAD), crop growth rate (CGR), leaf area index (LAI), net assimilation rate (NAR) and specific leaf area (SLA) were recorded through destructive sampling of three plants at every 18 days interval upto 90 DAS. SCMR, harvest index and pod yield per plant were recorded based on five randomly selected plants. Germination percentage and seedling vigour index were calculated by taking count of germinated seeds in a petridish and through measurement of length of seedling in petriplates after 10 days.

Analysis of variance revealed significant differences for all characters indicating the presence of considerable amount of variability among the cultivars except for number of primary branches per plant, number of mature pods per plant and number of immature pods per plant. Tirupati-4 showed high mean performance for pod yield per plant and number of mature pods per plant. The cultivars, TG-39, Abhaya and R-2001-2 exhibited high mean performance for yield components viz., 100-seed weight, shelling percentage and harvest index respectively. The cultivar, JL-24 recorded high mean LAD and LAI. Tirupati-4 exhibited high mean CGR. The cultivar, Kalahasti showed high SLA and NAR. While TCGS-750 and K-4 exhibited maximum mean SCMR and seedling vigour index respectively. Low SLA was recorded by JL-501, TCGS-888 and TCGS-750 which is desirable as it confers high water use efficiency.

A perusal of genetic parameters revealed that GCV, PCV, heritability (broad sense) and genetic advance as per cent of mean were high for length of primary branches, length of main axis, days to emergence, weight of immature pods per plant, number of fully expanded leaves, 100-seed weight, harvest index and pod yield per plant demonstrating sufficient variability for selection to act upon. Hence, these traits could be improved by simple phenotypic selection. Among the physiological characters, LAD, CGR, LAI, NAR, SLA at 72 DAS, seedling vigour index and harvest index showed higher to moderate GCV, PCV, high heritability coupled with high genetic advance as per cent of mean. Thus it can be inferred that these characters are amenable for simple phenotypic selection as there is wide variability for these traits among the cultivars involved in the study.

Genetic divergence studies were carried out based on data of morphological, yield and yield attributes and physiological characters using Mahalanobis's D^2 statistic and genetic diversity at molecular level was estimated using RAPD markers. Through D^2 analysis, 29 cultivars were grouped into 9 clusters based on data of morphological, yield and yield attributes and 8 clusters based on physiological attributes and yield respectively. Among morphological characters, harvest index, days to emergence and length of main axis contributed maximum towards genetic divergence. Heritability and genetic advance as % of mean were also found to be high for these trait in the present study. The cultivars,

Tirupati-4, TCGS-888, TCGS-913 and R-2001-2 (cluster V), Prasuna (cluster VI) and Narayani (cluster VIII) were found to be promising and crosses among these cultivars would produce desirable recombinants in segregating generations. Canonical analysis also confirmed the clustering pattern obtained by D^2 analysis. Among physiological characters, leaf area duration, leaf area index, crop growth rate and net assimilation rate were found to be contributing more to divergence and hybridization among cultivars, K-134, Tirupati-4 (cluster VI), TCGS-717 (cluster V), JL-24 (cluster IV) and TCGS-645 (cluster VII) would yield good segregants for yield with improvement in the physiological attributes.

Assessment of molecular diversity using RAPD markers revealed that there was a high level of genetic variation among 12 groundnut cultivars selected. Seven primers selected out of 60 primers screened produced a total of 58 bands among which 48 were polymorphic (87.750%). The primers, OPJ-6 (11 bands), OPA-3 and OPH-7 (10 bands) were found to be highly polymorphic. The similarity co-efficient values ranged from 32.6% to 92.9% indicating a wide range of genetic diversity among the groundnut cultivars. The dendrogram of 12 cultivars consisted of 6 groups having 3 cultivars each in group I (Narayani, Kalahasti and TCGS-653), II (TCGS-913, TG-47 and TCGS-750) and III (Prasuna, Abhaya and TCGS-888) respectively and group IV (TCGS-645), V (Tirupati-3) and VI (Tirupati-4) consisted of

single cultivar each. Mahalanobis's D^2 statistic and RAPD analysis revealed that the cultivars, Tirupati-4, TCGS-645, Prasuna and Narayani were more divergent in the set of 29 released and pre-release cultures.

The 12 cultivars showed different banding pattern with seven primers used. The cultivars, Tirupati-4 (300 bp) and TCGS-888 (200 bp) showed unique bands with primer OPA-3. The cultivars, Tiruapti-3 (400 bp), TG-47 (75-100 bp) and TCGS-913 (75-100 bp) produced unique bands with OPA-19 primer. With primer OPJ-6 the cultivars, Kalahasti (7000 bp) and TCGS-750 (500 bp) produced unique bands which can be used as markers to identify these cultivars.

The clustering pattern was different in different methods used. Cultivars with dissimilar pedigrees were grouped into the same cluster while cultivars with same pedigrees were farther apart. Likewise, certain genotypes were grouped together in either of ways *i.e.* grouping through morphological/RAPD data or physiological/RAPD data or morphological/physiological data. Narayani and Kalahasti were grouped in one cluster, while TCGS-913 and TCGS-750 were also grouped in one cluster when grouping of cultivars was done in both ways *i.e.* based on physiological characters influencing pod yield and RAPD analysis. Similarly Kalahasti and TCGS-653 appeared together in one cluster, while Tirupati-3 alone formed a separate cluster when grouping was carried out based on morphological, yield and yield attributes and RAPD based analysis. Some of the cultivars *i.e.* TIR-9, TCGS-91, Abhaya and

JL-501 formed a cluster when grouping was done based on morphological, yield and yield attributes data and based on physiological attributes influencing yield.

Character association studies of morphological, yield and yield attributes indicated that number of primary branches per plant, number of mature pods per plant and 100-seed weight had positive significant association with pod yield per plant. Among physiological characters, LAD, LAI, CGR, SLA and harvest index showed positive association with pod yield per plant. Hence, these characters could be considered in formulating selection criteria in breeding programme aimed at improvement of yield in groundnut.

Path co-efficient analysis indicated that number of mature pods per plant, number of primary branches per plant, 100-seed weight, LAD, CGR, LAI at 36, 72 DAS, germination percentage and SLA at 72 DAS exhibited high positive direct effects on pod yield per plant and also showed positive association with pod yield per plant. Thus, in a selection programme aimed at improvement of pod yield, due emphasis should be given for these traits.

Future line of work

From divergence studies, it has become very clear that a lot of variation exists among released and pre-release varieties of groundnut. In the present global context, it is essential to develop DNA finger prints,

for each released and pre-release groundnut cultures. Preliminary information generated through use of RAPD markers would pave the way for detailed molecular characterization through use of SSR and AFLP markers.

With the available variation, it is possible to produce different plant types suitable for different situations through hybridization involving genotypes for divergent clusters.

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