

**GENETIC ANALYSIS OF PHYSIOLOGICAL AND YIELD
ATTRIBUTES RELATED TO DROUGHT TOLERANCE
IN GROUNDNUT (*Arachis hypogaea* L.)**

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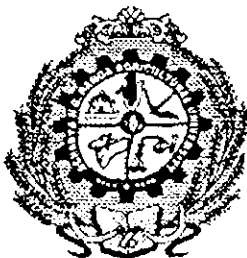
By

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M.Sc.(Ag)

THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY
(IN THE FACULTY OF AGRICULTURE)



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This is to certify that the thesis entitled "GENETIC ANALYSIS OF PHYSIOLOGICAL AND YIELD ATTRIBUTES RELATED TO DROUGHT TOLERANCE IN GROUNDNUT (*Arachis hypogaea* L.)" submitted in partial fulfillment of the requirements for the degree of "DOCTOR OF PHILOSOPHY IN AGRICULTURE" of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by Mr. O. Venkateswarlu under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

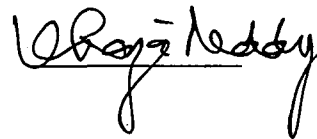
No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of investigations have been duly acknowledged by the author of the thesis.


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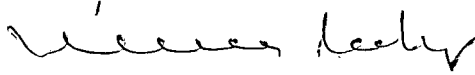
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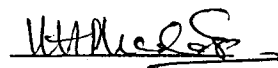
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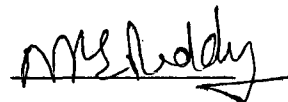
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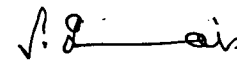
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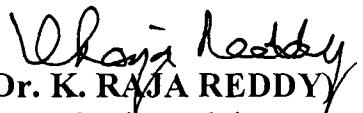
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Date: 11-7-05


(Dr. K. RAJA REDDY)
Major Advisor

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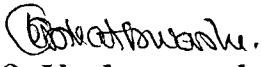
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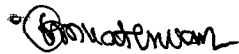
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DECLARATION

I, Mr. **O. Venkateswarlu** hereby declare that the thesis entitled
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ATTRIBUTES RELATED TO DROUGHT TOLERANCE IN
GROUNDNUT (*Arachis hypogaea* L.)”** submitted to Acharya N.G. Ranga
Agricultural University for the Degree of **DOCTOR OF PHILOSOPHY** in
Agriculture is a result of original research work done by me. I also declare
that the thesis or any part thereof has not been published earlier in any manner.

Date : 28-2-2004
□


(**O. VENKATESWARLU**)

LIST OF ABBREVIATIONS

%	:	per cent
BP	:	Better parent
cm	:	centi meter
df	:	Degrees of freedom
et al.	:	and others
Fv / Fm	:	Variable fluorescence / Maximum fluorescence
g	:	gram
GA	:	Genetic advance
GCV	:	Genotypic correlation coefficient
ha	:	Hectare
HI	:	Harvest index
MP	:	Mid parent
No.	:	Number
PCV	:	Phenotypic correlation coefficient
r_g	:	Genotypic correlation coefficient
r_p	:	Phenotypic correlation coefficient
SEd	:	Standard Error of difference
SLA	:	Specific leaf area
SLN	:	Specific leaf nitrogen
viz.,	:	Namely

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ABSTRACT

A study comprising 28 crosses derived from 8 x 8 diallel without reciprocals was carried out at the Regional Agricultural Research Station, Tirupati during *rabi* 2002 and *kharif* 2003 seasons. The data recorded on thirteen characters influencing yield and drought tolerance were subjected to combining ability, heterosis, genetic parameters, character associations and path co-efficient analysis.

Considering *per se* performance among parents, JUG-37 recorded as the maximum pod yield per plant, kernel yield per plant and oil per cent in *rabi* while in *kharif* K-134 recorded high *per se* performance for specific leaf nitrogen, oil per cent, harvest index and kernel yield per plant. Among F₁s,

K-134 x JUG-43 and K-134 x JL-24 during *rabi* and TIR-46 x JAL-6 during *kharif* recorded the highest mean values for number of well filled and mature pods per plant, kernel yield per plant and shelling per cent. Among the F_2 s, JUG-37 x JAL-6 has recorded the highest *per se* performance for specific leaf nitrogen and harvest index. Other F_2 s, which exhibited the highest *per se* performance are, TIR-46 x K-134 for shell thickness and shelling per cent, TIR-46 x JAL-6 for SPAD chlorophyll meter reading and per cent reduction of Fv/Fm, TIR-46 x TIR-10 for kernel yield per plant and JUG-37 x ICR-45 for both number of well filled and mature pods per plant and pod yield per plant.

Combining ability analysis indicated predominance of additive gene action for oil per cent and pod yield, non-additive gene action for specific leaf nitrogen, specific leaf area, harvest index, root length, sound mature kernel per cent and number of well filled and mature pods per plant and both additive and non-additive gene actions for per cent reduction of Fv/Fm (variable florescence / maximum florescence), soil plant analysis development (SPAD) chlorophyll meter reading and shell thickness

The parental genotypes, JUG-37, TIR-46 and JUG-43 during *rabi*, TIR-46, JUG-37 and JL-24 during *kharif* emerged as the best general combiners for most of the characters studied. Based on *sca* effects, F_1 s, K-134 x JUG-43 and K-134 x JL-24 in *rabi* and JUG-37 x ICR-45, JUG-37 x JL-24

and JUG-43 x JL-24 in *kharif* were found promising for pod yield and other physiological characters.

The highest magnitude of heterosis was observed for kernel yield per plant and pod yield per plant. The best heterotic crosses identified were K-134 x JUG-43 and K-134 x JL-24 for pod yield per plant, harvest index, number of well filled and mature pods per plant and kernel yield per plant in *rabi*. However during *kharif*, TIR-46 x JAL-6 exhibited highest heterosis for kernel yield per plant, pod yield per plant, specific leaf nitrogen, specific leaf area, per cent reduction of Fv/Fm and number of well filled and mature pods per plant

High heritability coupled with high genetic advance as per cent of mean were recorded for SLA, per cent reduction of Fv/Fm, shell thickness and SMK per cent indicating that these traits could be improved by simple selection methods.

Consistent and highly significant positive association of harvest index, number of well filled and mature pods per plant and kernel yield per plant with pod yield per plant in parents and crosses indicated that they could be used as selection criteria for higher pod yields.

Path coefficient analysis revealed positive direct effect of kernel yield per plant in parents and crosses and per cent reduction of Fv/Fm only in parents during both seasons; oil per cent in parents during *kharif*; shelling per cent and SMK per cent in parents during *kharif* and number of well filled and mature pods per plant in crosses during *kharif* and *rabi* on pod yield indicating that these characters should be given greater emphasis while making selections for higher pod yield.

Chapter - I

Introduction

CHAPTER - I

1

INTRODUCTION

Groundnut is the premier oilseed crop of India, which ranks first in area (8.2 m ha) and second in production (6.2 m t) after China with an area of 4.63 million hectares and production of 14.5 million tons. (FAO, 2001). In Andhra Pradesh it is being grown in an area of 18.6 lakh hectares with an annual production of 22.2 lakh tons. Though Andhra Pradesh ranks second in groundnut area in the country, its productivity is very low (555-1100 kg/ha). Due to continuous drought during 1997, 1999 and 2002 the groundnut area had declined from 22.2 lakh hectares (1995) to 18.6 lakh hectares (2002-03). The production also had declined from 26.2 lakh tons (1995) to 20.3 lakh tons (2002-03) due to drought (Jeevananda Reddy, 2002). Further more than 80 % of groundnut area in India and Andhra Pradesh is under rainfed conditions.

Drought is the single most factor limiting productivity under rainfed conditions. High temperatures associated with drought also affect many physiological processes in plant resulting poor yield. Further, heat tolerance will be necessary if the frequency of hot weather increases in the future because of global climatic change (Schneider, 1989), coupled with increase in CO₂ concentration. During *rabi* season, especially in the late sown crop, January and February, yield gets reduced due to high temperature in March and April months during flowering and pod development stages. Further, the variety must be acceptable to the producer, the processor and the consumer.

Groundnut has naturally evolved a number of mechanisms to avoid drought effects. But most of these adaptations are mainly concerned with survival of plants under water stress. However, from agronomic point of view, any drought tolerance mechanism would be relevant only when it is associated with higher yielding ability. Plant breeders and crop physiologists now believe that more rapid progress can be aided by a prior knowledge of the physiological basis of crop performance under drought conditions. Therefore identification of physiological traits contributing to superior performance of plants under drought and high temperature conditions and incorporating them into a well adopted variety has been a long term goal of groundnut scientists.

Passioura (1977) developed a useful frame work for examining crop yield performance under water limited conditions and this has been successfully used to analyse yield variation due to water stress in many crops (Wright *et al.*, 1988). Pod yield = water transpired (T) x WUE (W) x HI). Obviously, if any component of the yield equation can be improved without adversely affecting another component, then an increase in pod yield would result. Water Use Efficiency (WUE) is thus an important trait, which can contribute to productivity when water resources are scarce.

However, there are many practical problems in measuring WUE (carbon isotope discrimination) in both field and laboratory. Hand-held portable SPAD chlorophyll meter can be used effectively for rapid assessment of specific leaf area and specific leaf nitrogen, as surrogate measurement of water use efficiency in groundnut (Rao *et al.*, 2001). This would facilitate

screening of large number of segregating populations in the field with ease.

There are, however a few studies on application of these physiological attributes in the selection to improve the efficiency of selection of superior genotypes in large scale breeding programme. Therefore, the potential value of specific trait will be greatly enhanced if information is generated on their genetic architecture with the help of appropriate genetic analysis. Biometrical techniques such as diallel cross analysis provides a systematic approach to the detection of parents and crosses superior for traits under investigation. At the same time they help the plant breeder to choose the most appropriate selection technique by allowing the estimates of the magnitude and relative importance of various genetic parameters. Since commercial production of F_1 seed is not feasible, heterosis in groundnut is deemed unusable. Nevertheless, the yield data of F_1 hybrids and other early generation materials enables the breeder to give priority to the most deserving crosses.

There are very few published reports on genetic control of these physiological traits. Jayalakshmi *et al.* (1999) and Nigam *et al.* (2001) reported predominance of additive gene effects for SLA and HI in groundnut and suggested that effective selection for these characters could be practiced in the early generations of crosses.

Wright *et al.* (1993) observed a moderate strength of negative correlation between SLA and HI, suggesting that concurrent improvement in these traits may be difficult, but should be possible. A positive correlation between SCMR and SLN and negative correlation between SCMR and SLA in

groundnut was also reported by Crucickshank *et al.* (2003). For any trait to be successfully exploited in breeding programme, a sufficient genetic variability in that trait must exist. Genetic variation for WUE traits in peanut was reported by Hubick *et al.* (1986) and Shashidhar *et al.* (2002).

Keeping these in view in the present investigation 28 crosses of a 8 parent diallel of groundnut in F₁ and F₂ generations were subjected to genetic analyses with the following specific research objectives.

1. To study the nature of gene action of physiological traits and yield attributes in the F₁ generation.
2. To study combining ability of parents and crosses in F₁ generation for physiological traits, yield and yield attributes.
3. To estimate heterosis and inbreeding depression in F₁ and F₂ generations, respectively for physiological traits and yield attributes.
4. To elicit information on the extent of genetic variability, heritability and genetic advance for physiological traits and yield attributes in F₂ generations.
5. To work out interrelationships among various physiological traits and yield attributes influencing yield in parents, F₁ and F₂ generations.
6. To study the direct and indirect effects of physiological traits, yield attributes on yield in parents, F₁ and F₂ generations.

Chapter -II

Review of Literature

REVIEW OF LITERATURE

A brief resume of relevant literature is presented below under the following heads.

1. **Combining ability**
2. **Heterosis**
3. **Variability, heritability and genetic advance**
4. **Character Association**
5. **Path Coefficient analysis.**

Productivity of a crop species is the sum total effect of many biochemical, physiological, genetical and morphological traits of the plant. Donald (1968) suggested breeding for yield improvement in a particular type of environment by selection for physiological and morphological traits thought to be conducive to high yield in that environment. Duncan *et al.* (1978) and Wells *et al.* (1991) evaluated physiological changes which resulted in higher yields in groundnut cultivars released in USA. Nageswara Rao (1992) analysed groundnut production in terms of physiological traits like WUE, photosynthesis and stated that very little progress has been made in identification and exploitation of genetic and physiological traits contributing to yield potential and adaptation. Too often traits are advocated based on theory and there are few attempts to study

genetic variability and even fewer to establish their genetic control and heritability, variability, and genetic advance as per cent of mean.

The information on the nature and magnitude of gene action for different quantitative and qualitative traits in any crop species plays a vital role while formulating the efficient breeding programmes. Superior genotypes can be isolated by selection if considerable genetic variation exists within the population. Besides genetic variability, heritability and genetic advance also play vital role in the improvement of any character.

The progress in breeding for the economic traits, which are mostly polygenically controlled and environmentally influenced, is determined by the nature and magnitude of their genotypic variability. Hence, it is essential to partition the overall variability into heritable and non-heritable components with the help of genetic parameters like GCV and PCV, heritability and genetic advance. The magnitude of heritability on one hand and nature and extent of variability on the other hand give an idea for effective genetic improvement through selection.

Before actually reviewing the literature on genetic aspects an elaborate review on morphological traits, physiological and yield attributes related to drought is presented hereunder.

Morphological traits, physiological and yield attributes related to drought

Moisture stress is an important environmental variable influencing plant growth and yield (Hsiao and Bradford 1983). It affects many aspects of plant growth by modifying their anatomy, morphology, physiology and biochemistry. The prominent effects on crop plants are reduction in plant growth and changes in various physiological processes. Moisture stress can also adversely influence yield attributes like number of mature pods per plant, 100-pod weight, 100-kernel weight, shelling per cent and harvest index.

Earlier, many workers have studied the effects of water stress on groundnut genotypes at different growth stages (Nageswara Rao *et al.*, 1985; Parmar *et al.*, 1989)..Balasubramanian and Yayock (1981) reported that moisture stress at 9 to 13 weeks after sowing, coinciding with the period of peg and pod development lowered nitrogen uptake and increased the proportion of unfilled pods. Ramesh Babu *et al.* (1984) reported that in groundnut moisture stress during early pod development phase (55 to 67 DAS) affected maximal loss (34.7 per cent) in biomass accumulation and shelling percent while peak flowering and pegging (36 to 48 DAS) was the least affected phenophase. Pandey *et al.* (1984) reported that water stress affected seed formation more than the total dry matter yield and hence

harvest index declined. Venkateswara Rao et al. (1986) reported that moisture stress reduced harvest index in groundnut.

Gowda and Hegde (1986) reported that there was no significant decrease in 100-pod weight and 100-kernel weight of stressed groundnut crop from the normal irrigated crop. Srinivasan and Arjunan (1987) reported that mid season water stress especially at pod formation to maturity stage caused yield reduction to a greater extent when compared to earlier drought during growth period of the bunch groundnut cultivars. Crop water deficits occurring during early crop growth period reduced pod yields in all cultivars by 17 to 25 per cent relative to the fully irrigated treatment. Stem length and Stem dry weight of groundnut plants decreased markedly due to drought and the decrease was entirely dependent upon the availability of soil water to the plants (Orcutt and Hopkins, 1988). Patel and Golakiya (1988) reported that water stress at pegging to pod development reduced number of matured pods per plant.

Ravindra *et al.* (1990) observed that water stress during flowering and pod development in groundnut was highly detrimental to leaf area development compared with stress during the vegetative phase. Samsukumar *et al.* (1991) reported that moisture stress at flowering, pod formation and pod maturation stages in groundnut reduced the 100-kernel weight. Wright and Rao (1992) noted that cultivars with vigorous early growth, a relatively large biomass accumulation and capacity for

remobilizing stored assimilates to reproductive sinks may be better adapted to drought stress. Babitha, (1996) observed decreases in leaf dry weight, total dry weight, leaf area and pod yield (26 %) under simulated drought conditions compared to adequately irrigated conditions in Groundnut. Suvarna *et al.* (2002) while studying effect of both mid season and end of season drought on groundnut, observed significant reduction in number of mature pods, pod yield, 100-kernel weight, harvest index, sound mature kernel percent and oil percent indicating that these are most sensitive stages for drought in groundnut.

Water use efficiency(WUE)

Crop physiologists in recent years have identifying physiological traits contributing to superior performance under drought conditions. These include harvest index (HI) (Nageswara Rao *et al.*, 1993), total amount of water transpired (T) and transpiration efficiency (TE) or water use efficiency (WUE) (Wright *et al.*, 1994).

WUE is the ratio of the total drymatter produced per unit of water transpired. Variation in WUE among genotypes of same species was first documented by Briggs and Shantz (1913) and the possibility of using this as a selection trait in breeding for drought tolerant genotypes has been reported by Tanner and Sinclair (1983). Recent studies have confirmed that substantial genotypic variation for WUE exists in groundnut (Hubick *et al.*, 1986). Wright *et al.* (1988) showed that the genotypic variability for

WUE in groundnut ranged from 2.15 to 3.71 g of dry matter per kg of water used. Hebbar (1990) reported a variation from 1.57 to 2.66 g drymatter per kg of water. Wright *et al.* (1993) reported a genotypic variation from 1.8 to 3.7g of dry matter production per kg of water used. Genotypic differences in WUE of 4 peanut genotypes ranged from 1.81 to 3.05 g kg⁻¹ under intermittent water deficit and from 2.07 to 3.15 g kg⁻¹ under continuous water deficit. These studies suggest the possibility of using this trait in breeding for drought resistance.

Selection for higher WUE often resulted in decrease in crop growth rates and this was perhaps the most significant setback for further improvement in this trait. This lack of success arises primarily due to strong inter-dependency between transpiration and WUE. Therefore it is essential to identify types where this interdependency is lower. According to Udayakumar *et al.* (1998a), two important physiological traits that determine the variability in WUE are photosynthetic rate and transpiration rate. Photosynthetic rate is regulated by intrinsic mesophyll efficiency and the CO₂ diffusive process associated with stomata. Transpiration rate is predominantly controlled by differences in mesophyll efficiency. They stated that in crops like groundnut (capacity type) WUE is independent of total transpiration and selection for WUE is likely to result in higher total drymatter production.

Water use efficiency is known to increase with decrease in the quantity of water applied without substantial decrease in yield (Hammond and Boote, 1981). Nimitr Vorasoot *et al.* (1988) found WUE to be higher in groundnuts that received lower water regimes at longer irrigation intervals (14 days). Rosario and Fajardo (1988) reported that WUE decreased under water stress in all cultivars of groundnut.

Genotypes with greater decrease in stomatal conductance and a minimum change in assimilation rate always show a greater increase in WUE under stress (Hebbar, 1990). Significant positive relation between WUE values obtained in control and stress treatments was also reported by many workers indicating that the G X E is very low for this trait (Wright *et al.*, 1992). Even though WUE was high under stress, the genotypic ranking has been shown to remain constant under non stress and stress conditions (Udayakumar *et al.*, 1998a).

Hebbar *et al.* (1994) showed that more than 92 per cent of the variation in dry matter accumulation was accounted for by the variation in WUE. WUE varied significantly between genotypes and there was a positive correlation between WUE and the quantity of dry matter produced by the genotypes. Babitha and Reddy (2001) reported that total drymatter produced per plant had positive correlation with WUE in simulated drought ($r = 0.31$, $P < 0.05$) and rain fed treatments ($r = 0.42$, $P < 0.05$) and water use efficient genotypes were high TDM producers with poor harvest index.

Amongst several leaf characters, leaf thickness (associated with structural components and non-structural components) and chlorophyll content determines the leaf transmittance characters. Leaf nitrogen normally influences the leaf chlorophyll content. A device has been developed by Minolta company which measures the light attenuation at 430 nm (the peak wave length for Chl a and Chl b) at 750nm near infrared with no transmission. The unit less value measured by the SCMR which provides information on the relative amount of leaf chlorophyll.

SCMR is an indication of leaf nitrogen status. Since SLN (specific leaf nitrogen) determines the differences in WUE, it can be visualized that SCMR could reflect well the differences in WUE. Nageswara Rao *et al.* (2001) have shown a significant relationship between SCMR and SLA and suggested that SCMR could be used as a rapid, low-cost, non-destructive technique to screen large breeding populations for SLA or SLN. A significant positive correlation between SCMR and WUE in groundnut has provided an option to use SCMR as yet another potential technique to quantify variations in WUE in groundnut (Sheshshayee *et al.*, 2002). A significant positive relationship between WUE and SCMR ($r = 0.84$) was observed by Bindu Madhava *et al.* (2002) on six selected peanut genotypes suggesting that a quick determination of SLN through SCMR could reflect

intrinsic mesophyll efficiency and hence effectively estimate WUE in groundnut. Although several studies have shown that SLA can be used as a surrogate for Δ , (Nageswara Rao and Wright, 1994; Wright *et al.*, 1994) measurement of SLA requires accurate measurement of leaf area and dry weight. Measurement of SLA in large segregating populations is also time consuming and involves destructive sampling. Hence SPAD Chlorophyll meter reading is being suggested in place of SLA for rapid screening of large germplasm collections or segregating populations (ACIAR CS 97/114-project document).

Specific leaf nitrogen (SLN)

In groundnut, variation in WUE is primarily controlled by differences in chloroplast efficiency associated with chlorophyll and Rubisco contents that constitute the major pool of nitrogen in the plant. Photosynthetic enzymes account for upto 75 per cent of the total nitrogen invested in leaves of C_3 plants (Chapin *et al.*, 1987). Nageswara Rao and Wright (1994) reported that SLA was negatively correlated with nitrogen content per unit leaf area (SLN) which in turn was negatively correlated with Δ . In a study with six selected groundnut genotypes Nageswara Rao *et al.* (1995) demonstrated the relationship between delta and Rubisco content. The positive relationship observed between leaf nitrogen content and WUE under adequately irrigated and simulated drought treatments can

be explained via the relationship of leaf nitrogen content with the amount of Rubisco which accounts for 50 per cent of the soluble protein (Babitha, 1996). Since Rubisco level has a direct association with leaf nitrogen status, it is likely that SLN and photosynthetic efficiency are strongly related (Nageswara Rao *et al.*, 2001). Therefore in groundnut (capacity type), the leaf nitrogen status determines the differences in WUE. A genotype with high Rubisco content and SLN may have high WUE. Hence, SLN can also serve as a useful surrogate for WUE. Results of Bindu Madhava *et al.* (2002) revealed that strong association between SLN and TE in peanut can be largely attributed to the dependence of TE on intrinsic mesophyll efficiency.

Specific Leaf Area (SLA)

SLA is one of the physiological traits in plant growth analysis. Specific leaf area is the ratio of leaf area to leaf dry weight. SLA is often considered as an indirect measure of leaf expansion. Higher SLA means higher leaf area per unit biomass and a larger surface area for transpiration. On the other hand, if SLA is higher, the leaf thickness would be less and hence the capacity of photosynthesis would be smaller. Since transpiration and photosynthetic capacity determine the variability in TE, an inverse relationship between SLA and WUE is normally observed (Wright *et al.*, 1994). Wright *et al.* (1993) in a mini lysimeter study with four peanut

cultivars, observed that specific leaf area which is negatively related to leaf thickness is closely and negatively correlated with WUE, and SLA and Δ are positively related. Roystephen (1995) studied 21 selected groundnut genotypes which were raised in three moisture regimes viz., rainfed, irrigated and moisture stress condition. He observed that SLA was lower in moisture stress condition compared to irrigated condition in pot culture studies. The relationship of SLA with WUE was negative and significant, Whereas Δ was positively related to SLA in both field and pot culture experiments.

Nageswara Rao and Wright (1994) studied four peanut genotypes in the field either under adequately irrigated or rainfed conditions at two locations in Queensland, Australia. SLA was negatively correlated with nitrogen content per unit leaf area (SLN) Craufurd *et al.* (1999) concluded that there was a significant variation within and between botanical types in WUE, with Virginia botanical types having a higher WUE. SLA was correlated with measured WUE. Hence SLA is a good indirect selection criterion for Δ and WUE when identifying genotypes of groundnut well adapted to the semi-arid tropics. SLA had significant inverse relationship with SPAD Chlorophyll meter reading (SCMR) and total chlorophyll content (Project report, UAS-B, 1996). Bindumadhava *et al.* (2002) provided evidence that the relationship between TE and SLA is

predominantly due to a strong association between SLA and SLN. He further stated that a strong inverse relationship between SLA and SLN meant that SLN might be the cause of linkage between SCMR and SLA in peanut. SLA could therefore be used as a rapid and inexpensive selection index for high WUE in peanut as Δ requires expensive mass spectrometer facilities. Ramana Rao (1994) and Babitha (1996) observed that SLA was higher under adequately irrigated treatment compared to simulated drought conditions. SLA also had a significant negative relationship with total dry matter production under adequately irrigated and simulated drought conditions in their studies. Some workers reported that SLA had significant positive relationship with pod yield (Asalatha *et al.*, 1999). SLA was negatively related to WUE and was positively related to harvest index, suggesting that selection for low SLA might result in the production of more dry matter with minimal influence on pod weight (Wright *et al.*, 1993).

2.1 COMBINING ABILITY

Knowledge of the genetic system controlling quantitative characters is essential for the choice of the most effective and efficient selection and breeding procedure. In self-pollinated species, simple genetic models utilizing two factor-mating designs have been used rather extensively to estimate additive and dominance variances on the assumption of negligible

epistasis. Genetic models, which can detect and estimate the magnitude of epistatic variation in addition to the additive and dominance variations are also available. Although, their use has been rather limited in self pollinated species, there is evidence which indicated statistically significant variation attributable to epistatic effects of several economic characters (Stuber and Moll, 1971). Such studies in groundnut are rather limited, it is, therefore, necessary to evaluate the importance of epistasis, in particular the fixable additive by additive type interaction component utilizing varied genetic materials as well as genetic models.

The combining ability analysis gives useful information regarding the nature and magnitude of gene action involved in the expression of quantitative traits (Dhillon, 1975) which helps in selecting appropriate breeding method for crop improvement.

The review of literature on gene action governing the inheritance of yields and yield component traits is summarized and presented below.

Gregory (1945) crossed 10 divergent lines of peanuts and studied combining ability in F_1 generation. He found highly significant *gca* which was several times greater in magnitude than *sca* for yield and fruit characteristics.

Wynne *et al* (1970) in a 6 x 6 diallel studied combining ability for 17 characters. Estimates of *sca* were significant for 16 and estimates of *gca* were significant for 8 characters. Estimates of *sca* were greater for

yield and most of the fruit characters. Contrary to this Raman and Sree Rangaswamy (1970) observed that pod yield was largely controlled by additive gene action.

Garet (1976) reported predominant significant *gca* variance for number of mature pods per plant, kernel yield per plant and oil per cent, thereby indicating the importance of additive gene action in the control of all the above characters. He also reported predominance of non-additive gene action for shelling out turn.

Ramakrishnam Raju *et al.* (1979) in 5 parental diallel studies reported that *sca* variance was greater than *gca* in magnitude for yield and number of mature pods in crosses involving parents having high and low *gca*, indicating preponderance of non-additive gene action in the inheritance of these characters.

Singh and Labana (1980) reported the importance of non-additive gene action in the inheritance of kernel yield per plant.

Layrisse *et al* (1980) observed additive gene action for oil per cent, pod yield and protein content in F_2 generation of diallel set of crosses involving 10 lines. Similarly Sridharan and Marappan (1980) also reported additive gene action for pod yield. They further stated that good general combiners were not always found to be the best specific combiners.

Hamid *et al.* (1981) reported that *sca* effects were significant and found to be more important than *gca* effects for shelling percentage and

gca effects were found to be more pronounced than *sca* effects for the pod yield and kernel yield per plant. Significant of both general combining ability and specific combining ability effects were found predominant for percentage of oil content.

Labana *et al.* (1981) in their combining ability studies observed that the estimates of variance due to specific combining ability was greater in magnitude than that of general combining ability for number of pods and pod yield, whereas the reverse is the case for kernel yield per plant.

An analysis of combining ability by Mohinder Singh (1983) using 12 parents and 35 F_1 s studies indicated that both additive and non-additive gene actions were important for pod yield, kernel yield per plant and shelling per cent. Further, out of thirty five crosses with high *sca* effects for pod yield, fifteen crosses showed high specific combining ability effects that involved good x good general combiners.

Khanovkar *et al* (1984) analysed the data for combining ability in groundnut and observed additive type of gene action in the inheritance of number of pods per plant.

Vijayabhaskara Reddy (1984) observed that lines with high x low or low x high *gca* resulted in best specific combinations. Many crosses had significant *sca* for several attributes which included pod and kernel yield per plant. Non-additive gene action was found to be predominant for number of mature pods, pod yield, kernel yield and shelling percentage.

An analysis of combining ability by Habib *et al.* (1985) in 12 x 12 parent diallel analysis studies indicated that both additive and non-additive gene actions were important for pod yield while additive gene action was important for number of developed and undeveloped pods per plant. Further out of five crosses with high sca effects for pod yield four crosses involved good x good general combiners and one crosses good x poor general combiner, indicating the presence of epistasis- additive x additive and additive x dominance.

Manoharan *et al.* (1985) in a combining ability analysis reported additive gene action for shelling per cent and pod yield suggesting that improvement in these characters could be achieved through pedigree breeding. He also reported non-additive type of gene action for number of pods per plant. The crosses which have high specific combining ability effects either high x low or low x low combinations.

Basu *et al.* (1987) in a 8 x 8 diallel analysis for combining ability in groundnut revealed that *gca* variance was higher than the estimated sca variance for traits like number of mature pods per plant, pod yield per plant and shelling per cent, indicating the predominant role of additive gene action for the these traits. Further the parental performance as such and their *gca* effects showed a very good relationship of the two parents involved (GUAG 1 and Chico) in a higher specific combination for number

of pods per plant and shelling per cent, either both or one of them were also best combinations.

Nava and Layrisse (1987) in combining ability studies in groundnut observed that additive type of gene action was predominant for pod yield per plant, kernel yield per plant and shelling per cent. Basu *et al* (1986) also reported additive gene action for pod yield per plant.

Jagannadha Reddy and Raja Reddy (1987) reported predominance of both additive and non-additive gene actions for shelling per cent, kernel yield per plant, number of mature pods per plant and pod yield per plant. Similar studies of Sandhu and Khehra (1976) showed importance of non-additive gene action for pod yield per plant and number of mature pods per plant.

Makne and Bhale (1987) in a 10 x 10 diallel combining ability analysis in groundnut showed predominant role of additive gene action in the inheritance of pod yield per plant and non-additive gene action in the inheritance of oil per cent. The *per se* performance of parents was closely associated with their *gca* effects. The crosses with largest *sca* effects for pod yield were high x low and low x high general combiners and the *sca* effects for oil content were generally low in magnitude.

Nadaf *et al.* (1988) in their studies observed that *gca* estimates were 3 to 4 times greater in magnitude than *sca* effects for pod yield per plant, number of mature pods per plant and sound mature kernel per cent. They

also observed that estimates of *sca* effects were higher than *gca* for shelling per cent.

Reddy and Reddy (1988) studied combining ability in a half diallel cross involving five parental lines belonging to Spanish and Valencia botanical types and found that both *gca* and *sca* variances were significant for number of mature pods per plant and shelling per cent, while non-significant for pod yield per plant. The *gca* variance was greater in magnitude than *sca* variance for 100-kernel weight.

Dwivedi *et al.* (1989) in a 8 x 8 full diallel cross reported that fruit and seed traits and harvest index were controlled largely by additive genetic effects, whereas pods per plant and pod weight per plant by non-additive genetic effects. They also stated that in case of shelling percentage both were equally important.

Makne and Bhale (1989) analysed the data for combining ability in groundnut and observed importance of both additive and non-additive gene action in the inheritance of pod yield per plant. They also reported a good relationship between *per se* performance and *gca* effects of the parents for all the characters studied.

Reddi *et al.* (1989) in 6x6 diallel set of groundnut reported that non-additive gene action was important in the expression of pod yield per plant while additive gene action in the expression of shelling percentage.

Seshadri (1990) analysed the data for combining ability in groundnut and observed importance of both additive and non-additive gene action in the inheritance of number of pods per plant in groundnut.

Makne (1992) studied 55 F_1 s involving 10 diverse genotypes from different sub-species of groundnut. Variance due to *gca* and *sca* was significant for the characters number of developed pods per plant and harvest index indicating the importance of both additive and non-additive gene action in the inheritance of these characters.

Upadhyaya *et al.*, (1992) analysed the data for combining ability in groundnut and observed non-additive gene action for kernel yield per plant. Similarly Sateera Banu (1992) also observed the predominance of non-additive gene action for kernel yield per plant and pod yield per plant while additive gene action for number of mature pods per plant.

Bansal *et al.*, (1992) and Skyes and Michaels (1986 in combining ability studies in groundnut observed importance of additive gene action in the inheritance of oil per cent. Contrary to this Reddy and Murthy (1994) reported the importance of both additive and non-additive gene actions in the inheritance of oil per cent.

Suresh Kumar (1993) revealed the predominance of non-additive gene action in the inheritance of number of mature pods per plant, harvest index. Kernel and pod yields per plant. He also reported importance of both additive and non-additive gene actions for shelling percentage.

Varman and Raveendran (1994) in 22 F_1 s of 11 x 2 parents showed the predominance of non-additive gene action in the inheritance of number of pods and pod yield per plant. Both additive and non-additive gene action were found important in the inheritance of revealed for harvest index, shelling out turn and sound mature kernel per cent. They also observed that crosses involving either high x low or low x high specific combining ability effects showed heterosis and it may be due to non-additive gene interaction and might tend to unfixable.

Nisar Ahmed (1995) reported the importance of non-additive gene action for yield and yield component traits *viz.*, number of pods per plant, number of mature pods per plant and 100-kernel weight. In his studies, both additive and non-additive gene actions were found important in the control of harvest index, whereas additive gene action for shelling percentage.

Kalaimani and Thangavelu (1996) revealed the predominance of additive gene action in the inheritance of number of mature pods per plant, shelling per cent, and pod yields per plant in a study of 8 F_1 s for 13 quantitative characters.

Dwivedi *et al.* (1998) in their combining ability studies recorded significant *gca* effects for harvest index. Similarly Varman (1998) reported that variance due to *gca* was higher than *sca* indicating the predominance of additive gene action in the inheritance of pod weight.

Francies and Ramalingam (1999) revealed the predominance of non additive gene action for number of pegs, number of mature pods, pod yield and kernel yield and the role of both additive and non-additive gene action for oil per cent in 24 F_1 s of inter-specific crosses. It is evident that the crosses which exhibited desirable *sca* effects involved parents high and low *gca* effects indicating the influence of non-additive gene interactions in these crosses.

Mathur *et al.* (2000) studied gene action in crosses made by line x tester analysis fashion with four Virginia genotypes and reported the predominance of non-additive gene action in the inheritance of number and weight of mature pods and sound kernel.

Parmar *et al.* (2000) revealed the significance of both *gca* and *sca* variance for pod yield, shelling percentage and 100-kernel weight, whereas, Kuchanur *et al.* (1997) reported high *gca* variance than *sca* for shelling percentage and 100-seed weight.

Varman (2000) studied combining ability in 30 F_1 s for five traits and reported the predominance of *sca* variance than *gca* variance for number of mature pods, pod yield, shelling out turn and oil content whereas reverse is the true for kernel weight. He reported that seven out of 30 crosses had significant reciprocal effects for the pod yield per plant, thereby indicating the influence of maternal effects on these economic characters.

Nigam *et al.*, (2001) reported the importance of additive gene action in the inheritance of specific leaf area and harvest index in all the three crosses he studied.

Dasaradha Rami Reddy and Suneetha (2004) reported that higher specific combining ability variance than general combining ability variance for oil per cent and kernel yield per plant. They also observed higher *gca* variance for number of pods per plant, pod yield per plant and harvest index

2.2 HETEROSIS

Physical manifestation of the beneficial effects of hybridization between diverse parents is usually termed as heterosis and is referred as heterobeltiosis and relative heterosis based on F_1 superiority over better parent and mid parental value respectively. In plant breeding programmes, heterosis is referred to denote the expression of increased vigour of a hybrid over its better parent. Heterosis is a complex biological phenomenon often manifested in the superiority of a hybrid over parental forms according to the rate of development of one or more complex characters (Konarev, 1974). Practical exploitation of heterosis with phenomenal success has been undertaken in maize. With the realization of the possibility of producing F_1 hybrids on a large scale, increasing attention has been given to heterosis in self pollinated crops (Hayes and Foster, 1974).

The genetic causes involved in the expression of heterosis are dominance and non-allelic interactions (Hayes and Foster, 1976). A brief review of work done on the heterosis in groundnut is presented below.

Higgins (1940) obtained marked heterosis for vegetative traits and pod yield when crosses involving 16 cultivars in diallel fashion. Further individual plant yields were found to be highest for Spanish x Virginia crosses.

Hassan and Srivastava (1966) investigated heterosis in groundnut utilizing three cultivars differing in maturity as well as habit group and reported marked superiority of F_1 hybrid over better parents in yield.

Hammons (1973) reported heterotic response for fruit yield in F_1 hybrids resulting from crosses made between the sub-specific groups of groundnut.

Garet (1976) crossed five cultivars representing Virginia and Spanish groundnut in all possible combinations. He reported 1.6-1.9% heterosis over the mid parent in certain crosses for pod number per plant and shelling per cent. He also reported that shelling out turn was controlled by non-additive genetic variance. High heterosis for number of mature pods per plant (20.05) and pod yield per plant (37.02) was noticed by Ramakrishnam Raju *et al.* (1979) in F_1 hybrids of 5 x 5 diallel set of Virginia x Spanish crosses.

Dorairaj (1979) obtained marked heterosis for number of pods in Spanish x Valencia crosses and for number and weight of pods in Spanish x Virginia crosses.

Isleib and Wynne (1980) reported positive heterosis for pod yield, pod number and pod size in crosses of 28 diverse lines collected from South America, Africa and China with elite Virginia breeding lines. Parents of subspecies *fastigiata* generally had greater heterotic response than parents from subspecies *hypogaea*.

Positive heterosis over mid parent in 9 F_1 s was recorded by Sridharan and Marappan (1980) for all the nine traits they studied. They reported positive heterosis over the better parent in all the hybrids for number of mature pods per plant and pod yield. For number of mature pods, heterosis ranged from 23.33% to 87.50% over mid-parent and from 6.22% to 38.40% over better parent. Heterosis for pod yield ranged from 37.44% to 95.33% over mid-parent and from 4.20% to 70.30% over better parent.

Muralidharan and Raman (1980) recorded positive heterosis for pod yield per plant in the hybrids derived by crossing some bunch groundnut varieties with *Arachis monticola*, a wild species. Arunachalam *et al.* (1980) in study of heterosis for 15 characters in 15x15 diallel set observed positive heterosis for nine characters including pod yield in high x low crosses. Whereas they could record positive heterosis for 9 characters including pod yield in another 10x10 complete diallel set. Layrisse *et al.* (1980) found

that hybrid vigour for fruit yield and seed yield persisted in F_2 progenies of a diallel crosses of 10 lines.

Mahesh Kumar (1981) studied heterosis in 28 hybrids derived from crossing 4 established cultivars with 7 pollen parents in groundnut and observed a very high positive heterosis over the better parent for number of mature pods, pod yield per plant and oil per cent. Arunachalam *et al.* (1982) identified heterosis over the mean parental value for pod yield, pod size and seed yield in majority of the crosses involving parents with high and low gca.

Isleib (1982) observed heterosis over mid-parent as well as better parent for pod yield, pod number, seed yield and seed size when 27 exotic cultivars of groundnut representing each of five secondary centres of diversity in South America as well as China and Africa were crossed as males to NcAc1800, a high yielding breeding line.

Wynne and Coffelt (1983) reported that hybrid vigour was generally found in crosses between sub-specific groups and the magnitude of the phenomenon varied when different inter sub-specific crosses were compared. Similarly Arunachalam *et al.* (1984) reported high magnitude of heterosis for yield and its components *viz.*, per cent of mature pods, shelling percentage, pod yield and seed yield in crosses between the parents from intermediate divergence classes than extreme ones.

Deshmukh *et al.* (1985) observed positive heterobeltiosis for number of mature pods (16.67% to 24.60%) and pod yield per plant (29.50% to 100.80%) in four crosses for 12 morphological characters of involving JL-24 as the pollen parent. They concluded that the genetic diversity of parents is more important in the expression of heterosis than the habit group to which parents belong.

Basu *et al.* (1986) studied the extent of heterosis in inter and intra-subspecific crosses of groundnut over mid-parent and better parent in a diallel involving eight genotypes of sub-species *hypogaea* and *fastigiata* of the species *Arachis hypogaea* L. They found Spanish x Spanish crosses exhibited high positive heterosis over mid parent as well as better parent. Heterosis over mid-parent for pod yield per plant (34.72% to 57.28%) and number of mature pods. Heterosis over mid-parent and better parent was of lower magnitude in case of shelling per cent

Swe and Branch (1986) reported that crosses of Spanish x runner type parents showed greater heterosis for total pod weight, total pod number and total seed weight whereas negative heterosis was observed for harvest index.

Jagannadha Reddy and Raja Reddy (1987) in their studies on heterosis found that the average performance of F_1 hybrids excelled their parental limits for several characters studied. Highest heterosis over mid parent was observed for number of mature pods per plant. The highest

percentage of heterosis over better parent was observed for yield and it was low for number of mature pods.

Makne and Bhale (1987) in 10x10 diallel crosses studies observed that most of the crosses showed significant heterosis for pod yield per plant and oil per cent. Out of the 45 crosses 20-25 crosses had mean significant different from higher or lower parent. Similarly crosses showing positive heterosis over better parent was more common than negative heterosis for pod yield per plant. About one-half of the crosses showed negative heterosis for oil per cent. The extent of heterosis was also lower for oil per cent compared to pod yield per plant.

Nadaf *et al.* (1988) observed significant heterosis over mid-parental values for pod yield per plant, number of mature pods per plant, and shelling percentage. Dwivedi *et al.* (1989) in a 8x8 full diallel set of crosses, studied fruit yield and fruit and seed characters. They reported significant positive heterosis for fruits per plant and inferred that it may be due to predominance of non-additive gene action.

Reddi *et al.* (1989) in a 6x6 diallel analysis reported positive heterosis for mature pods per plant, pod yield and kernel yield. Spanish x Virginia combination resulted in positive heterosis for most of the yield components and heterosis was comparatively higher in magnitude when Spanish lines were used as ovule parents.

Manoharan *et al.* (1990a) in their studies on groundnut crosses observed heterosis over mid parent as well as better parent for number of mature pods per plant shelling per cent and pod yield per plant. Heterobeltiosis for pod number ranged from 1.7 % to 78.3% and relative heterosis from -17.8% to 64.47%. For pod yield the heterobeltiosis and relative heterosis ranged from 16.45% to 87.7% and -7.6% to 117.9 %, respectively. For shelling per cent 16 crosses exhibited negative heterosis.

Bansal *et al.* (1993) reported high relative heterosis for seed yield and mature pod number while moderate heterosis for pod yield. Varman and Raveendran (1994) in 22 F_1 s of 11 x 2 parents observed high heterobeltiosis for pod yield per plant, shelling per cent, sound mature kernel per cent and number of well filled and mature pods per plant.

Varman and Raveendran (1997) reported high levels of heterosis for number of mature pods and pod yield in single crosses while three way crosses exhibited heterotic effects for shelling out turn, pod weight and seed weight. Senthil and Vindhiyavarman (1998) Observed positive and significant heterosis for number of mature pods and seed size.

Rudraswamy *et al.* (1999) in F_1 , F_2 and F_3 generation of 6 crosses studied heterosis and inbreeding depression. They reported positive and significant heterosis in F_1 generation for pod yield. They concluded that heterosis in F_1 generation and inbreeding depression in F_2 and F_3 generations is due to additive gene action.

Jayalakshmi *et al.* (2000) reported highest average heterosis over mid parent for kernel yield from 25.52 per cent (ICG 2716 x Tirupati 1) to 73.73 per cent (ICG 2716 x ICGV 86031) followed by number of mature pods per plant and root dry mass. Specific leaf area and oil per cent were least heterotic of all characters studied. Highest inbreeding depression was observed for number of mature pods per plant and harvest index exhibited least inbreeding depression.

Manoharan (2002) reported that out of 72 hybrids studied for heterosis 20 hybrids exhibited positive relative heterosis which ranged from 12.5 to 56 per cent, six hybrids recorded positive heterobeltosis which ranged from 15.37 to 54.54 per cent and eleven hybrids registered positive standard heterosis (14.48% to 67.95%) for plant height while for number of branches, 21 hybrids exhibited positive relative heterosis (19.82 % to 86.41%), eight hybrids recorded positive heterobeltosis (24.77 % to 61.49%) and seven hybrids expressed positive standard heterosis (25.57 % to 46.11%).

Manivel *et al.* (2003) reported that Virginia bunch x Virginia bunch crosses were more heterobeltiotic than Spanish bunch x Spanish bunch crosses for late flowering, plant height and number of primary branches while Spanish bunch x Spanish bunch crosses were found more heterotic for early flowering and pod weight per plant than Virginia bunch x Spanish bunch crosses.

Parmar *et al.* (2004) studied 28 crosses for heterosis and reported heterosis for sound mature kernel per cent in 8 crosses, oil per cent in 10 crosses and pod yield in three crosses.

Dasaradha Rami Reddy and Suneetha (2004) observed low value of heterosis in general for most of the characters studied in 23 crosses, except number of mature pods per plant. Though heterosis was significant and in desirable direction none of the cross combinations registered more than 25% heterosis either over better parent or standard parent for pod yield per plant.

2.3 VARIABILITY, HERITABILITY AND GENETIC ADVANCE

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 coefficient of variation is a 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 the superior genotypes.

A brief review of literature on genetic parameters is furnished here under:

Majumdar *et al.* (1969) reported a wide range of phenotypic coefficient of variation for characters viz., number of mature pods per plant, shelling percent and pod yield per plant. They also observed moderate estimates of broad sense heritability for shelling percentage and low for number of mature pods per plant and pod yield,.

The studies on heritability estimates of some quantitative characters in F_2 population of J11 x Gujarat Narrow Leaf Mutant cross by Balaiah and Reddy (1975) showed a high range of heritability (71.7 to 95.1 %) for number of mature pods per plant and pod yield per plant. The high heritability estimates along with moderate to high coefficients of variability for above character indicated that selection for number of mature pods and pod yield in the early segregating generations will be effective.

Sandhu and Khehra (1976) reported high broad sense heritability for number of mature pods and pod yield in their study on crosses C-501 x Ah-6595 and C-501 x AK-12-24 in early generations. Patra (1975) also reported high estimates of broad sense heritability and expected genetic gain for yield per plant indicating substantial additive gene action in F_2

generation. Contrary to this Labana *et al.* (1980) observed low heritability estimates for pod yield in F_2 segregating population of crosses.

Hari Singh *et al.* (1982) from studies on genetic variability and heritability for morpho-physiological attributes in groundnut revealed 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 values.

Chiew and Wynne (1983) reported substantial genetic variability for yield in advanced generations of a cross between an early maturing Spanish and a large fruited Virginia type.

Basu *et al.* (1986) in an 8 parent diallel involving different habit group reported narrow sense heritability of 31.68% for number of mature pods per plant and 59.75% for pod yield per plant.

Reddy *et al.* (1987) in 6x6 diallel study of groundnut observed high heritability and genetic advance for the kernel yield and pod yield whereas shelling percentage had high heritability and moderate genetic advance.

Wang *et al.* (1987) recorded low heritability estimates for pod number per plant, number of filled pods per plant and yield per plant. Similarly Patil and Bhapkar (1987) reported a wide range of variation for pod number and pod yield.

Manoharan *et al.* (1990a) recorded high heritability combined with high genetic advance for pod weight, drymatter production and kernel weight in F₂ population of J11x Chico. Further, drymatter production exhibited highest (47.8%) genotypic coefficient of variation. Drymatter production, pod weight and pod yield were highly heritable.

Manoharan *et al.* (1990b) in a study of 21F₁s reported the highest phenotypic coefficient of variation and genotypic coefficient of variation for pod yield per plant followed by pod number. Low heritability was recorded for pod number, shelling per cent 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.

Patra *et al.* (1992) while studying genetic variation in advanced generations of groundnut reported high phenotypic coefficient of variation for number of mature pods per plant, harvest index, shelling per cent and pod yield per plant.

Chavan and Dhoble (1994) while studying genetic variation in groundnut under water stress and natural conditions reported high genotypic coefficient of variation for number of mature pods per plant and moderate heritability for pod yield per plant (<65%) and number of mature pods per plant.

Nisar Ahamed (1995) reported that in parents, heritability, genotypic and phenotypic coefficients were moderate to high for characters like pod yield per plant, kernel yield per plant and shelling percentage. But they were low to moderate in crosses.

Sumathi and Ramanathan (1995a) in 30 selected lines from F_2 generation of 5 crosses reported high heritability estimates for number of mature pods (57.6%), pod yield (57.7%) and shelling outturn (56.6%).

Varman and Raveendran (1996)⁹ in F_2 population of 6 crosses observed high heritability for number of mature pods per plant (59.6%), pod yield per plant (55.3%) and oil per cent (81.4%). They also revealed high heritability and low genetic advance for oil per cent indicating contribution of non-additive gene action. High heritability and high genetic advance for pod yield per plant and number of mature pods per plant indicate role of additive gene action in the inheritance of these characters.

Jayalakshmi (1997) among morphological and physiological attributes studied at population level, high genotypic coefficient of variation and heritability observed for harvest index and root dry mass in segregating generations. Despite low genetic variance specific leaf area and oil per cent exhibited high heritability values. Yield and yield attributes exhibited high heritability in F_3 generation.

Vasanthi *et al.* (1998) from their study in advanced breeding lines found high heritability and genetic advance for shelling percentage and

sound mature kernel per cent and moderate heritability and genetic advance for haulms weight per plant. Parmar *et al.* (2000) also reported moderate to high narrow sense heritability for shelling percentage and pod yield while low estimates for percentage of mature seeds. Similarly Sharma and Varshney (1995) noticed high GCV, PCV, heritability and genetic advance for harvest index, pod yield per plant and sound mature kernel per cent.

Talwar *et al.* (1999) recorded that genotypic variations for per cent decrease in Fv/ Fm ratio with increasing level of heat stress over their respective controls were evident among non-acclimatized plants and acclimatized plants of three genotypes (ICG-1236, 44 and Chico). The decrease in Fv/Fm ratio with increasing stress level least in the acclimated plants of ICG-1236 while it was greatest in non-acclimated plants.

Rudraswamy *et al.* (1999) in parents, F₁, F₂ and F₃ generations of six crosses of groundnut observed moderate genetic advance and high heritability for number of immature pods, pod yield per plant and shelling percentage. Singh and Singh (1999) also reported high heritability values for pod yield per plant and shelling percentage.

Rostini *et al.* (2000) studied variability and heritability for chlorophyll content and yield in 40 peanut genotypes and reported wide variability and moderate heritability values for chlorophyll content (estimated from chlorophyll meter *minolta* SPAD 502), seed weight per plant.

Naik *et al.* (2000) revealed high GCV for pod weight per plant, suggesting that selection for these characters would be more effective. It was also found that GCV was low for number of pods per plant, shelling percentage and sound mature kernel percentage. They also recorded medium heritability and high genetic advance as percentage of mean for pod weight per plant.

Vasanthi and Raja Reddy (2002) in their study in five F_2 populations reported high heritability for shell thickness. Moderate to high heritability coupled with moderate to high genetic advance was reported for pod and kernel yields per plant.

Talwar *et al.* (2002) while studying genetic variability for thermostability in groundnut observed existence of genetic variability among genotypes for both heat killing temperature and heat killing time. They opined that any one of them can be used as screening technique for heat tolerance.

Makhan Lal *et al.* (2003) reported high GCV for root length. High GCV and PCV were also observed for number of mature pods per plant and pod yield per plant. Low heritability was noticed for pod yield per plant (20%), root length and (41.7%) and number of mature pods per plant (40%). Low estimates of genetic advance for root length (1.77), number of mature pods per plant (4.38) and pod yield per plant (6.95) was observed.

Bindhu Madhava *et al.* (2003) observed significant genetic variation in SPAD chlorophyll meter reading, specific leaf nitrogen and specific leaf area among the three-non nodulating lines the nitrogen levels in groundnut.

Seethala Devi (2004) from the analysis of estimates of genetic parameters in F_2 population of 10 groundnut crosses reported that pod yield per plant, kernel yield per plant and harvest index exhibited moderate to high heritability and genetic advance as per cent of mean hence governed by additive gene action and fixable in early generations with simple selections methods. SPAD chlorophyll meter reading and shell thickness show low variability and low genetic advance hence governed by non-additive gene action.

Suneetha *et al* (2004) studied genetic parameters in 15 F_1 s of groundnut and reported that high heritability coupled with high genetic advance as per cent of mean was observed for number of mature pods per plant indicating the importance of additive gene action in the inheritance of this character. High heritability coupled with moderate genetic advance as per cent of mean was observed for pod yield per plant and high heritability coupled with low genetic advance as per cent of mean was observed for shelling per cent, sound mature kernel per cent and oil per cent .

2.4 CHARACTER ASSOCIATION

Yield is a polygenically controlled character and highly influenced by the environment. Selection merely based on yield is not effective. Selection based on its component increases yield as they are not only less complex but also relatively simply inherited and is much less influenced by environmental deviations. Character association analysis measures the actual relationship between various plant characters and helps the plant breeder in formulating selection criteria for pod yield in parental lines and segregating populations. Phenotypic correlation is the association between two characters, which can be directly observed and is subjected to changes in 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). Correlation coefficient reveals the type, nature and magnitude of correlation between any pair of characters.

Yield component characters show association among themselves and with yield. Unfavorable associations between the desired attributes under selection may limit genetic advance. Hence, a sound knowledge of association between the yield components is essential for planning an effective selection programme.

Syakudo and Kawabata (1965) studied the F₂ progeny of a cross between Virginia, Spanish and Valencia botanical groups. They found a

significant positive correlation between pod and kernel weights. Similarly Dholaria *et al.* (1973) reported positive and significant association of pod yield with number of mature pods per plant.

Coffelt and Hammons (1974) studied correlation coefficients for 9 characters in an five F_2 population between Argentine (Spanish type) and Early Runner (Virginia type) observed highly significant positive correlation between number of pods and pod weight and number of seeds and seed weight.

Sandhu and Khehra (1977) studied correlations in a cross between semi-spreading x bunch varieties of groundnut and reported positive and significant correlation of pod yield with number of mature pods. Balkisan (1979) also reported positive and significant correlation of pod yield with number of mature pods in the parents and F_2 progenies. Sangha *et al.* (1979) in F_2 progenies of a crosses M145xTiffon 1108 reported that pod yield was positively and highly associated with number of pods.

Correlation studies of Reddy and Reddy (1979) indicated that pod yield per plant was positively correlated with number of mature pods per plant regardless of the habit group in the segregating populations from the cross M145 x U-2-47-3..

High positive association of pod yield with number of mature pods was observed by Labana *et al.* (1980) in the segregating F_2 population from the cross M145 x U2-47-3. Layrisse *et al.* (1980) obtained significant and

positive correlation for pod yield and kernel yield with oil per cent in the F_2 generation of 10 parent diallel studies. Similarly in 105 semi-spreading F_2 segregants yield was positively and significantly correlated with number of mature pods per plant (Balaiah et al., 1980).

Mahesh Kumar (1981) studied correlations in 28 F_1 s and their parents. Correlations studies among parents revealed a positive and significant association of pod yield per plant with number of mature pods per plant (0.8831). Among F_1 s also the association of pod yield per plant with number of mature pods per plant (0.7962) was positive and significant.

Raju *et al.* (1981) studied correlations in both parents and 10 F_1 s of 5 parent diallel. They found that number of mature pods positively correlated with pod yield in both ai parents and F_1 s at genotypic level.

Yadava *et al.* (1981) in their study for 6 yield components in 26 groundnut strains observed that pod yield was significantly and positively associated with number of mature pods per plant. Pod yield in groundnut was positively and significantly correlated with number of mature pods and shelling out turn (Nagabhushanam *et al.* 1982).

Deshmukh *et al.* (1986) reported significant positive association of pod yield with number of mature pods per plant, 100-kernel weight and percentage of sound mature kernels, while negative association with dry matter at harvest.

Makne and Bhale (1987) in a 10 x 10 diallel combining ability analysis in groundnut showed that both in ten parents and 45 crosses pod yield per plant was negatively correlated with oil per cent both at phenotypic (-0.199) and genotypic levels(-0.258), suggesting that pod yield per plant would not be assisted by oil per cent. Similarly Naazar Ali *et al.* (2000) also reported that pod yield was positively and significantly correlated with seed yield and oil content.

Reddy *et al.* (1987) reported that primary yield components of groundnut viz., shelling percentage, kernel yield and number of mature pods per plant were correlated with each other and with pod yield in the F₂ generation.

Correlation studies of Nadaf and Habib (1989) and Dahiphale *et al.* (1990) showed that pod yield per plant was positively correlated with number of developed pods per plant and Pod yield showed highly significant association with kernel yield and pods per plant (Prasanthi *et al.*, 1989 and Mishra and Yadav, 1992).

Manoharan *et al.* (1990a) recorded positive correlation of pod yield per plant with drymatter production, harvest index, number of mature pods per plant in F₂ population of J11x Chico. Further pod number positively correlated with drymatter production and harvest index.

Manoharan *et al.* (1990b) in study of 21 F₁ hybrids observed significant positive association of pod yield per plant with pod number.

They also observed non-significant positive association of pod yield per plant with shelling per cent

Sudarsanam *et al.* (1989); Prasanthi *et al.* (1990) and Venkateswarlu *et al.* (1991) showed that pod yield was closely associated with kernel yield, number of pods per plant and harvest index.

Patra *et al.* (1992) while studying correlations in advanced generations of groundnut reported significant positive association of pod yield with number of mature pods per plant and harvest index. Further negative association between shelling per cent and harvest index indicates that high shelling per cent was linked with low harvest index and low pod yield.

Pushkaran and Nair (1993) reported that pod yield was significantly and positively correlated with haulms yield, number of mature pods and number of immature pods. They also observed the significant and positive association of number of mature pods with shelling percentage.

Wright *et al.* (1993) 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 maximized.

Gupta *et al.* (1994) found significant and positive correlation between root mass and plant dry matter and concluded that root length

contributed significantly towards pod yield in groundnut. Rucker *et al.* (1995) also observed a positive significant association between root weight and shoot weight (0.76) indicating that plants with large shoot also had large root system. The correlation coefficient between root weight and root length (0.41) was significant and positive. Further Gupta and Bali (1997) observed positive association between root length and yield. Arjunan *et al.* (1997) observed non-significant positive association of pod weight with specific leaf area and non –significant negative association of specific leaf area with harvest index

Sharma and Varshney (1995) reported positive correlation of pod yield, pods per plant and shelling per cent with harvest index and concluded that improvement in harvest index with an ultimate objective of improvement in yield could be achieved by increasing pods per plant, kernels per pod and shelling per cent. They also reported positive correlation between pods per plant and shelling per cent.

Sumathi and Ramanathan (1995b) revealed strong positive association of pod yield per plant with number of mature pods per plant (0.907) and with kernel yield per plant (0.908) and in 32 F₂ progenies of crosses. Further number of mature pods per plant registered positive and highly significant association (0.657) with kernel yield per plant .

Mishra (1995) recorded that pod yield was positively and significantly correlated with harvest index and number of pods per plant,

whereas number of pods per plant was significantly and positively correlated with harvest index 48

Francies and Ramalingam (1996) from their studies in F_2 generation indicated that kernel yield was strongly associated with pod yield. Similarly Ofori (1996) observed positive correlation between number of pods per plant and seed yield.

Varman and Raveendran (1996) in 63 F_1 populations observed significant positive correlation of pod yield per plant with shelling percentage (0.520) and number of mature pods per plant (0.497), shelling outturn had non-significant positive association with oil content. Similarly pods per plant also exhibited non-significant positive association with kernel yield per plant and pod yield per plant.

Moinuddin (1997) revealed strong positive association of pod yield with number of mature pods per plant and bio-mass per plant. It was also revealed that haulms yield per plant and shelling percentage was negatively correlated with pod yield. Uddin *et al.* (1995) observed significant negative association of seed yield with shelling percentage

Jayaramaiah and Thimmegowda (1998) observed positive significant correlation of pod yield with number of filled pods per plant and oil yield. Vasanthi *et al.* (1998) from their study in advanced breeding lines found that pod weight per plant showed significant positive correlation with sound mature kernel per cent.

Singh and Singh (1999) indicated that yield improvement could be achieved by selection for number and weight of pods per plant and kernel weight. Total dry matter at harvest had significant negative relationship with harvest index. Pod yield had significant positive association with harvest index.

Jayalakshmi *et al.* (2000) in parents and 21 F_1 s revealed that mature pods per plant, specific leaf area and harvest index had positive significant correlation with kernel yield per plant in both parents and crosses. Significant association of specific leaf area with harvest index in parents and F_1 s and non-significant association in F_3 s generations suggesting that concurrent improvement in both low specific leaf area and high harvest index may be possible in the advanced generations of the material studied, while oil content had negative association with kernel yield per plant in parental genotypes.

Singh *et al.* (2000) observed highly significant positive association of pod yield with number of mature kernels. Similarly, Venkataravana *et al.* (2000) revealed that pod yield had significant positive association with number of mature pods, shelling per cent, 100-kernel weight and kernel oil yield. Similarly, it was also observed that number of mature pods, shelling per cent and kernel yield were significantly and positively associated *inter-se* as well as with pod yield.

Johar Singh and Mohinder Singh (2001) studied correlations in 5 advanced lines and 8 segregating populations of two crosses. They observed that number of pods had the significant positive association with pod yield per plant which is an indication of favourable partition of source to sink. Positive association of harvest index with pod yields per plant and sound mature kernel per cent was also observed.

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

Nageswara Rao *et al.*, (2001) observed a strong inverse relationship between specific leaf area and specific leaf nitrogen ($r = 0.54$) and opinioned that SLN might be the course of linkage between SPAD chlorophyll meter reading and SLA in peanut. This was evident from strong positive relationship between SPAD chlorophyll meter reading and SLN. Hence SPAD chlorophyll meter reading could be used as a rapid, low cost, non-destructive technique to screen large breeding populations for specific leaf nitrogen and specific leaf area.

Bindu Madhava *et al.* (2003) reported positive relationship between specific leaf nitrogen and chlorophyll content ($r = 0.76$) and also between SPAD chlorophyll meter reading and leaf chlorophyll content ($r = 0.86$).

Leaf nitrogen status is often reflected through leaf chlorophyll content and such association has been shown in several crops (Takebe *et al.*, 1990 and Chapman and Baretto, 1997). Significant relationship between

SPAD chlorophyll meter reading and chlorophyll content and Nitrogen content in leaves have been found in crops such as rice, Balasubramanian *et al.*, 2000; Corn, Dwyer *et al.*, 1995 and in wheat, Reeves *et al.*, 1993.

Makhan lal *et al.* (2003) reported significant positive association between pod yield per plant and number of mature pods per plant; root length and number of nodules per plant; root length and root weight and root weight and pod yield in groundnut.

Seethala Devi (2004) reported significant positive association of kernel yield per plant, harvest index and sound mature kernel per cent with pod yield per plant in parents and F_2 populations, whereas Suneetha *et al.* (2004) in parents and F_1 s reported significant positive association of pod yield per plant with number of well mature pods per plant and harvest index.

2.5 PATH COEFFICIENT ANALYSIS

Path coefficient analysis is a statistical device developed by Wright (1921) helps in partitioning of the correlation coefficients into direct and indirect effects of independent variable on dependent variable. The correlation coefficients do not give a complete picture of the causal basis of association. Path coefficient 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 coefficient

— *groups in formulating the selection criteria based on these direct and*

indirect effects. Hence, path analysis of much importance in any plant breeding programmes.

The available literature on path coefficient analysis is furnished here under.

Sandhu and Khehra (1977) found that in Virginia x Spanish and Virginia x Virginia crosses of groundnut, large direct contribution to the pod yield per plant affected by the number of mature pods per plant, whereas the contribution of the other characters was largely indirect through pod number.

Balkisan (1979) in a study with 5 parents and F_2 progenies of 8 crosses involving them reported that pod yield was mainly contributed by number of mature pods per plant.

Raju *et al.* (1981) in their studies on 5 parents and 10 F_1 s indicated that number of mature pods had pronounced indirect effect on pod yield. Similarly Yadava *et al.* (1981) also reported that pod number had maximum direct effect on pod yield.

Nagabhushanam *et al.* (1982) studied 18 genotypes of groundnut and reported that number of mature pods had direct contribution to pod yield. Prakash Kumar and Yadava (1982) studied 22 bunch genotypes of groundnut and reported that pod yield has positive association with number of mature pods per plant owing to direct effects.

Mohindersingh *et al.* (1984) observed high indirect effect of pod length and 100-kernel weight on pod yield via different characters. Deshmukh *et al.* (1986) observed high positive direct effect of mature pods, 100-kernel weight and percentage of sound matured kernels on pod yield.

Reddi *et al.* (1986b) reported that kernel yield had maximum positive direct effect on pod yield followed by number of mature pods per plant similarly Kuriakose and Joseph (1986) and Bhagat *et al.* (1986) revealed the high and positive direct effect of mature pod number on pod yield.

Durgarani *et al.* (1987) revealed that number of pods, shelling percentage and 100- kernel weight exhibited positive direct effect on yield. Selection for the above characters may be highly effective for increasing yield in groundnut.

Sathyanarayana *et al.* (1988) in their path analysis studies using all the three types of groundnut reported strong contribution of total bio-mass per plant to pod yield.

Manoharan *et al.* (1990a) observed that drymatter production, pod weight, number of mature pods per plant had maximum positive direct effect (0.225, 0.442 and 0.650 respectively) on pod yield in F₂ population of J11x Chico. Further both drymatter production and harvest index has positive indirect effects via pod number, on pod yield.

Manoharan *et al.* (1990b) in study of 21 F_1 hybrids observed pod number had the highest positive direct effect (0.953) on pod yield. Shelling per cent exhibited a higher positive indirect effect on pod yield per plant via pod number and low residual effect.

Prasanthi *et al.* (1990) reported that weight of kernels had high positive direct effect on pod yield. Pods per plant expressed moderate negative direct effect even though the association was significant.

Abraham (1990) reported that kernels per plant had high positive direct effect on kernel yield. It was also found that 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 positive indicating that kernels per plant and 100-kernel weight are the major yield contributors.

Patra *et al.* (1992) while studying path coefficient analysis in advanced generations of groundnut reported that number of mature pods per plant had high positive direct effect (0.629) on pod yield per plant followed by harvest index (0.089).

Manoharan *et al.* (1993) from their studies in F_2 population of a cross between Robut 33-1 and Chico noted low positive direct effect of total drymatter production on pod yield.

Pathirana (1993) studied 125 diverse bunch groundnut genotypes and indicated that number of pods per plant and seed size had positive

direct effects on pod yield. Similarly Patel and Shelke (1991) indicated that filled pods per plant and total dry matter had positive and direct effect on pod yield.

Nisar Ahamed (1995) revealed that pod yield per plant had high positive direct effect on kernel yield per plant in both parents and crosses. Number of mature pods per plant and harvest index in crosses exerted their indirect effect via source contributions through several other characters. Kernel yield per plant had highest positive direct effect on pod yield per plant in both hybrids and parents

Sumathi and Ramanathan (1995b) reported that number of mature pods per plant, kernel yield per plant had the highest positive direct effect on pod yield per plant, while negative direct effect was recorded for shelling per cent. The path analysis showed that pod yield per plant was highly influenced by number of mature pods per plant and kernel yield per plant in 32 F₂ progenies of crosses.

Uddin *et al.* (1995) revealed that nuts per plant had large direct effects on seed yield per plant. Contrary to this, Ofori (1996) observed that the number of pods per plant had high positive direct effects on 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 and also their direct effects were positive and high in almost all

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environments. Haulms yield per plant and shelling per cent exhibited negative association and negative direct effect on pod yield.

Varman and Raveendran (1996) in 63 F_1 populations observed that kernel yield had high positive direct effect on oil content and significant positive correlation. The highest direct effect of pod yield was nullified by indirect effect of oil content.

Studies of Arjunan *et al.* (1989) for drought resistance and pod yield per plant in 24 crosses of groundnut genotypes revealed that drymatter production had the highest positive direct effect on pod yield per plant, while leaf area had the highest negative direct effect.

Studies of Bera and Das (2000) in 44 genotypes of groundnut for path coefficient analysis showed positive direct contribution of pods per plant and harvest index to the seed yield. Their correlation with seed yield is also significant and positive. So pod yield per plant and harvest index can be used directly as selection criteria for improvement of seed yield in groundnut.

Mathews *et al.* (2000) revealed maximum direct effect of kernel yield per plant followed by plant height on dry pod yield per plant, hence emphasis should be given on these characters while breeding for high yield in groundnut.

Azad and Hamid (2000) path analysis revealed that highest and positive direct effects of pod number on pod yield per plant followed by

kernel yield per plant contributed significantly both directly and indirectly to pod yield per plant. Similarly Venkataravana *et al.* (2000) revealed high and positive direct effects of kernel yield and number of mature pods on pod yield.

Johar Singh and Mohinder Singh (2001) studied correlations in 5 advanced lines and 8 segregating populations of two crosses. They found that the sound mature kernel percentage, harvest index and number of pods per plant had maximum positive direct effect on pod yield.

Makhan lal *et al.* (2003) reported that the direct effect of number of mature pods per plant and root length on pod yield per plant is positive and high. Yield which has so far been improved through the use of selection of yield contributing traits showed now include root length as selection criteria for improving 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) in his path coefficient analysis studies reported that harvest index had the highest positive direct effect (1.3269) 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 (0.2233) followed by indirect effect of shelling per cent through haulms yield.

Chapter - III

Material & Methods

CHAPTER - III

MATERIAL AND METHODS

The present investigation entitled was carried out at the Regional Agricultural Research Station, Tirupati, for three seasons i.e during *kharif* 2002, *rabi* 2002 and *kharif* 2003 (altitude of 54.9 m above MSL, latitude of 13°N and a longitude of 79°E).

3.1 MATERIAL

Stabilised breeding lines (TIR-46, JUG-37, ICR-45, TIR-10, JAL-6 and JUG-43) with high water use efficiency traits obtained from earlier breeding programme under taken at Regional Agricultural Research Station, Tirupati under ACIAR-ICRISAT - APAU - ICAR, collaborative programme were selected as parents. Two more locally well adopted varieties (K-134 and JL-24) were also included as parents to make 8 x 8 diallel set of crosses. Hence, the material for the present study comprised of parents, F_1 and F_2 generations of crosses involving eight parents viz., TIR-46, JUG-37, ICR-45, TIR-10, K-134, JAL-6, JUG-43 and JL-24. Characteristics of parents are furnished in Table 1.

Table 1 : Important characteristics of parental genotypes

Sl. No.	Genotype	Pedigree	Botanical type / Variety	Origin	Duration (days)	Oil per cent	Shelling per cent	Seed colour	Other important features
1	TIR-46	K-134 x TAG-24	Spanish bunch	Tirupati	108	47	78	Rose	Pods medium bold, slightly reticulated with shallow constriction
2	JUG-37	ICGV-86031 x TAG-24	Virgina bunch	Junagadh	110	48	77	Rose	High SPAD, pods with thick shell moderate constriction and moderate reticulation
3	ICR-45	ICGS-44 x ICGS-76	Virgina bunch	ICRISAT	110	43	76	Rose	High SPAD and kernel harvest index, moderate constriction and reticulation with prominent beak
4	TIR-10	ICGS-76 x CSMG-84-1	Virgina bunch	Tirupati	110	44	77	Rose	Very high SPAD and kernel harvest index, shallow constriction and high reticulation
5	K-134	JL-24 x K-3	Spanish bunch	Kadiri	105	49	75	Rose	Tolerant to drought and foliar disease, well adopted variety with dark green foliage
6	JAL-6	ICGS-44 x CSMG-84-1	Virgina bunch	Jalgaon	110	43	73	Variegated	Short pod, moderate reticulation, beak absent, thick shell and round seed
7	JUG-43	GG-2 x ICGV-86031	Virgina bunch	Junagadh	110	45	72	Rose	High SPAD, pod bold, shallow constriction and moderate reticulation with long kernel
8	JL-24	Selection from EC-94943	Spanish bunch	Jalgaon	95	50	75	Rose	Early, smooth pod, susceptible to mid season drought, widely adopted variety

3.2 METHODS

3.2.1 Generation of Experimental Material

Eight parents were crossed in a half-diallel manner to generate 28 crosses during *kharif* 2002. One more set of F_1 s were produced during *rabi* 2002 for conducting simultaneous evaluation of F_1 and F_2 generations during *kharif* 2003. Emasculation and pollinations were done as per the procedure outlined by Norden (1973).

3.2.2 Field trials

3.2.2.1 Experiment -1

Twenty eight F_1 s along with eight parents were sown in a Randomised Block Design (RBD) with three replications during *rabi* 2002. ✓ Each parent was sown in 3 rows of 3 m length while F_1 s were raised in a single row of 3 m length. All the 28 treatments were allotted at random to the experimental plots in each replication. Observations were recorded on ten random plants in each treatment per replication.

3.2.2.2 Experiment -2

Twenty-eight F_1 s (generated during *rabi* 2002), as well as their F_2 populations (obtained from experiment 1) along with their eight parents were grown in a RBD with 3 replications during *kharif* 2003. All the 64 treatments were randomized in each replication. Each F_1 was raised in a single row of 3 m length while parents and F_2 s were raised in 3 rows of 3 m length. Ten random plants per replication were sampled in case of

parents and F_1 s, while 20 plants per replication were tagged at random in each F_2 population for recording observations.

3.2.3 Crop Husbandry

The experiment was conducted in a red sandy loam soil with a neutral pH, low in organic carbon. Recommended agronomic and plant protection measures were adopted for the conduct of experiment..

3.2.4 Data Recording

The following observations were recorded on sampled plants.

3.2.4.1 SPAD chlorophyll meter reading (SCMR)

SCMR was measured on all four-leaflets of apex third leaf on main axis at 75 DAS under normal sunlight using SPAD meter of Minolta Company, NJ, USA (SPAD-502).

3.2.4.2 Specific leaf nitrogen (SLN)

Leaf nitrogen was estimated at 75 days after sowing by microkjeldal method using Kjelttec 1002 auto distillation set and expressed as g N/ m² leaf area (Amount of Nitrogen per unit mass per unit leaf area).

3.2.4.3 Specific leaf area (SLA)

Calculated at 75 DAS, as the ratio of the leaf area of 3rd fully expanded leaf on the main axis to the oven dried weight of the leaf sample and is expressed as cm²/g dry weight.

3.2.4.4 Per cent reduction of F_v / F_m

Chlorophyll fluorescence was measured using modulated² fluorimeter (Hansatech Electronics Ltd., UK) on the abaxil surface of four leaflets

taken from two fully expanded young leaves, two from each plant, excised from heat -non-hardened plants. There were three replicated plants per genotype for each hardening treatment. The leaflets were placed in 1 ml distilled water in test tubes and the tubes were covered with Aluminum foil and either left at room temperature and or heated for 5 minutes at 55°C temperature in a water bath to induce heat injury to the photosynthetic apparatus. A set of non-heated tubes served as control. After the heat treatment, leaflets were placed in the dark for 30 minutes at room temperature; after which dark adapted leaflets were placed into a leaf clip to which a modulated light probe and a detector probe were attached.

The leaflets were exposed to actinic light and saturating light pulses through the fiber-optic cables connected to Bjorkman Lam Photosynthetically photon flux. The fluorescence (F_o), the maximum fluorescence (F_m) and the variable fluorescence (F_v) derived by subtracting F_o from F_m and the F_v / F_m ratio were recorded. F_v/F_m ratio is a measure of efficiency with which light is utilised for photosynthesis. Upon heat treatment, F_v/F_m ratio declines indicating photo-inhibitory damage due to heat stress.

Per cent reduction of F_v/F_m was calculated as follows.

$$\frac{F_v/F_m \text{ in heat-treated leaves}}{F_v/F_m \text{ in control leaves}} \times 100$$

3.2.4.5 Root length (cm)

At maturity, the field was well irrigated and the sample plants were lifted carefully and length of root was measured from base of the plant up to end of root.

3.2.4.6 Harvest index : Calculated by using the formula.

$$\frac{\text{Pod yield per plant (g)}}{\text{Total dry matter at maturity (g)}}$$

3.2.4.7 Shell thickness:

Shell thickness was measured using Screw gauge and expressed in milli meters.

3.2.4.8 Oil per cent (%)

The oil content of sample kernels of parents, F₁s and F₂s was determined through Nuclear Magnetic Resonance (NMR) Analyzer.

3.2.4.9 Shelling per cent : Calculated by using the formula

$$\frac{\text{Weight of kernels per plant (g)}}{\text{Weight of pods per plant (g)}} \times 100$$

3.2.4.10 Sound mature kernel per cent (SMK %) :

Calculated by using the formula

$$\frac{\text{Weight of sound mature kernels (g)}}{\text{Weight of total kernels (g)}} \times 100$$

3.2.4.11 Number of well-filled and mature pods per plant

Total number of well-filled and mature pods per plant at harvest was counted.

3.2.4.12 Kernel yield per plant (g)

Weight of kernels obtained from pods of each plant.

3.2.4.13 Pod yield per plant (g)

Weight of dried and matured pods per plant was measured in grams.

3.3 STATISTICAL ANALYSIS

The data collected on sampled plants in all the entries in different replications were averaged (replication wise) and mean values were subjected for statistical analysis.

3.3.1 Analysis of variance

Analysis of variance for each character for parents and F_1 s (*Rabi*, 2002), parents and F_1 s (*Kharif*, 2003) and parents and F_2 s (*Kharif*, 2003) were carried out separately for each season. The significance of treatment differences was tested at five and one per cent levels of probability.

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-ratio
Replications	$r-1$	M_s	M'_s	M'_s / M'_e
Treatments	$t-1$	M_t	M'_t	M'_t / M'_e
Error	$(r-1) (t-1)$	M_e	M'_e	
Total	$tr-1$			

3.4 Combining Ability Analysis

The combining ability analysis was carried out according to Model I and Method II of Griffing (1956). The fixed effect model (Model I) was considered to be more appropriate in the present investigation, since the study was restricted to the parents and direct crosses only.

The mathematical model used is as follows :

$$\begin{aligned}
 Y_{ij} &= \mu + g_i + g_j + S_{ij} + \frac{1}{bc} \sum \sum e_{ijkl} \\
 i, j &= 1, 2 \dots n \\
 k &= 1, 2 \dots b \\
 l &= 1, 2 \dots c
 \end{aligned}$$

Where,

- Y_{ij} is the mean of $i \times j^{\text{th}}$ genotype over k and l
- μ is the population mean common to all parents
- g_i is the general combining ability (GCA) effect of i^{th} parent
- g_j is the GCA effect of j^{th} parent
- s_{ij} is the interaction i.e., specific combining ability effect for the cross between the i^{th} and j^{th} parent
- e_{ijkl} is the environmental effect associated with the $ijkl^{\text{th}}$ individual observation.

The restrictions $\sum_i g_i = 0$ and $\sum_{ij} (S_{ij} + S_{ji}) = 0$ for each i are imposed on the combining ability elements.

For combining ability estimates, the degree of freedom for genotypes was further divided into GCA and SCA as indicated below.

ANOVA for combining ability

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Expected mean sum of squares model I
General combining ability	n-1	S _g	M _g	$\sigma_e^2 + \sigma_s^2 + (n+2) \sigma_g^2$
Specific combining ability	$\frac{n(n-1)}{2}$	S _s	M _s	$\sigma_e^2 + \sigma_s^2$
Error	m	S _e	M'e	σ_e^2

S.S. due to GCA $S_g = \frac{1}{n+2} \left[\sum_i (y_i + y_{ii})^2 - \frac{4}{n} Y^2 \dots \right]$

S.S. due to SCA (S_s) = $\sum_{i < j} \sum Y_{ij}^2 - \frac{1}{n+2} \sum_i (Y_i + Y_{ij})^2 + \frac{2}{(n+1)(n+2)} Y^2 \dots$

Keeping in view the expectations of the mean squares, the estimates of components are obtained as under

Component due to gca = $\frac{(M_g - M'e)}{n + 2}$

Component due to sca = $M_s - M'e$

3.4.1 Estimation of general and specific combining ability effects

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

$$g_i = \frac{1}{(n+2)} \left[Y_i + Y_{ii} - \frac{2}{n} Y_{..} \right] /$$

with the restriction $\Sigma g_i = 0$

$$\hat{S}_{ij} = Y_{ij} - \frac{(Y_{i.} + Y_{.i} + Y_{.j} + Y_{jj})}{n+2} + \frac{2}{(n+1)(n+2)} Y_{..}$$

With the restriction $\Sigma S_{ii} + S_{ij} = 0$ (for each i)

The variance of estimates and those of differences between effects were estimated as follows :

$$\text{Var}(\hat{\mu}) = \frac{2}{n(n+1)} \sigma_e^2$$

$$\text{Var}(\hat{g}_i) = \frac{(n-1)}{n(n+2)} \sigma_e^2$$

$$\text{Var}(\hat{S}_{ii}) = \frac{n(n-1)}{(n+1)(n+2)} \sigma_e^2$$

$$\text{Var}(\hat{S}_{ij}) = \frac{n^2 + n + 2}{(n+1)(n+2)} \sigma_e^2 \quad (i \neq j)$$

$$\text{Var}(\hat{g}_i - \hat{g}_j) = \frac{2}{n+2} \sigma_e^2 \quad (i \neq j)$$

$$\text{Var}(\hat{S}_{ii} - \hat{S}_{jj}) = \frac{2(n-2)}{n} \sigma_e^2 \quad (i \neq j)$$

$$\text{Var} (\hat{S}_j - \hat{S}_{ik}) = \frac{2 (n + 1)}{n + 2} \sigma_e^2 \quad (i \neq j, k; j \neq k) \quad \checkmark \quad 68$$

$$\text{Var} (\hat{S}_j - \hat{S}_{kl}) = \frac{2n}{n + 2} \sigma_e^2 \quad (i \neq j, k, l; j \neq k, l; k \neq l) \quad \checkmark$$

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

3.5 ESTIMATION OF HETEROSIS

The overall mean values of each character for each parent and F_1 utilized and relative heterosis was calculated as the per cent deviation of mean of the F_1 from its mid parental value between two corresponding parents. Heterobeltiosis was estimated as difference between the mean of the F_1 and that of the parent with greater expression for each of the character in each F_1 combination. Standard heterosis was calculated as the per cent deviation of mean of F_1 from standard parent (K-134).

$$\text{Relative heterosis (per cent)} = \frac{\bar{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Heterobeltiosis (per cent)} = \frac{\bar{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Standard heterosis (per cent)} = \frac{\bar{F}_1 - \overline{SP}}{\overline{SP}} \times 100$$

Where

$\bar{F}_1$ = Mean of the hybrid

$\overline{MP}$ = Mid parental value : the arithmetic mean of two parents involved in the respective cross combination.

$\overline{BP}$ = Better parental value : the mean of the superior parent in the respective cross combination

$\overline{SP}$ = Standard parental value : the mean of K-134 parent

Parents with high value were considered as better parent for all the characters except for specific leaf area, per cent reduction of Fv/Fm and shell thickness for which parents having low values were considered as better parents.

The significance of heterosis was tested in both the situations by calculating the critical difference (C.D) at 5 and 1 per cent levels of error degrees of freedom.

$$C.D = S.E \times t_{\alpha \text{ error d.f}}$$

$$S.E. \text{ for relative heterosis} = \sqrt{\frac{3}{2} \times \frac{M'e}{r}}$$

$$S.E. \text{ for heterobeltiosis and standard heterosis} = \sqrt{2 \times \frac{M'e}{r}}$$

3.6 ESTIMATION OF INBREEDING DEPRESSION

$$\text{Inbreeding depression (\%)} = \frac{\bar{F}_1 - \bar{F}_2}{\bar{F}_1} \times 100$$

where, $\bar{F}_1$ and $\bar{F}_2$ are the mean value of F_1 and F_2 progeny, respectively for the same cross for a given character.

Mean error variance from the combined analysis of variance of parents, F_1 s and F_2 s is used for calculating the SE of difference.

3.7 ESTIMATION OF GENETIC PARAMETERS

Phenotypic and Genotypic coefficients of variation (PCV and GCV) were computed according to the Burton (1952).

$$\text{Phenotypic coefficient of variation (\%)} = \frac{\text{Phenotypic standard deviation}}{\text{General Mean}} \times 100$$

$$\text{Genotypic coefficient of variation (\%)} = \frac{\text{Genotypic standard deviation}}{\text{General Mean}} \times 100$$

Categorization of the range of variation was effected by Stansfield (1969)

Low	0 - 20 %
Moderate	20 % - 50 %
High	Above 50 %

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

$$h^2(b) = \frac{\text{Genotypic variance}}{\text{Total variance}} \times 100$$

As suggested by Johnson et al (1955) heritability estimates were categorized as follows

Low	0 - 30 %
Moderate	30 % - 60 %
High	Above 60 %

3.7.1 Genetic advance (GA)

This was calculated as per the formula as suggested by Johnson et al. (1955).

$$\text{Genetic advance (GA)} = \sigma_p \times H \times K$$

where,

σ_p = Phenotypic standard deviation

H = Heritability in broad sense

K = Selection differential at 5% selection intensity (2.06)

$$3.7.2 \text{ Genetic advance as per cent of mean (GAM)} = \frac{\text{GA}}{\text{Grand mean}} \times 100$$

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

Low	0 - 10 %
Moderate	10% - 20 %
High	Above 20 %

Genotypic and phenotypic correlation coefficients were calculated among eight parents, 28 F₁s and 28 F₂s separately using the formulae suggested by Al-Jibouri *et al.* (1958) and their significance was tested by using the 'r' table values (Fisher and Yates, 1963) at n-2 degrees of freedom.

3.8.1 Phenotypic correlation coefficients

$$r_p(XY) = \frac{COV P(XY)}{\sigma^2 P(X) \sigma^2 P(Y)}$$

Where

$r_p(XY)$ = Phenotypic correlation between X and Y

COV P(XY) = Phenotypic covariance between characters X and Y

$\sigma_p^2(X)$ = Phenotypic variance of X

$\sigma_p^2(Y)$ = Phenotypic variance of Y

3.8.2 Genotypic correlation coefficients

$$r_g(XY) = \frac{COV G(XY)}{\sigma^2 G(X) \sigma^2 G(Y)}$$

Where

$r_g(XY)$ = Genotypic correlation between X and Y

COV G(XY) = Genotypic covariance between characters X and Y

$\sigma_G^2(X)$ = Genotypic variance of X

$\sigma_G^2(Y)$ = Genotypic variance of Y

Path coefficient analysis was carried out by using phenotypic and genotypic correlation coefficients to know the direct and indirect effects of the yield components as suggested by Wright (1921) and illustrated by Dewey and Lu (1959).

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

$$\begin{aligned}
 r_{1y} &= P_{1y} + r_{12} P_{2y} + r_{13} P_{3y} + \dots r_{1K} P_{KY} \\
 r_{2y} &= r_{21} P_{1y} + P_{2y} + r_{23} P_{3y} + \dots r_{2K} P_{KY} \\
 &\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
 &\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
 &\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
 r_{ky} &= R_{k1} P_{1y} + r_{k2} P_{2y} + r_{k3} P_{3y} + \dots P_{KY}
 \end{aligned}$$

Where,

$r_{1y}, r_{2y}, \dots, r_{ky}$ are the correlation coefficients of independent variables $X_1, X_2, \dots, X_K$ with the dependent variable y .

$r_{12}, r_{13}, \dots, r_{k-1, k}$ are the coefficients of correlation among the independent variables.

$P_{1y}, P_{2y}, \dots, P_{ky}$ are the direct effects of variables $X_1, X_2, \dots, X_K$ on y .

The above equations were written in the matrix form as under.

$$\begin{array}{ccc}
 \text{A} & & \text{C} & & \text{B} \\
 \left[\begin{array}{c} r_{1y} \\ r_{2y} \\ \cdot \\ \cdot \\ \cdot \\ r_{ky} \end{array} \right] & = & \left[\begin{array}{cccccccc} r_{11} & r_{12} & r_{13} & \cdot & \cdot & \cdot & \cdot & r_{1k} \\ r_{21} & r_{22} & r_{23} & \cdot & \cdot & \cdot & \cdot & r_{2k} \\ \cdot & \cdot & \cdot & & & & & \cdot \\ \cdot & \cdot & \cdot & & & & & \cdot \\ \cdot & \cdot & \cdot & & & & & \cdot \\ r_{k1} & r_{k2} & r_{k3} & \cdot & \cdot & \cdot & \cdot & 1 \end{array} \right] & \left[\begin{array}{c} P_{1y} \\ P_{2y} \\ \cdot \\ \cdot \\ \cdot \\ P_{ky} \end{array} \right]
 \end{array}$$

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

$$\begin{array}{ccc}
 \text{Where,} & & \\
 C^{-1} & = & \left[\begin{array}{ccccccc} C_{11} & C_{12} & C_{13} & \cdot & \cdot & \cdot & C_{1k} \\ C_{21} & C_{22} & C_{23} & \cdot & \cdot & \cdot & C_{2k} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ C_{k1} & C_{k2} & C_{k3} & \cdot & \cdot & \cdot & C_{kk} \end{array} \right]
 \end{array}$$

Then, direct effects were calculated as follows :

$$P_{1Y} = \sum_{i=1}^k C_{1i} \cdot r_{iy}$$

$$P_{2Y} = \sum_{i=1}^k C_{2i} \cdot r_{iy}$$

$$P_{kY} = \sum_{i=1}^k C_{ki} \cdot r_{iy}$$

■

The residual effect which measures the contribution of the characters not considered in the causal scheme was obtained as **75**

$$\text{Residual effect (P}_{RY}) = \sqrt{1 - \Sigma R^2}$$

where,

$$R^2 = \sum_{i=1}^k P_{iy}^2 + \sum_{\substack{i \ j \\ i \neq j}} P_{iy} \cdot P_{jy} \cdot r_{ij}$$

Chapter - IV

Results

RESULTS

In the present study, genetic analysis of physiological, yield and yield attributes was carried out in a 8 x 8 diallel set of crosses of groundnut. The results obtained on mean performance, combining ability, heterosis, inbreeding depression, genetic parameters, character association and path analysis for thirteen characters are presented here under.

4.1 ANALYSIS OF VARIANCE (*Rabi* –2002 and *Kharif* -2003)

The analysis of variance for 13 characters for parents and F₁s (*rabi*-2002); parents and F₁s (*kharif*-2003) and parents and F₂s (*kharif*-2003) is furnished in Tables 2, 3 and 4. Significant differences were observed for all the characters among the genotypes in both the seasons.

4.2 MEAN PERFORMANCE OF PARENTS AND F₁s (RABI – 2002)

Mean performance of parents and F₁s for characters viz., SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area, per cent reduction of Fv/Fm, root length, harvest index, shell thickness, oil per cent, shelling per cent, sound mature kernel per cent, number of well filled and mature pods per plant, kernel yield per plant and pod yield per plant during rabi 2002 are presented hereunder (Tables 5, 6 and 7).

4.2.1 SPAD chlorophyll meter reading (SCMR)

Among parents, mean SCMR ranged from 41.53 (JL-24) to 49.97 (JUG-43) with a general mean of 46.40. The SPAD chlorophyll meter

Table 2 : Analysis of variance (Mean squares) for 13 characters among 8 parents and 28 F₁s of groundnut (Rabi -2002)

Character	Replications d.f. = 2	Treatments d.f. = 35	Error d.f. = 70
SPAD chlorophyll meter reading	1.8575	9.8405**	1.1819
Specific leaf nitrogen	0.0008	0.3331**	0.0009
Specific leaf area	15.9645	233.5913**	33.7835
Per cent reduction of Fv/Fm	20.3709	182.6672**	12.9706
Root length	13.9108	13.9054**	1.1769
Harvest index	0.0036	0.0156**	0.0017
Shell thickness	0.0016	0.1739**	0.0017
Oil per cent	1.0298	24.7298**	4.1853
Shelling per cent	9.0093	108.5616**	18.0474
Sound mature kernel per cent	0.3333	131.2071**	11.9714
Number of well filled and mature pods per plant	29.9180	56.2642**	16.7862
Kernel yield per plant	8.9362	38.5169**	12.9949
Pod yield per plant	22.7818	64.6042**	18.9279

** Significant at 1 % level of probability

Table 3 : Analysis of variance (Mean squares) for 13 characters among 8 parents and 28 F₁s of groundnut (*Kharif* - 2003)

Character	Replications d.f. = 7	Treatments d.f. = 35	Error d.f. = 70
SPAD chlorophyll meter reading	9.0840	11.7321**	2.0697
Specific leaf nitrogen	0.0054	0.3522**	0.0093
Specific leaf area	69.4920	778.0466**	35.5620
Per cent reduction of Fv/Fm	6.7884	339.3586**	13.9693
Root length	11.7821	18.7501**	3.0043
Harvest index	0.0056	0.0173**	0.0010
Shell thickness	0.0008	0.1349**	0.0028
Oil per cent	0.8316	17.8035**	6.7636
Shelling per cent	54.4814	63.6410**	18.6243
Sound mature kernel per cent	44.5925	193.4211*	15.3068
Number of well filled and mature pods per plant	59.7893	16.1577*	8.6821
Kernel yield per plant	10.8427	4.7225*	3.1973
Pod yield per plant	39.8048	12.0429*	5.2790

* Significant at 5 % level of probability

** Significant at 1 % level of probability

Table 4 : Analysis of variance (Mean squares) for 13 characters among 8 parents and 28 F₂s of groundnut (*Kharif* - 2003)

Character	Replications d.f. = 2	Treatments d.f. = 35	Error d.f. = 70
SPAD chlorophyll meter reading	3.2220	12.9907**	2.1615
Specific leaf nitrogen	0.0232	0.6944**	0.0217
Specific leaf area	62.4805	2074.0949**	63.3241
Per cent reduction of Fv/Fm	3.0354	420.2215**	8.2766
Root length	4.0223	10.7356**	5.4982
Harvest index	0.0007	0.0123**	0.0011
Shell thickness	0.0024	0.0752**	0.0029
Oil per cent	4.1465	18.2977*	5.2745
Shelling per cent	40.1482	83.8179**	17.8719
Sound mature kernel per cent	6.2870	237.8315**	14.8394
Number of well filled and mature pods per plant	1.2545	5.8962*	3.3122
Kernel yield per plant	5.3860	4.8021**	1.8506
Pod yield per plant	9.6075	6.4526*	3.5728

* Significant at 5 % level of probability,

** Significant at 1 % level of probability

reading of five parental lines viz., JUG-37, ICR-45, TIR-10, K-134 and JUG-43 exceeded the general mean. The general mean of F_1 s was 48.21 that ranged from 46.10 (TIR-46 x ICR-45) to 50.40 (ICR-45 x JAL-6) and sixteen F_1 s were found to exceed general mean of F_1 s. (Table -5).

4.2.2 Specific leaf Nitrogen (g N m^{-2})

Among parents, specific leaf nitrogen (SLN) ranged from 2.58 (JAL-6) to 3.58 (ICR-45) with a general mean of 3.17. Mean SLN was higher than the general parental mean in five genotypes viz., TIR-46, JUG-37, ICR-45, TIR-10 and JUG-43. It ranged between 1.74 (K-134 x JL-24) and 2.80 (JUG-43 x JL-24) among F_1 s with a general mean of 2.26 and it was surpassed by 14 F_1 s.

4.2.3 Specific leaf area ($\text{cm}^2 \text{g}^{-1}$)

The mean specific leaf area (SLA) ranged from 94.00 (K-134) to 125.48 (JAL-6) among parents. Five parents exceeded the parental general mean of 104.07. A wide range from 93.63 (JUG-43 x JL-24) to 191.23 (ICR-45 x JAL-6) of SLA was observed among the F_1 s with a general mean of 152.62. As many as 15 out of 28 F_1 s surpassed the general mean.

4.2.4 Per cent reduction of Fv/Fm

Among parents mean per cent reduction of Fv/Fm ranged from 54.86% to 82.40% with a general mean value of 70.20%. The parents JUG-43 (54.86%) and ICR-45 (82.40%) recorded minimum and maximum per cent reduction of Fv/Fm respectively. Four parents viz., K-134, JAL-6, JUG-43

and JL-24 have shown lower mean values than general mean. Among the F_1 s it ranged from 53.01% (K-134 x JUG-43) to 81.24% (TIR-46 x K-134) with a general mean of 67.60%. Fifteen F_1 s expressed lower per cent reduction of Fv/Fm than general mean (67.60%).

4.2.5 Root length (cm)

Mean root length ranged from 12.87cm (JL-24) to 15.33cm (JUG-43) among parents with a general mean 13.73cm. Three out of eight parents had greater root length than their mean. Among F_1 s, TIR-46 x K-134 (7.87cm) and TIR-46 x JL-24 (19.77cm) registered lower and higher mean root length respectively with a general mean of 14.06cm. Twelve F_1 s exceeded the general mean.

4.2.6 Harvest index (HI)

The mean harvest index among the parents ranged from 0.30 (JUG-43) to 0.51 (TIR-46) with a mean harvest index of 0.43. Five parental lines viz., TIR-46, JUG-43, ICR-45, K-134 and JAL-6 exceeded the general mean (0.43). Among F_1 s, it ranged from 0.30 (JUG-43 x JAL-6) to 0.63 (K-134 x JL-24) with a general mean of 0.48 which was exceeded by eleven F_1 s. (Table - 5).

4.2.7 Shell thickness (mm)

Mean shell thickness varied between 1.03mm (JUG-43) and 1.65mm (JUG-37) with a general mean of 1.22mm among the parents. Six parents recorded thin shell than general mean. Among the F_1 s thin shell (0.85mm)

Table 5 : *Per se* performance of 8 parents and 28 F₁s for 13 characters (*Rabi* - 2002)

Parents/crosses	SPAD chloro- -phyll meter read- ing	Specific leaf nitro- gen (g N/ m ²)	Specific leaf area (cm ² /g)	Per cent reduction of Fv/Fm	Root length (cm)	Harvest index	Shell thickness (mm)	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant (g)	Pod yield per plant (g)
Parents													
TTR-46	46.0	3.21	110.37	75.43	13.87	0.51	1.51	47.79	72.00	87.33	16.43	16.90	22.13
JUG-37	47.90	3.45	106.91	79.84	13.40	0.49	1.65	48.41	62.00	79.67	20.13	27.67	38.30
ICR-45	46.97	3.58	106.82	82.40	12.97	0.46	1.16	43.71	67.67	88.67	14.30	16.00	22.60
TTR-10	47.23	3.31	095.17	76.92	13.53	0.37	1.08	42.15	60.00	75.00	11.63	12.73	17.20
K-134	47.13	3.11	094.00	59.16	13.50	0.45	1.15	46.13	63.67	81.33	19.73	15.37	21.27
JAL-6	44.50	2.58	125.48	64.45	14.33	0.45	1.14	43.17	65.33	66.67	28.17	20.23	28.00
JUG-43	49.97	3.35	085.16	54.86	15.33	0.30	1.03	45.01	68.33	75.33	16.93	18.00	22.57
JL-24	41.53	2.75	108.68	68.55	12.87	0.38	1.04	45.90	68.67	85.33	17.2	15.10	20.10
Crosses													
TTR-46 x JUG-37	46.23	1.76	163.18	66.00	11.00	0.47	1.03	48.35	72.67	81.00	21.57	21.80	29.60
TTR-46 x ICR-45	46.10	2.52	148.79	73.29	10.60	0.58	0.94	50.51	73.00	79.67	22.60	23.80	29.60
TTR-46 x TTR-10	46.13	2.31	156.14	67.04	12.07	0.52	0.99	48.43	72.00	85.00	15.00	14.83	21.40
TTR-46 x K-134	47.63	2.15	153.62	81.24	07.87	0.52	0.85	51.15	71.67	70.00	20.80	16.40	24.30
TTR-46 x JAL-6	46.70	2.68	151.17	67.25	15.47	0.42	1.38	43.54	69.00	81.33	25.77	19.93	32.67
TTR-46 x JUG-43	48.30	2.40	152.59	68.12	11.47	0.48	1.04	45.42	72.00	88.33	19.67	18.23	22.96
TTR-46 x JL-24	46.50	2.54	147.08	69.92	19.77	0.48	1.20	44.77	66.67	77.00	15.57	12.10	22.30
JUG-37 x ICR-45	49.17	2.38	139.90	72.63	16.40	0.51	1.77	44.69	65.00	82.67	21.83	19.90	25.10
JUG-37 x TTR-10	49.87	2.65	138.69	66.11	15.38	0.43	1.62	50.36	59.33	78.33	16.40	16.20	27.13
JUG-37 x K-134	48.43	2.30	155.48	71.79	11.20	0.51	1.43	46.98	66.00	85.00	19.70	16.60	20.90
JUG-37 x JAL-6	49.83	2.48	140.38	78.20	13.36	0.30	1.50	46.60	72.67	79.33	18.37	17.97	25.38
JUG-37 x JUG-43	49.20	2.75	131.95	69.74	16.43	0.46	1.45	48.19	69.33	84.67	24.23	17.40	25.27

Contd...

Contd...

crosses	SPAD chloro- -phyll meter read- Ing	Specific leaf nitro- gen (g N/m ²)	Specific leaf & ca (cm ² /g)	Per cent reduction of Fv/Fm	Root length (cm)	Harvest index	Shell thickness (mm)	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant (g)	Pod yield per plant (g)
JUG-37 x JL-24	50.30	2.64	149.49	69.44	13.00	0.49	1.54	49.23	57.00	85.67	25.90	15.33	26.70
ICR-45 x TTR-10	49.90	2.04	164.77	67.04	15.67	0.57	1.45	43.74	62.67	79.67	21.87	20.20	27.90
ICR-45 x K-134	49.37	2.14	158.98	74.80	16.20	0.52	1.02	47.84	70.00	77.67	20.70	19.97	27.83
ICR-45 x JAL-6	50.40	2.10	191.23	69.96	12.70	0.43	1.67	50.05	61.00	80.67	24.67	19.07	27.47
ICR-45 x JUG-43	49.77	2.06	164.89	65.38	15.43	0.45	1.04	46.52	59.33	81.33	19.07	14.03	31.93
ICR-45 x JL-24	47.40	2.02	157.83	56.64	13.47	0.57	1.32	39.56	63.33	72.67	26.05	16.93	24.90
TTR-10 x K-134	48.17	2.73	161.28	67.19	14.07	0.42	1.16	45.94	70.33	75.00	16.30	16.20	19.33
TTR-10 x JAL-6	48.00	1.83	180.58	67.53	14.30	0.39	1.22	47.79	55.33	66.33	17.23	13.36	22.43
TTR-10 x JUG-43	48.83	1.86	173.13	58.89	14.60	0.47	1.32	44.14	64.00	72.33	21.63	18.70	23.67
TTR-10 x JL-24	48.43	1.85	185.57	79.45	15.33	0.47	1.40	41.20	65.33	70.33	23.00	15.83	24.90
K-134 x JAL-6	48.37	1.85	153.37	58.82	13.37	0.46	1.07	46.44	75.00	73.00	26.33	20.77	24.63
K-134 x JUG-43	46.77	1.84	149.11	53.01	13.03	0.57	1.39	46.57	60.33	73.67	29.27	26.60	36.78
K-134 x JL-24	45.93	1.74	171.12	59.03	14.13	0.63	1.36	50.34	55.33	67.67	28.27	23.17	29.03
JAL-6 x JUG-43	48.67	2.25	128.10	65.95	17.73	0.44	1.16	41.69	71.33	81.33	17.38	15.63	20.10
JAL-6 x JL-24	47.03	2.70	111.39	54.18	14.73	0.44	1.42	50.27	61.00	75.67	17.27	21.30	28.20
JUG-43 x JL-24	48.40	2.80	93.63	74.21	13.87	0.37	1.02	44.79	50.00	62.33	22.40	16.90	22.80
Mean of parents	46.40	3.17	104.07	70.20	13.73	0.43	1.22	45.28	65.96	79.92	18.07	17.75	24.02
Range among parents	41.53- 49.97	2.58- 3.58	94.00- 125.48	54.86- 82.40	12.87- 15.33	0.30- 0.51	1.03-1.65	42.15- 48.41	62.00- 72.00	66.67- 88.67	11.63- 28.17	12.73- 27.67	17.20- 38.30
Mean of F ₁ s	48.21	2.26	152.62	67.60	14.06	0.48	1.24	46.67	65.38	77.42	21.42	18.15	25.90
Range among F ₁ s	46.10- 50.40	1.74- 2.80	93.63- 191.23	53.01- 81.24	7.87- 19.77	0.30- 0.63	0.85-1.77	41.20- 51.15	50.00- 75.00	62.33- 88.33	15.00- 29.39	12.10- 26.60	19.33- 36.78
CD (0.05)	1.74	0.05	9.30	5.77	1.74	0.07	0.07	3.29	6.80	5.54	6.56	5.76	6.96

was observed in cross TIR-46 x K-134 and thick shell (1.77mm) in 84
JUG-37 x ICR-45 with a general mean of 1.24mm. Thirteen F_1 s had thin
shell compared to general mean F_1 s.

4.2.8 Oil per cent

Mean Oil per cent ranged from 42.15% (TIR-10) to 48.41% (JUG-37)
among the parents with a mean of 45.28 %. Four parents had higher oil per
cent than parental mean. Among F_1 s, TIR-10 x JL-24 recorded the
minimum (41.20%), while TIR-46 x K-134 recorded maximum (51.15%)
oil per cent with a general mean of 46.67%. Thirteen crosses exceeded the
general mean of F_1 s.

4.2.9 Shelling per cent

Mean shelling percent ranged from 62.00% (JUG-37) to 72.00%
(TIR-46) among parents and four parents exceeded the general mean of the
parents (65.96). Among F_1 s, K-134 x JAL-6 recorded as high as 75.00%
and JUG-43 x JL-24 displayed minimum (55.00%) mean shelling per cent,
the general mean being 65.38%. Twelve F_1 s had greater shelling per cent
than the general mean of F_1 s.

4.2.10 Sound mature kernel per cent (SMK per cent)

Mean SMK per cent among parents ranged from 66.67% to 88.67%,
while among F_1 s it ranged from 62.33% to 88.33%. The genotype, ICR-45
among parents (88.67%) and among F_1 s, TIR-46 x JUG-43 (88.33%)
recorded the highest SMK per cent. The mean SMK per cent of F_1 s was

lower (77.42%) than parents (79.92%). Out of 28 F_1 s fifteen F_1 s had higher SMK per cent than their general mean.

4.2.11 Number of well filled and mature pods per plant

The parent, TIR-10 recorded as low as 11.63 mean number of well filled and mature pods per plant whereas, JAL-6 displayed maximum of 28.17. Two genotypes exceeded the general parental mean (18.07). Among the F_1 s, K-134 x JUG-43 exhibited the highest number of well filled and mature pods per plant (29.27), while TIR-46 x TIR-10 (15.00) recorded the lowest number of pods per plant. Fifteen F_1 s expressed more mean number of pods per plant than general mean.

4.2.12 Kernel Yield per plant (g)

Mean kernel yield per plant ranged from 12.73g (TIR-10) to 27.67g (JUG-37) among parents. Three parents exceeded the general mean of the parents (17.75g). Among the F_1 s, it ranged between 12.10g (TIR-46 x JL-24) and 26.60g (K-134 x JUG-43) with a general mean of 18.15g. Twelve F_1 s exceeded the general mean. (Table -5)

4.2.13 Pod yield per plant (g)

The range of variation for mean pod yield per plant was between 17.20g (TIR-10) and 38.30g (JUG.37). Two genotypes viz., JUG-37 and JAL-6 recorded higher pod yield per plant than general mean (24.02 g), Among the F_1 s, K-134 x JUG-43 exhibited the highest pod yield per plant (36.78g), while TIR-10 x K-134 recorded the lowest pod yield per plant

(19.33g). Twelve F_1 s registered more pod yield per plant than general mean (25.90g).

4.3 MEAN PERFORMANCE OF PARENTS, F_1 s AND F_2 s

(KHARIF – 2003)

Mean performance of parents, F_1 s and F_2 populations during Kharif 2003 are presented hereunder (Table 6 and 7).

4.3.1 SPAD chlorophyll meter reading (SCMR)

The genotype, JL-24 recorded SCMR as low as 39.57 while ICR-45 exhibited a maximum SCMR of 48.47. The general mean of parents being 43.91. Five genotypes viz., JUG-37, ICR-45 TIR-10, K-134 and JUG-43 have shown higher SCMR than the parental mean. Ten F_1 s surpassed the general mean. SCMR among the F_1 s ranged from 40.20 to 46.57 with a general mean of 42.87. The F_1 of JUG-43 x JL-24 showed the highest SCMR (46.57) while the lowest (40.20) was observed in ICR-45 x JL-24. In F_2 populations, mean SCMR ranged from 41.30 (TIR 46 x ICR 45) to 48.50 (TIR 46 x JAL 6) with a general mean of 44.55. The F_2 population mean of 14 crosses exceeded the general mean (44.55)

4.3.2 Specific leaf Nitrogen (g N m^{-2})

The mean specific leaf nitrogen (SLN) among parents ranged from 1.56 (JL-24) to 2.41 (K-134) with a general mean of 1.96. Three parental lines viz., JUG-37, K-134 and JUG-43 recorded more mean SLN than general mean (1.96). Among F_1 s, the SLN of ICR-45 x JUG-43 was low

Table 6 : *Per se* performance of parents and F₁s for 13 characters (*Kharif-2003*)

Parents/crosses	SPAD chloro- -phyll meter read- Ing	Specific leaf nitrogen (g N/m ²)	Specific leaf area (cm ² /g)	Per cent red- uction of Fv/Fm	Root length (cm)	Harvest index	Shell thickn ess (mm)	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant (g)	Pod yield per plant (g)
Parents													
TIR-46	40.20	1.59	187.84	63.08	17.60	0.53	1.47	44.74	72.00	80.00	12.13	8.00	12.07
JUG-37	46.30	2.36	126.49	61.90	18.83	0.52	1.50	39.66	66.67	78.00	11.70	7.97	11.93
ICR-45	48.47	1.91	167.00	73.92	21.23	0.46	1.23	39.71	70.33	82.67	11.30	7.23	10.13
TIR-10	44.07	1.88	141.48	56.45	19.67	0.35	1.13	37.72	66.67	57.87	09.93	7.00	10.80
K-134	45.87	2.41	152.15	68.79	22.00	0.53	1.23	45.92	71.37	85.00	10.27	8.90	11.37
JAL-6	41.70	1.63	169.46	42.18	23.00	0.46	1.28	40.65	76.33	88.00	11.93	7.33	09.60
JUG-43	45.10	2.30	148.86	56.56	21.63	0.34	1.25	38.46	76.00	70.33	10.97	8.00	11.00
JL-24	39.57	1.56	181.93	41.42	22.17	0.45	1.12	44.57	71.00	85.87	11.07	7.73	07.44
Crosses													
TIR-46 x JUG-37	42.20	2.04	153.23	71.08	19.20	0.45	1.29	42.62	68.67	73.00	12.40	9.00	14.43
TIR-46 x ICR-45	42.60	1.59	137.17	62.89	20.60	0.50	1.18	40.41	66.00	73.00	10.37	6.40	09.60
TIR-46 x TIR-10	42.57	1.78	159.00	64.82	15.27	0.40	1.24	37.85	67.67	66.33	12.43	7.13	10.57
TIR-46 x K-134	41.93	1.93	156.08	55.01	17.13	0.48	1.48	45.55	65.00	62.33	14.33	8.40	14.47
TIR-46 x JAL-6	42.60	2.00	162.84	65.86	19.07	0.44	1.43	42.58	71.33	68.67	17.33	9.53	13.47
TIR-46 x JUG-43	41.00	1.60	159.47	55.92	17.60	0.38	1.17	42.82	63.67	66.67	12.47	8.70	14.30
TIR-46 x JL-24	42.67	1.68	172.93	52.04	20.47	0.39	0.98	41.61	66.33	56.67	09.53	7.57	11.33
JUG-37 x ICR-45	43.17	1.86	158.71	57.93	17.38	0.31	1.46	42.05	59.67	58.33	11.03	8.40	13.33
JUG-37 x TIR-10	44.77	2.00	169.44	65.64	20.73	0.33	1.58	40.78	65.67	57.33	10.53	6.50	10.53
JUG-37 x K-134	42.73	2.09	175.76	44.74	19.50	0.32	1.73	43.91	66.33	56.33	13.13	7.63	12.77
JUG-37 x JAL-6	41.83	2.45	164.77	54.67	23.57	0.32	1.63	43.31	70.33	66.67	08.00	6.73	09.20
JUG-37 x JUG-43	43.70	2.75	147.93	68.66	14.6	0.25	1.27	41.43	68.00	70.33	08.77	5.20	08.37

Contd...

Crosses	SPAD chloro- -phyll meter read- ing	Specific leaf nitro- gen (g N/m ²)	Specific leaf area (cm ² /g)	Per cent redu- ction of Fv/Fm	Root length (cm)	Harvest index	Shell thick- ness (mm)	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of mature pods per plant	Kernel yield per plant (g)	Pod yield per plant (g)
JUG-37 x JL-24	43.47	2.38	162.32	55.74	19.37	0.26	1.96	40.96	62.00	78.67	11.70	7.07	11.17
ICR-45 x TIR-10	42.47	1.91	184.79	67.01	18.39	0.36	1.21	37.78	65.00	53.33	11.80	5.73	88.80
ICR-45 x K-134	44.47	1.85	179.37	64.86	17.37	0.41	1.22	43.98	69.00	53.33	10.60	6.27	88.93
ICR-45 x JAL-6	40.53	2.04	168.06	63.72	17.44	0.34	1.46	39.53	64.00	62.67	09.13	6.13	09.60
ICR-45 x JUG-43	42.73	1.28	167.58	72.37	16.3	0.32	1.31	41.81	60.67	54.33	09.20	5.40	07.37
ICR-45 x JL-24	40.20	1.91	182.16	50.27	16.13	0.33	1.34	40.61	60.00	51.67	09.00	4.13	08.93
TIR-10 x K-134	44.50	2.11	165.25	67.33	19.50	0.35	1.06	38.74	59.00	55.67	08.03	5.50	09.33
TIR-10 x JAL-6	42.43	2.05	176.21	60.54	14.67	0.27	1.42	36.04	61.33	67.67	09.57	6.33	09.17
TIR-10 x JUG-43	46.0	1.78	187.58	61.33	20.97	0.35	1.60	43.53	66.33	66.67	11.50	6.67	10.17
TIR-10 x JL-24	40.53	1.69	207.57	64.35	14.87	0.34	1.16	44.53	69.33	56.33	10.07	6.53	08.93
K-134 x JAL-6	42.17	2.12	187.40	62.00	13.57	0.33	1.23	40.46	64.67	62.00	11.33	7.10	11.60
K-134 x JUG-43	44.20	1.67	193.13	67.76	17.97	0.36	1.37	42.33	57.00	69.67	09.07	5.53	09.07
K-34 x JL-24	42.10	1.92	186.15	39.68	19.60	0.38	1.05	43.60	69.33	65.67	09.10	7.03	10.10
JAL-6 x JUG-43	43.53	2.19	162.18	66.00	16.73	0.43	1.27	39.94	67.33	56.00	10.38	6.40	10.20
JAL-6 x JL-24	42.77	1.84	181.27	25.08	21.17	0.31	1.26	42.71	60.00	64.33	08.67	530	08.43
JUG-43 x JL-24	46.57	2.15	158.12	73.01	20.33	0.36	1.30	38.87	62.33	65.67	07.67	4.97	07.03
Mean of parents	43.91	1.96	159.40	58.04	20.77	0.46	1.28	41.43	71.30	78.47	11.16	7.77	10.54
Range among parents	39.57- 48.47	1.56- 2.41	126.49- 187.84	41.42- 73.92	17.60- 23.00	0.34-0.53	1.12- 1.50	37.72- 45.92	66.67- 76.33	57.87- 88.00	9.93- 12.13	7.00- 8.90	7.44- 12.07
Mean of F ₁ s	42.87	1.95	170.23	60.01	18.20	0.36	1.35	41.44	64.86	62.83	10.61	6.69	10.40
Range among F ₁ s	40.20- 46.57	1.28- 2.75	137.17- 207.57	25.08- 73.01	13.57- 23.57	0.25-0.50	0.98- 1.96	36.04- 44.53	57.00- 71.33	51.67- 78.67	7.67- 17.33	4.13- 9.53	7.37- 14.47
CD (0.05)	2.30	0.15	9.11	5.98	2.76	0.05	0.09	4.16	2.65	6.25	4.71	2.86	3.68

Table 7 : *Per se* performance of F₂s for 13 characters during (*Kharif* – 2003)

Parents/crosses	SPAD chloro- -phyll meter reading	Specific leaf nitro- gen (g N/ m ²)	Specific leaf area (cm ² /g)	Per cent reduct- ion of FvFm	Root length (cm)	Harvest index	Shell thick- ness (mm)	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant (g)	Pod yield per plant (g)
Crosses													
TIR-46 x JUG-37	43.70	1.45	178.34	50.71	17.33	0.43	0.87	45.01	74.87	84.67	9.03	6.40	7.80
TIR-46 x ICR-45	41.30	1.42	228.34	37.40	18.67	0.42	1.01	39.49	64.33	73.00	11.97	5.53	9.43
TIR-46 x TIR-10	47.37	1.75	158.07	44.55	18.37	0.49	0.87	42.23	72.00	80.00	12.03	7.27	10.10
TIR-46 x K-134	45.73	1.56	160.51	36.08	19.23	0.44	0.85	43.96	85.00	70.00	9.67	4.30	9.27
TIR-46 x JAL-6	48.50	1.78	160.53	31.38	21.17	0.40	1.04	41.59	80.67	62.00	11.47	5.33	8.80
TIR-46 x JUG-43	44.60	1.88	147.04	39.00	19.13	0.44	0.90	43.47	66.67	62.67	10.47	5.87	9.43
TIR-46x JL-24	44.13	1.90	182.75	40.78	22.53	0.48	0.90	41.07	70.33	61.33	11.73	6.73	9.53
JUG-37 x ICR-45	46.13	2.64	151.41	44.67	21.67	0.52	1.27	40.36	61.00	53.67	13.37	6.33	11.10
JUG-37 x TIR-10	44.00	2.09	137.12	45.78	20.17	0.38	1.24	42.48	67.67	54.33	10.80	6.23	10.17
JUG-37 x K-134	46.10	1.55	167.56	44.29	22.20	0.44	1.16	45.37	57.67	55.33	9.73	4.87	7.47
JUG-37 x JAL-6	47.17	3.27	113.72	38.84	20.43	0.39	1.15	40.12	67.67	59.67	9.30	5.40	8.07
JUG-37 x JUG-43	46.70	2.46	136.14	41.65	21.30	0.37	1.27	44.47	72.33	82.00	9.07	6.23	9.20
JUG-37 x JL-24	44.27	2.66	125.13	47.43	20.54	0.42	1.40	44.31	69.00	55.33	9.50	4.83	7.00
ICR-45 x TIR-10	45.10	1.95	143.49	37.15	20.27	0.36	1.03	44.84	60.67	55.00	12.27	5.97	9.80
ICR-45 x K-134	45.23	1.37	184.75	36.94	20.33	0.41	0.97	38.15	61.00	64.00	9.98	6.10	10.07
ICR-45 x JAL-6	45.30	1.48	201.64	51.04	20.13	0.44	1.11	39.60	61.67	60.00	9.70	4.77	7.70
ICR-45 x JUG-43	45.57	1.17	236.11	44.47	21.57	0.36	1.00	45.31	66.00	69.67	11.20	5.47	8.33
ICR-45 x JL-24	42.00	1.42	190.87	60.42	22.47	0.43	1.05	38.37	69.00	65.67	9.30	5.33	8.80
TIR-10 x K-134	43.03	1.24	163.49	68.92	20.30	0.32	0.99	42.46	63.67	52.67	9.90	5.30	8.37
TIR-10 x JAL-6	43.00	1.45	183.73	57.51	23.57	0.38	1.05	38.02	63.00	67.33	9.77	4.20	9.20
TIR-10 x JUG-43	44.43	1.39	161.40	66.24	27.90	0.38	1.03	15.38	61.67	56.67	9.43	5.13	8.37
TIR-10 x JL-24	45.47	1.21	156.97	49.56	21.80	0.34	0.94	39.21	65.33	74.00	8.83	5.30	8.80
K-134 x JAL-6	43.33	0.89	159.98	37.54	21.10	0.53	1.01	42.00	69.67	73.33	11.33	5.07	8.20
K-134 x JUG-43	44.90	1.32	135.44	61.10	22.20	0.32	1.00	42.17	67.33	69.00	9.60	4.77	7.07
K-34 x JL-24	42.10	2.12	163.45	66.53	21.23	0.45	1.00	42.75	70.67	65.00	11.60	5.57	7.87
JAL-6 x JUG-43	45.83	2.22	137.27	72.47	21.90	0.34	1.16	38.55	55.00	64.33	8.00	3.73	7.17
JAL-6 x JL-24	43.20	2.20	168.18	53.85	21.70	0.33	0.99	38.90	58.00	63.00	11.43	4.50	7.27
JUG-43 x JL-24	44.33	1.58	171.09	53.47	20.67	0.39	0.95	42.32	61.33	70.67	10.10	4.63	7.64
Mean of F ₂ s	44.55	1.97	163.33	50.65	20.99	0.42	1.09	41.39	66.48	66.38	10.56	5.92	9.15
Range among F ₂ s	41.30- 48.50	0.89- 3.27	113.72- 236.11	31.38- 72.47	17.33- 27.90	0.32-0.53	0.85- 1.40	35.38- 45.37	55.00- 85.00	52.67- 84.67	8.00- 13.37	3.73- 7.27	7.00- 11.10
CD (0.05)	2.35	0.27	16.76	4.07	4.99	0.05	0.08	3.55	6.68	6.13	2.59	1.39	2.47

(1.28) while it was high in JUG-37 x JUG-43. The overall mean of SLN 90 among F_1 s was 1.95. Thirteen out of 28 F_1 s had more specific leaf nitrogen than general mean (1.95). F_2 mean SLN ranged from 0.89(K-134 x JAL-6) to 3.27 (JUG-37 x JAL-6) with a general mean of 1.97. The mean of eight crosses combinations in F_2 generation exceeded the general mean.

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

Mean specific leaf area (SLA) ranged from 126.49 (JUG-37) to 187.84 (TIR-46) and four parental genotypes exceeded the general mean of the parents (159.40). Among F_1 s, it ranged between 137.17 (TIR-46 x ICR-45) and 207.57 (TIR-10 x JL-24) with a general mean of 170.23, which was exceeded by twelve F_1 s. Mean SLA ranged from 113.72 (JGU-37 x JAL-6) to 236.11 (ICR-45 x JUG-43) among F_2 populations derived from 28 crosses. Eleven out of 28 F_2 populations had higher SLA than F_2 general mean of 163.33 and seventeen out of 28 F_2 populations showed lower SLA than general mean of F_2 populations.

4.3.4 Per cent reduction of Fv/Fm

Mean per cent reduction of Fv/Fm among parents ranged from 41.42% (JL-24) to 73.92% (ICR-45) with a general mean of 58.04%. Four parents recorded lower per cent reduction of Fv/Fm than general mean. The mean per cent reduction of Fv/Fm in F_1 generation was 60.01% with a range of 25.08% to 73.01%. Ten F_1 s registered lower per cent reduction of Fv/Fm than general mean. The F_1 , JAL-6 x JL-24 recorded the lower mean

per cent reduction of Fv/Fm. The highest mean per cent reduction of Fv/Fm **91** was observed in JUG-43 x JL-24 (73.01). In F₂ populations, mean per cent reduction of Fv/Fm ranged from 31.38% (TIR-46 x JAL-6) to 72.47% (JAL-6 x JUG-43) with a general mean of 50.65%. Seventeen out of 28 F₂ populations recorded lower per cent reduction of Fv/Fm than general mean (50.65%).

4.3.5 Root length (cm)

The range observed for root length was from 17.60cm (TIR-46) to 23.00cm (JAL-6) and five genotypes exceeded the general mean of the parents (20.77cm). A wide range of 13.57cm (K-134 x JAL-6) to 23.57cm (JUG-37 x JAL-6) was noticed among the F₁s with a general mean of 18.20cm. Thirteen out of 28 F₁s surpassed the general mean. In F₂ generation mean root length ranged from 17.33cm (TIR-46 x JUG-37) to 27.90cm (TIR-10 x JUG-43) with a general mean value of 20.99cm. Fifteen out of 28 F₂ populations showed higher mean root length than F₂ generation mean root length. (Table 7).

4.3.6 Harvest index (HI)

The parental genotype, JUG-43 (0.34) recorded the lowest and K-134 the highest harvest index (0.53) with the general mean of 0.46. Three parents had higher harvest index than parental mean. Harvest index ranged from 0.25 to 0.50 among the F₁s with a general mean of 0.36, which was surpassed by ten F₁s. The F₁, TIR-46 x ICR-45 had the highest harvest

index (0.50) and it was lowest (0.25) in JUG-37 x JUG-43. Harvest index 92
ranged from 0.32 to 0.53 with a overall mean of 0.42 in F₂ generation.
Eleven F₂ populations mean exceeded the mean harvest index (0.42).
K-134 x JAL-6 recorded the highest harvest index (0.53). Two F₂
populations viz., TIR-10 x K-134 and K-134 x JUG-43 registered the
lowest harvest index (0.32).

4.3.7 Shell thickness (mm)

Mean shell thickness ranged from 1.12mm to 1.50mm among
parents. The genotype, JL-24 possessed the thinner shell with a shell
thickness of 1.12mm while, JUG-37 had the thickest shell with a shell
thickness of 0.50mm. Five parents recorded thin shell than parental
general mean. A wide range of 0.98mm (TIR-46 x JL-24) to 1.96mm
(JUG-37 x JL-24) was observed among F₁s with a general mean of
1.35mm. Seventeen out of 28 F₁s registered lower shell thickness than
general mean of F₁s. Among 28 F₂ population, the mean shell thickness
was minimum (0.85mm) in TIR-46 x K-134 while it was maximum
(1.40mm) in JUG-37 x JL-24. Twenty F₂ populations showed lower shell
thickness than the general mean of 1.09mm.

4.3.8 Oil per cent

Among parents, TIR-10 recorded the lower mean oil per cent
(37.72%) and K-134 exhibited the highest (45.92%). Three parental
genotypes exhibited more mean oil per cent than parental general mean

(41.43%). Among the F_1 s, it ranged from 36.04% (TIR-10 x JAL-6) to 44.53% (TIR-10 x JL-24) and fifteen F_1 s exceeded the general mean (41.44%) of F_1 s. Mean oil per cent ranged from 35.38% to 45.37% among the F_2 s with a general mean value of 41.39%. TIR-10 x JUG-43 and JUG-37 x K-134 recorded the lowest (35.38%) and highest (45.37%) mean oil per cent respectively. F_2 populations derived from sixteen crosses had higher oil per cent than general mean of F_2 populations.

4.3.9 Shelling per cent

The range of variation for shelling per cent was between 66.67% and 76.33% with a general mean of 71.30%. The genotypes, JUG-37 and TIR-10 registered the lower shelling percent of 66.67%, while maximum shelling per cent was recorded by JAL-6. Four parents exhibited more shelling per cent than general mean of parents. Mean shelling percent ranged from 57.00% (K-134 x JUG-43) to 71.33% (TIR-46 x JAL-6) among F_1 s with general of 64.86%. Sixteen F_1 s had higher mean shelling per cent than general mean of F_1 s. Among F_2 populations, JAL-6 x JUG-43 and TIR-46 x K-134 recorded the lowest (55.00%) and highest (85.00%) shelling per cent, respectively. Thirteen F_2 populations had higher shelling per cent than general mean (66.48%).

4.3.10 Sound mature kernel per cent (SMK per cent)

The mean SMK per cent among parents ranged between 57.87% (TIR-10) and 88.00% (JAL-6) with a general mean of 78.47%. Five

parental genotypes exceeded the general parental mean. Among the F_1 s, ICR-45 x JL-24 and JUG-37 x JL-24 recorded the lowest (51.67%) and highest (78.67%) SMK per cent, respectively. Fourteen F_1 s have shown higher mean SMK per cent than F_1 s general mean (62.83%). Among F_2 populations, TIR-10 x K-134 and TIR-46 x JUG-37 had the lowest (52.67%) and the highest (84.67%) SMK percent, respectively with a general mean of 66.38%. Ten F_2 populations registered high mean SMK per cent than general mean of F_2 s.

4.3.11 Number of well filled and mature pods per plant

Among parents, TIR-10 recorded the lowest mean number of well filled and mature pods per plant (9.93) while it was highest (12.13) in TIR-46, the general mean being 11.16. Four parents had higher mean number of pods than parental mean. The mean number of mature pods per plant ranged from 7.67 (JUG-43 x JL-24) to 17.33 (TIR-46 x JAL-6) among F_1 s. The general mean of 10.61 was exceeded by ten F_1 s. It ranged from 8.00 to 13.37 in F_2 generation of 28 crosses. The F_2 populations. JUG-37 x ICR-45 exhibited the highest mean number of mature pods per plant (13.37), while JAL-6 x JUG-43 had the least mean number of mature pods per plant (8.00). Eleven F_2 populations recorded more mean number of pods per plant than general mean (10.56).

4.3.12 Kernel yield per plant (g)

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Among parents, kernel yield per plant varied from 7.00 (TIR-10) to 8.90 (K-134) with a general mean of 7.77. Four parental genotypes had higher kernel yield per plant than general mean. (Table 7). The F_1 , ICR-45 x JL-24 recorded as low as 4.13g mean kernel yield per plant while TIR-46 x JAL-6 registered maximum kernel yield of 9.53g per plant with the general mean being 6.69 g. Twelve F_1 s had more kernel yield per plant than F_1 general mean. In F_2 generation kernel yield per plant ranged from 3.73 g (JAL-6 x JUG-43) to 7.27g (TIR-46 x TIR-10). Eight F_2 populations had more mean kernel yield per plant than general mean (5.92g).

4.3.13 Pod yield per plant (g)

The mean pod yield per plant ranged between 7.44g (JL-24) and 12.07g (TIR-46) with a general mean of 10.54 g among parents. Among F_1 s, ICR-45 x JUG-43 and TIR-46 x K-134 recorded the lowest (7.37g) and the highest (14.47g) pod yield per plant, respectively. Eleven F_1 s had higher mean pod yield per plant than general mean (10.40g) (Table 6). Among F_2 populations, the range of variation was between 7.00g to 11.10g with a general mean of 9.15g. The F_2 populations JUG-37 x JL-24 registered the lowest mean pod yield per plant (7.00g) while JUG-37 x ICR-45 recorded the highest pod yield per plant (11.10g). Eleven F_2 populations had higher mean pod yield per plant than F_2 general mean (9.15g).

4.4 COMBINING ABILITY

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Combining ability was studied for all the characters in 8 parents and 28 F₁s both in *rabi* 2002 and in *kharif* 2003 and are presented below (Tables 8,9,10,11,12 and 13)

4.4.1 Analysis of variance for combining ability

The analysis of variance for combining ability of 8 parents and 28F₁s for both *rabi* and *Kharif* seasons are presented in Tables 8 and 9. Mean squares due to gca and sca variances were significant for all the characters in parents and F₁s in both the seasons. The magnitude of mean squares due to gca was more than that of sca for all characters, except specific leaf nitrogen, specific leaf area and root length in *rabi* 2002. In *kharif* 2003 mean square due to gca was greater than that of sca for all characters except root length, shell thickness, and shelling percent. The estimates of variance component suggested that the estimates of sca variance components were larger than the estimates of gca variance components for all the characters except oil per cent in *rabi*. In *kharif* also estimates of sca variance component was larger than estimates of gca variance component for all the characters.

4.4.2 RABI-2002

The estimates of general combining ability (gca) effects of the eight parents and specific combining ability (sca) effects of 28 crosses for

physiological, yield and yield component characters in *rabi* (2002) are presented in Tables 10 and 11. 97

4.4.2.1 SPAD chlorophyll meter reading (SCMR)

Estimates of gca effects for SCMR varied from -1.33 (JL-24) to 0.96 (JUG-43). Three parental genotypes viz., JUG-37 (0.84), ICR-45 (0.58) and JUG-43 (0.96) showed significant positive gca effects. The parents, TIR-46 (-1.06) and JL-24 (-1.33) registered significant negative gca effects (Table-12.).

The estimates of sca effects ranged from -1.87 (K-134 x JUG-43) to 2.82 (JUG -37 x JL-24). Among 28 F₁s studied only four F₁s viz. ICR-45 x JAL-6 (2.24), JUG -37 x JL-24, TIR-10 x JL-24 (1.61) and JUG-37 x JAL-6 displayed significant positive sca effects in desirable direction and three F₁s expressed significant negative sca effects.

4.4.2.2 Specific leaf nitrogen (SLN)

For specific leaf nitrogen the minimum gca effect of -0.17 in K-134 and maximum gca effect of 0.18 in JUG-37 was noticed. Positive and significant gca effects were observed in TIR-46 (0.08), JUG-37 (0.18) and JUG-43 (0.07). Four parents viz., TIR -10 (-0.08), K-134 (-0.17), JAL-6 (-0.10) and JL-24 (-0.02) showed significant negative gca effects.

Estimates of sca effects ranged from -0.95 (TIR-46 x JUG-37) to 0.52 (K-134 x JL-24). Four F₁s recorded significant positive sca effects and they are TIR-46 x JAL-6 (0.25), K-134 x JL-24, JAL-6 x JL-24 (0.38) and

Table 8 : Combining ability analysis for 13 characters in 8 parents and 28 F₁s of groundnut (*Rabi* -2002)

Source	d.f.	SPAD chlorophyll meter reading	Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound Mature Kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Pod yield per plant
sca	7	7.25**	0.13**	392.12**	108.26**	4.03*	0.01**	0.14**	10.39**	61.91**	80.02**	24.92**	15.07**	26.90**
tca	28	2.29**	0.29**	874.31**	49.05**	4.79**	0.00	0.04**	7.71**	29.76**	34.67**	17.21**	12.28**	20.19**
Error	70	0.39	0.00	11.26	4.32	0.39	0.00	0.00	1.40	6.02	3.99	5.60	4.33	6.32
Var (gca)		0.69	0.02	38.09	10.39	0.36	0.00	0.01	0.90	5.59	7.60	1.93	1.07	2.06
Var (sca)		1.89	0.10	863.05	44.72	4.93	0.00	0.04	0.63	23.74	30.68	11.62	7.95	13.89
Var (narrow sense)		0.38	0.29	0.08	0.30	0.12	0.00	0.33	0.47	0.27	0.30	0.18	0.15	0.17

* Significant at 5 % level of probability,
* * Significant at 1 % level of probability

Table 9 : Combining ability analysis for 13 characters in 8 parents and 28 F₁s of groundnut (*Kharif-2003*)

Source	d.f.	SPAD chlorophyll meter reading	Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound mature kernel Per cent	No. of well filled & mature pods per plant	Kernel yield per plant	Pod yield per plant
gea	7	7.78**	0.19*	449.36**	243.54**	2.74*	0.01**	0.97**	13.63**	13.68*	87.17**	6.80*	2.98*	9.42**
sca	28	2.94**	0.05**	211.83**	80.52**	7.38**	0.00	3.19**	4.01*	23.85**	58.80**	4.99*	1.82*	2.86*
Error	70	0.69	0.00	10.85	4.65	1.01	0.00	0.00	2.26	6.21	5.01	2.89	1.07	1.76
Var .(gea)		0.71	0.02	43.85	23.89	0.17	0.00	0.10	1.14	0.75	2.84	0.39	0.19	0.66
Var .(sca)		2.25	0.10	200.98	75.86	6.38	0.00	3.19	1.76	17.37	53.70	2.10	0.77	1.10
h ² (narrow sense)		0.33	0.29	0.29	0.37	0.04	0.00	0.06	0.36	0.06	0.09	0.14	0.17	0.32

* Significant at 5 % level of probability,

** Significant at 1 % level of probability

Table : 10 Estimates of general combining ability effects for 13 characters in 8 parental genotypes of groundnut (*Rabi* - 2002)

Parents	SPAD chlorophyll meter reading	Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound Mature Kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Pod yield per plant
TIR-46	-1.06**	0.08**	1.67	3.01**	-0.09**	0.03**	-0.08**	1.06*	5.14**	3.63**	-1.22	-0.16	-0.31
JUG-37	0.84**	0.18**	-4.37**	4.00**	-0.16	0.00	0.24**	1.40**	-0.36	3.43**	0.26	1.80*	2.71**
ICR-45	0.58*	0.04	6.34**	3.09**	0.05	0.03**	0.03**	-0.69*	0.01	2.99**	-0.02	0.34	1.24
TIR-10	0.36	-0.08**	7.39**	1.35	0.31	-0.02*	0.00	-1.03*	-2.06*	-2.47**	-3.16**	-2.27**	-2.89**
K-134	-0.13	-0.17**	1.47	-2.94**	-0.87**	0.03**	-0.11**	1.13*	0.64	-1.71*	1.44	0.69	-0.49
JAL-6	-0.22	-0.10**	3.09**	-2.28**	0.51*	-0.04**	0.04**	-0.34	0.64	-3.07**	1.80	0.60	0.73
JUG-43	0.96**	0.07**	11.29**	-4.86**	0.74**	-0.04**	-0.13**	-0.99*	-0.66	-0.71	0.19	0.10	-0.14
JL-24	-1.33**	-0.02**	-4.31**	-1.36	0.42	0.00	0.01	-0.53	-3.36**	-1.97*	0.72	-1.08	-0.85
SE(gi)	0.19	0.03	0.99	0.62	0.19	0.01	0.01	0.35	0.73	0.60	0.70	0.62	0.74

* Significant at 5 % level of probability

** Significant at 1 % level of probability

Table 11 : Estimates of specific combining ability effects for 13 characters in 28F₁s of groundnut (*Rabi* - 2002)

Crosses	SPAD chlorophyll meter reading	Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound Mature Kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Pod yield per plant
TIR-46 x JUG-37	-1.35*	-0.95**	24.04**	-9.19**	-1.84**	-0.02	-0.38**	-0.47**	2.37	-3.92*	1.86	2.120	1.64
TIR-46 x ICR-45	-1.22**	-0.04	-1.07	-1.00	-2.45**	0.05**	-0.26**	3.78**	2.34	-4.82**	3.17	5.57**	3.11
TIR-46 x TIR-10	-0.96	-0.13	5.24	-5.58*	-1.23*	0.04	-0.19**	2.04	3.41	5.98**	-1.29	-0.79	-0.96
TIR-46 x K-134	1.02	-0.21**	8.63**	12.99**	-4.26**	-0.01	-0.20**	2.60*	0.37	-9.79**	0.09	-2.19	-0.62
TIR-46 x JAL-6	0.18	0.25**	4.56	-1.65	1.96**	-0.04	0.17**	-3.44**	-2.29	2.91	4.52*	1.44	6.69**
TIR-46 x JUG-43	0.60	-0.19**	20.36**	1.79	-2.26**	0.02	0.00	-1.01	2.01	7.54**	0.03	0.24	-2.14
TIR-46 x JL-24	1.09	0.04	7.88**	0.10	6.36**	-0.02	0.02	-2.12	-0.63	-2.52	-4.61*	-4.72*	-2.10
JUG-37 x ICR-45	-0.06	-0.28**	-3.91	-2.64	2.52**	0.01	0.26**	-2.37*	-0.16	-1.72	0.93	-0.30	-4.41
JUG-37 x TIR-10	0.86	0.09	-6.17	-7.42**	1.70**	-0.01	0.12**	3.64**	-3.76	-0.59	-1.37	-1.39	1.75
JUG-37 x K-134	-0.08	-0.16*	16.53**	2.57	-1.76**	0.01	0.05*	-1.90	0.21	5.31**	-2.67	-3.95*	-6.88**
JUG-37 x JAL-6	1.41*	-0.06	-0.19	8.31**	-0.70	-0.12**	-0.04	-0.82	6.87**	1.01	-4.00	-2.49	-3.17
JUG-37 x JUG-43	-0.41	0.06	5.76	2.42	1.87**	0.03	0.09**	1.42	4.84*	3.98*	3.11	-2.56	-2.86
JUG-37 x JL-24	2.82**	0.03	16.33**	-1.37	-1.24**	0.03	0.04	2.00	-4.79**	6.24**	4.25*	-3.45	-0.72
ICR-45 x TIR-10	1.16	-0.37**	9.19**	-5.56**	1.32*	0.08**	0.17**	-0.90	-0.79	1.18	4.38*	4.08*	3.99
ICR-45 x K-134	1.11	-0.18**	9.32**	6.47**	3.03**	-0.01	-0.14**	1.04	3.84	-1.59	-1.39	0.88	1.53
ICR-45 x JAL-6	2.24**	-0.29**	39.95**	0.97	-1.85**	-0.03	0.34**	4.71**	-5.16*	2.78	2.22	0.07	-0.06
ICR-45 x JUG-43	0.42	-0.49**	27.99**	-1.04	0.66	-0.01	-0.11**	1.84	-5.53*	1.08	-1.77	-4.46*	5.28*
ICR-45 x JL-24	0.35	-0.49**	13.95	-13.27**	-0.99	0.07**	0.04	-5.58**	1.17	-6.32**	5.13*	-0.39	1.42
TIR-10 x K-134	0.14	-0.13	10.57**	0.60	0.64	-0.06*	0.02	0.49	6.24**	1.21	-2.92	-1.28	-2.85
TIR-10 x JAL-6	0.06	-0.45**	28.25**	0.28	-0.50	0.01	-0.00	2.80*	-8.76**	-6.09**	-2.08	-3.02	-0.97
TIR-10 x JUG-43	-0.29	-0.57**	35.18**	-5.78**	-0.43	0.06*	0.19**	-0.19	1.21	-2.46	3.93	2.82	1.14
TIR-10 x JL-24	1.61**	-0.49**	40.65**	11.29**	0.63	0.02	0.14**	-3.60**	5.24*	-3.19	4.77*	1.12	3.08
K-134 x JAL-6	0.92	-0.33**	7.32*	-4.14*	0.10	0.00	-0.11**	-0.71	8.21**	-0.19	2.32	1.42	-1.16
K-134 x JUG-43	-1.87**	-0.50**	17.08**	-7.37**	-0.82	0.10**	-0.08**	0.07	-5.16*	-1.89	6.96**	7.75**	11.78**
K-134 x JL-24	-0.41	0.52**	32.12**	-4.84*	0.60	0.13**	0.22**	3.38**	-7.46**	-6.62**	5.43*	5.49*	4.82*
JAL-6 x JUG-43	0.12	-0.16*	-5.55	4.91*	2.50**	0.05*	-0.01	-3.34**	5.84*	7.14**	-4.83*	-3.12	-6.04**
JAL-6 x JL-24	0.79	0.38**	29.23**	-10.36**	-0.18	0.01	0.12**	4.78**	-1.79	2.74	-5.93*	3.27	2.76
JUG-43 x JL-24	0.97	0.31**	-32.61**	12.25**	-1.27*	-0.06*	-0.11**	-0.05	-11.49**	-12.96**	0.81	-0.18	-1.76
SE (Sii)	0.57	0.06	3.04	1.89	0.57	0.02	0.02	1.07	2.22	1.81	2.15	1.89	2.28

* Significant at 5 % level of probability

** Significant at 1 % level of probability

JUG-43 x JL-24 (0.31). As many as sixteen F_1 s exhibited significant negative sca effects. 102

4.4.2.3 Specific leaf area (SLA)

Among parents, JUG-43 recorded highly significant negative gca effect (-11.29). The gca effects varied from -11.29 (JUG-43) to 7.39 (TIR-10). Positive and significant gca effects were shown by ICR-45 and TIR-10. Significant negative gca effect was registered by JUG-37(-4.37), JUG-43 and JL-24 (-4.31).

Sca effects for specific leaf area ranged from -32.61 (JUG-43 x JL24) to 40.65 (TIR-10 x JL-24), only one F_1 , JUG-43 x JL-24 exhibited significant negative sca effect in desirable direction. As many as eighteen F_1 s showed significant positive sca effects.

4.4.2.4 Per cent reduction of F_v/F_m

The genotype, JUG-43 (-4.86) was the best general combiner for per cent reduction of F_v/F_m , whereas JUG-37 was a poor combiner (4.00) for the same trait. Gca effects of TIR-46 (3.01), ICR-45 (3.09) and JUG-37 were significant and positive, while K-134 (-2.94), JAL -6 (-2.28) and JUG-43 exhibited significant negative gca effects.

Estimates of sca effects ranged from -13.27 (ICR-45 x JL-24) to 12.99 (TIR-46 x K-134). Ten F_1 s out of 28 showed significant negative sca effects in desirable direction and significant positive sca effects were observed in eleven F_1 s.

4.4.2.5 Root length

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For root length, gca effects varied from -0.87 (K-134) to 0.74 (JUG-43). Positive and significant of gca effects were shown by JAL-6 (0.51) while negative significant gca effects in TIR-46 (-0.09).

Estimates of sca effect for root length ranged from -4.26 (TIR-46 x K-134) to 6.36 (TIR-46 x JL-24). Eight F_1 s showed positive significant sca effect in desirable direction. Negative and significant sca effects were observed in nine F_1 s.

4.4.2.6 Harvest Index

Harvest index recorded gca effects that ranged from -0.04 (JAL-6 and JUG-43) to 0.03 (TIR-46, ICR-45 and K-134). Three genotypes viz., TIR-46, ICR-45 and K-134 exhibited significant positive gca effects, while TIR-10, JAL-6 and JUG-43 showed significant negative gca effects (Table 10).

The sca effects for harvest index ranged between -0.12 (JUG-37 x JAL-6) and 0.13 (K-134 x JL-24). Seven F_1 s exhibited significant positive sca effects while three F_1 s viz., JUG-37 x JAL-6, TIR-10 x K-134 and JUG-43 x JL-24 showed significant negative sca effects.

4.4.2.7 Shell thickness

For shell thickness the minimum gca effect of -0.13 (JUG-43) and maximum gca effect of 0.24 (JUG-37) were observed. Highly significant

positive gca effects were observed in JUG-37, ICR-45 (0.03) and JAL-6 (0.04). TIR-46 (-0.08), K-134 (-0.11) and JUG-43 showed significant and negative gca effects.

Shell thickness recorded, sca effect ranging from -0.38 (TIR-46 x JUG-37) to 0.34 (ICR-45 x JAL-6). Eleven F_1 s has shown positive significant sca effects. Negative significant sca effects were observed in nine crosses.

4.4.2.8 Oil per cent

The gca effects ranged from -1.03 (TIR-10) to 1.40 (JUG-37) for oil per cent. Highly significant and positive gca effects were observed in TIR-46 (1.06), JUG-37 and K-134 (1.13), while ICR-45 (-0.69), TIR-10 and JUG-43 (-0.99) have showed significant negative gca effects.

Estimates of sca effects for oil per cent ranged from -5.58 (ICR-45 x JL-24) to 4.78 (JAL-6 x JL-24). Seven F_1 s viz., JAL-6 x JL-24, K-134 x JL-24, TIR-46 x ICR-45 (3.78), TIR-46 x K-134 (2.60), JUG-37 x TIR-10 (3.64), ICR-45 x JAL-6 (4.71) and TIR-10 x JAL-6 (2.80) recorded positive significant sca effects. Six F_1 s exhibited significant negative sca effects.

4.4.2.9 Shelling per cent

The gca effects ranged from -3.36 (JL-24) to 5.14 (TIR-46). Highly significant and positive gca effects were observed in TIR-46 whereas significant negative gca effects were registered by JL-24 and TIR-10 (-2.06).

The lowest sca effects (-11.49) for shelling per cent were observed in F_1 of JUG-43 x JL-24, while the highest positive significant sca effects were recorded by F_1 K-134 x JAL-6 (8.21). Other F_1 s which have shown positive significant sca effects were viz., JUG-37 x JAL-6 (6.87), JUG-37 x JUG-43 (4.84); TIR-10 x K—134 (6.24) TIR-10 x JL-24 (5.24), K-134 x JAL-6 and JAL-6 x JUG-43 (5.84). As many as eight F_1 s exhibited significant negative sca effect.

4.4.2.10 Sound mature kernel per cent (SMK per cent)

The gca effects for SMK per cent ranged from -3.07 (JAL-6) to 3.63 (TIR-46). Positive and significant gca effects were observed in TIR-46, JUG-43 (3.43) and ICR-45 (2.99). The genotype TIR-10 (-2.47), K-134 (-1.71), JL-24 (-1.97) and JAL-6 showed significant and negative gca effects.

Sca effect for SMK per cent varied from -12.96 (JUG-43 x JL-24) to 7.54 (TIR-46 x JUG-43). Five F_1 s exhibited significant positive sca effects. Significant negative sca effects were observed in seven F_1 s .

4.4.2.11 Number of well filled and mature pods per plant

The genotype TIR-10 (-3.16) only showed significant negative gca effect during *khari*f. The gca effects ranged from -3.16 (TIR-10) to 1.80 (JAL-6). The lowest significant sca effect (-5.93) was observed in F_1 of JAL-6 x JL-24, whereas the highest significant positive sca effect (6.96) was recorded by F_1 of K-134 x JUG-43. Seven more F_1 s also exhibited

significant positive sca effect. Three F_1 s showed significant negative sca effects.

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4.4.2.12 Kernel yield per plant

Kernel yield per plant registered gca effects that varied from -2.27 (TIR-10) to 1.80 (JUG-37). Parents TIR-10 and JUG-37 recorded negative and positive significant gca effects respectively.

Kernel yield per plant registered sca effect which varied from -4.72 (TIR-46 x JL-24) to 7.75 (K-134 x JUG-43). Other F_1 s which showed significant positive sca effects were TIR-46 x ICR-45 (5.57) and ICR-45 x TIR-10

4.4.2.13 Pod yield per plant

When pod yield per plant was taken into account, the range observed was from -2.89 (TIR-10) to 2.71 (JUG-37). Significant positive and negative gca effects were noticed in genotypes JUG-37 and TIR-10, respectively (Table 10).

The lowest significant sca effect was observed in F_1 , JUG-37 x K-134 (-6.88) while the highest positive significant sca effect was exhibited by F_1 K-134 x JUG-43 (11.78). Four crosses viz., TIR-46 x JAL-6 (6.69), ICR-45 x JUG-43 (5.28), K-134 x JUG-43 and K-134 x JL-24 (4.82) showed significant positive sca effects. Negative significant sca effects were recorded in F_1 s, JUG-37 x K-134 (-6.88) and JAL-6 x JUG-43 (-6.04).

4.4.3 KHARIF -2003

General combining ability (gca) effects of parents and specific combining ability (sca) effects of 28 crosses for physiological, yield and yield components during *kharif* (2003) are presented below. (Tables 11 and 13).

4.4.3.1 SPAD chlorophyll meter reading (SCMR)

The gca effects for SCMR were varied between -1.19 (TIR-46) and 1.01 (JUG-43). Three parental genotype, viz., JUG-37 (0.65), K-134 (0.59) and JUG-43 (1.01) recorded significant positive gca effects and remaining three parents viz., TIR-46 (-1.19), JAL-6 (-0.87) and JL-24 (-1.05) exhibited significant negative gca effects.

The F_1 , ICR-45 x JL-24 recorded the lowest sca effects (-2.37) while the highest in JUG-43 x JL-24 (3.50). Four F_1 s viz., JUG-43 x JL-24, TIR-46 x JL-24 (1.80) JAL-6 x JL-24 (1.58) and TIR-46 x JAL-6 (1.55) expressed significant positive sca effects, whereas significant negative sca effects were observed in other six F_1 s.

4.4.3.2 Specific leaf nitrogen (SLN)

Gca effects for SLN ranged from -0.19 (TIR-46) to 0.26 (JUG.37). Three parents viz., JUG-37 (0.26), K-134 (0.08) and JUG-43 (0.08) showed positive significant gca effects. The parents, TIR-46 (-0.19), ICR-45 (-0.09) and TIR-10 (-0.06) also registered significant negative gca effects (Table 11).

Table 12 : Estimates of general combining ability effects for 13 characters in 8 parental genotypes of groundnut (*Kharif- 2003*)

Parents	SPAD chlorophyll meter reading	Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound Mature Kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Pod yield per plant
TIR-46	-1.19**	-0.19**	-0.70	1.76*	-0.47	0.07**	-0.04**	1.00	1.61'	4.55**	1.65**	1.04*	1.80**
JUG-37	0.65*	0.26**	-13.43**	0.61	0.33	-0.01	0.23**	0.15	-0.26	3.55**	0.22	0.41	0.93*
ICR-45	0.52	-0.09**	2.84*	5.07**	-0.20	0.01	-0.04**	-0.74	-1.16	-0.92	-0.30	-0.54	-0.99*
TIR-10	0.34	-0.06**	1.34	2.78**	-0.49	-0.03**	-0.06**	-1.82**	-0.89	-4.25**	-0.30	-0.40	-0.52
K-134	0.59*	0.08**	2.80*	0.28	-0.02	0.03**	-0.05**	1.75**	-0.36	-2.62**	-0.06	0.29	0.47
JAL-6	-0.87**	0.02	2.22	-5.38**	0.30	-0.01	0.02	-0.71	1.51	-0.12	0.21	-0.01	-0.35
JUG-43	1.01**	0.08**	-4.57**	4.20**	-0.14	-0.03**	0.02	-0.53	0.08	0.88	-0.53	-0.35	-0.58
JL-24	-1.05**	-0.10	9.50**	-9.31**	0.71*	-0.02**	-0.08**	0.91	-0.25	-0.108	-0.89	-0.43	-0.76
SE(gi)	0.25	0.01	0.98	0.64	0.30	0.01	0.01	0.44	0.74	0.67	0.50	0.31	0.39

* Significant at 5 % level of probability
* * Significant at 1 % level of probability

Table : 13 Estimates of specific combining ability effects for 13 characters in 28F₁s of groundnut
(*Kharif- 2003*)

Crosses	SPAD chlorophyll meter reading	Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound Mature Kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Pod yield per plant
TIR-46 x JUG-37	-0.37	0.01	-1.46	9.13**	0.54	0.02	-0.24**	0.03	1.03	0.33	-0.22	0.62	1.22
TIR-46 x ICR-45	0.17	-0.10*	2.20	-3.52	2.46*	0.05**	-0.08**	-1.29	-0.74	4.70*	-1.73	-1.02	-1.69
TIR-46 x TIR-10	0.30	0.06	-10.46**	0.71	-2.57**	-0.02	-0.01	2.76	0.66	1.46	0.33	-0.44	-1.19
TIR-46 x K-134	-0.57	0.07	-14.84**	-6.60**	-1.18	0.00	0.23**	1.37	-2.54	-4.17	2.00	0.14	1.72
TIR-46 x JAL-6	1.55**	0.20**	-7.51*	9.92**	0.43	0.00	0.11**	0.85	1.93	-0.34	4.83**	1.58	1.54
TIR-46 x JUG-43	-1.83**	-0.26**	-4.08	-9.62**	-0.59	-0.04*	-0.16**	0.91	-4.30	-3.34	0.60	1.08	2.61*
TIR-46 x JL-24	1.80**	0.00	-4.69	0.02	1.43	-0.04*	-0.25**	-1.73	-1.04	-11.37**	-1.98	0.03	-0.19
JUG-37 x ICR-45	-1.10	-0.27**	0.47	-7.32**	-1.10	-0.06**	-0.07*	1.20	-5.20*	-8.87**	0.36	1.60	2.91*
JUG-37 x TIR-10	0.66	-0.17**	12.70**	2.68	2.10*	-0.01	0.06*	1.02	0.53	-6.54**	-0.14	-0.44	-0.36
JUG-37 x K-134	-1.61**	-0.22**	17.56**	-15.72**	0.39	-0.07**	0.21**	0.58	0.66	-9.17**	2.22	0.00	0.89
JUG-37 x JAL-6	-1.06	0.20**	7.15*	-0.12	4.14**	-0.04*	0.04	2.43	2.80	-1.34	-3.18*	-0.59	-1.87
JUG-37 x JUG-43	-1.07	0.44**	-2.90	4.28*	-4.38**	-0.09**	0.13**	0.38	1.90	1.33	-1.67	-1.79	-2.46*
JUG-37 x JL-24	0.76	0.26**	2.257	4.87*	-0.47	-0.09**	0.47**	-1.51	-3.50	11.63**	1.62	0.15	0.51
ICR-45 x TIR-10	-1.50	0.10*	11.79**	-0.42	0.82	0.01	-0.03	-1.10	0.76	-6.07**	1.65	-0.26	-0.17
ICR-45 x K-134	0.26	-0.11*	4.90	-0.07	-0.85	0.00	-0.03	1.53	4.23	-7.71**	0.21	-0.41	-1.01
ICR-45 x JAL-6	-2.22**	0.14**	-5.83	4.47*	-1.47	-0.04*	0.15**	-0.47	-2.64	-0.87	-1.52	-0.24	0.45
ICR-45 x JUG-43	-1.90*	-0.14**	0.48	3.52	-2.16*	-0.04*	-0.01	1.64	-4.54	-10.21**	-0.72	-0.64	-1.54
ICR-45 x JL-24	-2.37**	0.13*	1.0	-5.06*	-3.18**	-0.04*	0.12**	-1.00	-4.60	-10.91**	-0.56	-1.83	-2.17
TIR-10 x K-134	0.46	0.13**	-7.72*	4.70*	1.21	-0.03	-0.18**	-2.62	-6.04**	-2.04	-2.36	-1.32	-1.09
TIR-10 x JAL-6	-0.15	0.12**	3.83	3.58	-3.94**	-0.07**	0.11**	-2.86*	-5.57*	7.46**	-1.10	-0.19	-0.44
TIR-10 x JUG-43	1.54	-0.21**	21.99**	-5.22**	2.80**	0.03	0.30**	4.44**	0.86	5.46*	1.58	0.48	0.79
TIR-10 x JL-24	-1.87**	-0.11*	27.91**	11.32**	-4.15**	0.01	-0.05	4.01*	4.46	-2.91	0.50	0.43	-0.27
K-134 x JAL-6	-0.66	0.01	13.55**	7.54**	-5.51**	-0.07**	-0.09**	-2.02	-2.77	0.16	0.44	-0.11	1.00
K-134 x JUG-43	-0.50	-0.46**	26.08**	3.71	-0.67	-0.02	0.06*	-0.32	-9.00**	6.83**	-1.09	-1.34	-1.30
K-134 x JL-24	-0.54	-0.02	5.03	-10.87**	0.11	-0.01	-0.17**	-0.26	-0.54	-9.34**	0.40	-0.17	0.65
JAL-6 x JUG-43	0.29	0.12**	-4.29	7.62**	-2.22*	0.09**	-0.11**	-0.26	-0.54	-9.34**	0.40	-0.17	0.65
JAL-6 x JL-24	1.58*	-0.05	0.37	-19.78**	1.36	-0.05**	-0.02	1.06	-7.27**	0.96	-1.40	-1.16	-0.94
JUG-43 x JL-24	3.50**	0.20*	-15.63**	18.55**	0.97	0.02	0.02	-2.95*	-3.50	1.29	-1.66	-1.19	-2.11
SE (Sij)	0.75	0.04	2.99	1.95	0.91	0.02	0.21	1.36	2.26	2.05	1.54	0.94	1.20

The sca effects ranged from -0.46 to 0.44. The F_1 s, K-134 x JUG-43 (-0.46) and JUG-37x JUG-43 (0.44) recorded the lowest and the highest sca effects, respectively. Eleven F_1 s showed positive significant sca effects, whereas ten F_1 s exhibited negative significant sca effects.

4.4.3.3 Specific leaf area (SLA)

Gca effects for SLA varied from -13.43 (JUG-37) to 9.50 (JL-24). The genotypes, ICR-45 (2.84) and K-134 (2.80) also showed significant positive gca effects, while JUG-43 (-4.57) exhibited significant negative gca effect.

Among the F_1 s, JUG-43 x JL-24 recorded highly significant negative sca effect of -15.63 whereas TIR-10 x JL-24 (27.91) showed highly positive significant sca effect. Positive significant sca effect was observed in eight F_1 s, while four F_1 s exhibited negative significant sca effects in desirable direction (Table 13).

4.4.3.4 Per cent reduction of F_v/F_m

Gca effects varied between -9.31 (JL-24) and 5.07 (ICR-45). The significant gca effects in positive direction were observed in TIR-46 (1.76), ICR-45 (5.07), TIR-10 (2.78) and JUG-43 (4.20) while significant negative gca effects was recorded by JAL-6 (-5.38) and JL-24.

The lowest significant sca effect was observed in cross JAL-6 x JL-24 (-19.78), while the highest significant sca effects was showed by JUG-43 x JL-24 (18.55). As many as eight F_1 s registered significant and

negative sca effects in desirable direction. Positive significant sca effect was noticed in ten F_1 s .

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4.3.5 Root length

When root length was taken in to account, the gca effects ranged from -0.49 (TIR-10) to 0.71 (JL-24) and only one genotype i.e. JL-24 showed positive significant gca effect.

Four F_1 s viz., TIR 46 x ICR-45, JUG-37 x TIR-10, TIR-10 x JUG-43 and JUG-37 x JAL-6 exhibited significant positive sca effects and eight F_1 s exhibited significant negative sca effects. The range of sca effects in F_1 s varied from -5.51 (K-134 x JAL-6) to 4.14 (JUG-37 x JAL-6).

4.3.6 Harvest Index

Estimates of gca effects for harvest index ranged from -0.03 (TIR-10 and JUG-43) to 0.07 (TIR-46). Three parental genotypes viz., TIR-10, JUG-43 and JL-24 (-0.02) exhibited significant negative gca effects, while TIR-46 and K-134 (0.03) showed significant positive gca effects.

Sca effects among F_1 s ranged from -0.09 (JUG-37 x JUG-43, JUG-37 x JL-24) to 0.09 (JAL-6 x JUG-43). Only two F_1 s namely, TIR-46 x ICR-45 and JAL-6 x JUG-43 showed significant positive sca effects whereas as many as thirteen F_1 s exhibited significant negative sca effects.

Gca effects for shell thickness ranged from -0.08 (JL-24) to 0.23 (JUG-37). Five parental genotypes registered significant negative gca effects and they are TIR-46 (-0.04), ICR 45 (-0.04), TIR-10 (-0.06), K-134 (-0.05) and JL-24. Only JUG-37 showed positive significant gca effect.

Seven out of twenty eight F_1 s exhibited significant negative sca effects in desirable direction for shell thickness. Positive significant sca effect was observed in eleven F_1 s. The F_1 s, TIR-46 x JL-24 and JUG-37 x JL-24 recorded the lowest (-0.25) and the highest (0.47) significant sca effects

4.4.3.8 Oil per cent

Oil per cent recorded gca effects ranging from -1.82 (TIR-10) to 1.75 (K-134). Sca effects for oil per cent ranged from -2.95 (JUG-43 x JL-24) to 4.44 (TIR-10 x JUG-43). The positive significant sca effect was observed in F_1 s, TIR-10 x JUG-43 and TIR-10 x JL-24.

4.4.3.9 Shelling per cent

Gca effects for shelling per cent ranged from -1.16 (ICR-45) to 1.61 (TIR-46). None of the parents recorded significant gca effects. Estimates of sca effects ranged from -9.00 (K-134 x JUG-43) to 4.46 (TIR-10 x JL-24). None of the F_1 s exhibited significant positive sca effects, while significant negative sca effects were observed in five F_1 s.

4.4.3.10 Sound mature kernel per cent (SMK per cent)

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Gca effects ranged from -4.25 (TIR-10) to 4.55 (TIR-46). Highly significant and positive gca effects exhibited by TIR-46 and JUG-37 (3.55), whereas negative and significant gca effects was observed in TIR-10 and K-134 (-2.62). Sca effects ranged from -11.37 (TIR-46 x JL-24) to 11.63 (JUG-37 x JL-24). Significant positive sca effects were observed in five F_1 s while significant negative sca effects were noticed in ten F_1 s.

4.4.3.11 Number of well filled and mature pods per plant

Estimates of gca effects for number of mature pods per plant ranged from -0.89 (JAL-6) to 1.65 (TIR-46). Only one parent (TIR-46) showed positive significant gca effect. None of the parents exhibited significant negative gca effects. Sca effects ranged from -3.18 (JUG.37 x JAL-6) to 4.83 (TIR-46 x JAL-6). Except above two F_1 s, none of the F_1 s exhibited either positive or negative significant sca effects.

4.4.3.12 Kernel yield per plant

Estimates of gca effects varied from -0.54 (ICR-45) to 1.04 (TIR-46). Significant and positive gca effect was observed in TIR-46. None of the parents showed significant negative gca effects. Sca effects ranged from -1.83 (ICR-45 x JL-24) to 1.60 (JUG-37 x ICR-45). None of the crosses showed either positive or negative significant sca effects.

4.3.13 Pod Yield per plant

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Estimates of gca effects for pod yield per plant ranged from -0.99 (ICR-45) to 1.80 (TIR-46). Positive significant gca effect was recorded in TIR-46 and JUG-37 (0.93) while ICR-45 showed significant negative gca effect. Sca effects among F_1 s varied from -2.46 (JUG-37 x JUG-43) to 2.91 (JUG-37 x ICR-45). Only one F_1 , (JUG-37 x JUG-43) exhibited negative and significant sca effect. Positive and significant sca effect was observed in two F_1 s, TIR-46 x JUG-43 (2.61) and JUG-37 x ICR-45.

4.5 HETEROSIS AND INBREEDING DEPRESSION

Heterosis or hybrid vigour is measured as an increase or decrease of a trait over better parent (heterobeltiosis), mid-parental value (relative heterosis) and standard parent (standard heterosis). Inbreeding depression for physiological, yield and yield component characters are computed and presented in Tables 14 to 26.

4.5.1 RABI - 2002

4.5.1.1 SPAD chlorophyll meter reading (SCMR)

Heterobeltiosis for SCMR ranged from -6.40 (K-134 x JUG-43) to 20.77 (JUG-37 x JL-24). Among twenty eight F_1 s studied, seven F_1 s exhibited significant positive heterosis over better parent. Out of remaining

twenty one F_1 s, one F_1 recorded significant and negative heterosis over better parent.

The range of heterosis over mid parent varied from -3.67 (K-134 x JUG-43) to 12.11 (JUG-37 x JL-24). Significant positive heterosis was observed in fifteen F_1 s, while significant negative heterosis was noticed in only one F_1 . (Table 14).

Standard heterosis ranged from -2.55 (K-134 x JL-24) to 6.94 (ICR-45 x JAL-6). Significant positive heterosis was observed in ten F_1 s.

4.5.1.2 Specific leaf nitrogen

Heterobeltiosis ranged from -49.04 (TIR-46 x JUG-37) to -1.58 (JAL-6 x JL-24). Relative heterosis ranged from -47.18 (TIR-46 x JL-24) to 1.50 (JAL-6 x JL-24). Standard heterosis ranged from -44.05 (K-134 x JL-24) to -9.97 (JUG-43 x JL-24). None of the F_1 s recorded significant positive heterosis over better parent, mid parent and standard parent (Table 15).

4.5.1.3 Specific leaf area

Heterobeltiosis ranged from 2.50 (JAL-6 x JL-24) to 94.98 (TIR-10 x JL-24). Significant and positive heterosis was observed in all twenty eight F_1 s. The range of heterosis over mid parent varied from -4.86 (JAL-6 x JL-24) to 82.07 (TIR-10 x JL-24). Out of twenty eight F_1 s, twenty six F_1 s recorded significant positive heterosis over mid parent (Table16). Standard heterosis ranged from -0.39 (JUG-43 x JL-24) to 103.44

(ICR-45 x JAL-6). Out of twenty eight F_1 s, twenty one F_1 s recorded significant positive heterosis over standard parent.

4.5.1.4 Per cent reduction of Fv/Fm

Heterobeltiosis ranged from -17.37 (ICR-45 x JL-24) to 37.33 (TIR-46 x K-134). Significant and negative heterosis in desirable direction was observed in eight F_1 s. Ten F_1 s recorded positive significant heterosis.

The heterosis over mid parent ranged from -24.95 (ICR-45 x JL-24) to 20.73 (TIR-46 x K-134). Five F_1 s recorded significant positive heterosis over mid parent, while eleven F_1 s showed significant negative heterosis (Table 17). Standard heterosis ranged from -8.42 (JAL-6 x JL-24) to 37.33 (TIR-46 x K-134). Significant and positive heterosis over standard parent was observed in two F_1 s.

4.5.1.5 Root length

Heterobeltiosis for root length ranged from -43.47 (TIR-46 x K-134) to 42.55 (TIR-46 x JL-24). Seven F_1 s each recorded significant positive and negative heterosis over better parent. Relative heterosis was minimum in the F_1 , TIR-46 x K-134 (-42.51) and it was maximum in the F_1 , TIR-46 x JL-24 (47.88). Eight F_1 s recorded significant positive heterosis, while six F_1 s registered significant negative heterosis over mind parent. Standard heterosis ranged from -41.70 (TIR-46 x K-134) to 46.44 (TIR-46 x JL-24). Significant and positive heterosis over standard parent was observed in eight F_1 s (Table 18).

Heterobeltiosis was minimum in the F_1 , JUG-37 x JAL-6 (-38.51) and was maximum in K-134 x JL-24 (38.24). Eight and four F_1 s recorded significant positive and negative heterosis over better parent, respectively (Table 19). Relative heterosis ranged from -35.29 (JUG-37 x JAL-6) to 51.00 (K-134 x JUG-43 and K134 x JL-24). As many as fourteen F_1 s recorded significant positive heterosis over mid parent while significant negative heterosis was observed in F_1 s, TIR-46 x JAL6 and JUG-37 x JAL-6.

Standard heterosis ranged from -17.78 (JUG-43 x JL-24) to 40.00 (K-134 x JL-24). Significant and positive heterosis in desirable direction was observed in eighteen F_1 s.

4.5.1.7 Shell thickness

The minimum and maximum heterosis over better parent was observed in F_1 s TIR-46 x JUG-37 (-31.97) and JUG-37 x ICR-45 (52.83) respectively. Positive and significant heterosis was noticed in eighteen F_1 s. Six F_1 s exhibited significant negative heterosis over better parent. Relative heterosis ranged from -35.82 (TIR-46 x K-134) to 44.74 (ICR-45 x JAL-6). Fourteen F_1 s exhibited positive significant relative heterosis. Significant negative heterosis over mid parent was observed in seven F_1 s. Standard heterosis ranged from -26.09 (TIR-46 x K-134) to 53.91 (JUG-37 x ICR45). Significant and positive heterosis over standard parent was observed in eighteen F_1 s. (Table 20)

4.5.1.8 Oil per cent

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Heterosis over better parent for oil per cent ranged from -13.81 (ICR-45 x JL-24) to 10.25 (TIR-10 x JL-24). Four F_1 s recorded significant positive heterosis while three F_1 s exhibited significant and negative heterosis (Table 21). The F_1 s recorded minimum and maximum relative heterosis are ICR-45 x JL-24 (-11.71) and ICR-45 x JAL-6 (14.51), respectively. Nine F_1 s registered significant positive heterosis and one F_1 showed significant negative heterosis. Standard heterosis ranged from -10.69 (TIR-10 x JL-24) to 10.88 (TIR-46 x K-134). None of the F_1 s recorded significant positive heterosis over standard parent.

4.5.1.9 Shelling per cent

Heterobeltiosis ranged from -27.18 (JUG-43 x JL-24) to 14.80 (K-134 x JAL-6). Two F_1 s recorded significant positive heterosis over better parent. The F_1 s that recorded the lowest and the highest relative heterosis are JUG-43 x JL-24 (-27.01) and K-134 x JAL-6 (16.28), respectively. Significant positive heterosis was observed in five F_1 s. Six F_1 s registered significant negative heterosis. Standard heterosis ranged from -21.47 (JUG-43 x JL-24) to 17.79 (K-134 x JAL-6). None of the F_1 s recorded significant heterosis over standard parent. (Table 22)

4.5.1.10 Sound mature kernel per cent

The F_1 s, K-134 x JL-24 and JAL-6 x JUG-43 recorded the lowest (-20.70) and the highest heterosis (7.96) over better parent, respectively.

Eighteen F_1 s expressed significant negative heterosis. Relative heterosis ranged from -22.41 (JUG-43 x JL-24) to 14.55 (JAL-6 x JUG-43). Five F_1 s recorded significant positive heterosis and eight F_1 s significant negative heterosis. Standard heterosis ranged from -23.36 (JUG-43 x JL-24) to 8.61 (TIR-46 x JUG-43). None of the F_1 s recorded significant heterosis over standard parent (Table 23).

4.5.1.11 Number of well filled and mature pods per plant

Better parent heterosis ranged from -38.82 (TIR-10 x JAL-6) to 54.07 (ICR-45 x JL-24). Four F_1 s recorded significant positive heterosis (Table 24). Significant negative heterosis was observed in F_1 s, JUG-37 x JAL-6 and TIR-10 x JAL-6. The minimum and maximum heterosis over mid parent was observed in F_1 s, JAL-6 x JL-24 (-28.88) and ICR-45 x TIR-10 (68.64), respectively. Nine F_1 s recorded significant positive heterosis over midparent. Standard heterosis ranged from -23.97 (TIR-46 x TIR-10) to 48.35 (K-134 x JUG-43). None of the F_1 s recorded significant heterosis over standard parent.

4.5.1.12 Kernel yield per plant

The $F_{1,1}$ JUG-37 x JL-24 recorded the lowest heterosis over better parent (-44.56). The maximum heterobeltiosis was observed in F_1 , K-134 x JL-24 (73.10). Three F_1 s registered positive significant heterosis while negative significant heterosis was observed in seven F_1 s. Relative heterosis ranged from -28.29 (JUG-37 x JL-24) to 59.44

(K-134 x JUG-43). Twelve F₁s recorded significant positive heterosis while seven F₁s significant negative heterosis (Table 25). Standard heterosis ranged from -13.07 (TIR-10 x JAL-6) to 73.06 (K-134 x JUG-43). None of the crosses recorded significant heterosis over standard parent.

4.5.1.13 Pod yield per plant

Heterobeltiosis ranged from -45.43 to 62.63. The highest heterosis was observed in F₁, K-134 x JUG-43. The lowest heterosis was noticed in -45.34 (JUG-37 x K-134). Five F₁s recorded significant positive heterosis while eight F₁s registered significant negative heterobeltiosis (Table 26).

Relative heterosis ranged from -29.83 (JUG-37 x K-134) to 66.43 (K-134 x JUG-43). Six F₁s recorded significant positive heterosis and two F₁s significant negative heterosis. Standard heterosis ranged from -9.12 (TIR-10 x K-134) to 72.92 (K-134 x JUG-43). None of the F₁s recorded significant heterosis over standard parent.

4.5.2 KHARIF 2003

4.5.2.1 SPAD chlorophyll meter reading

The heterosis over better parent varied from -17.6 (ICR-45 x JL-24) to 6.14 (TIR-46 x JL-24). Only one F₁, TIR-46 x JAL-6 recorded significant positive heterobeltiosis. As many as fifteen F₁s showed significant negative heterobeltiosis. Relative heterosis ranged from -10.09 to 10.00. Significant positive relative heterosis was observed in F₁s, TIR-46 x JL-24, JAL-6 x JUG-43 and JAL-6 x JL-24 while significant

negative relative heterosis was noticed in nine F_1 s. Standard heterosis ranged from -11.64 (ICR-45 x JAL-6 and ICR-45 x JL-24) to 1.53 (JUG-43 x JL-24). None of the crosses recorded significant heterosis over standard parent (Table 14).

Inbreeding depression ranged from -13.85 (TIR-46 x JAL-6) to 4.8 (JUG-43 x JL-24). One F_2 , JUG-43 x JL-24 recorded significant positive inbreeding depression. As many as twelve F_2 s exhibited significant negative inbreeding depression. Non-significant positive and negative inbreeding depression was observed in five and ten F_2 s respectively.

4.5.2.2 Specific leaf nitrogen

Heterobeltiosis ranged from -30.60 (K-134 x JUG-43) to 22.31 (TIR-46 x JAL-6). Four F_1 s, TIR-46 x JAL-6, JUG-37 x JUG-43, and TIR-10 x JAL-6 and JAL-6 x JL-24 recorded significant positive heterosis while negative and significant heterosis was observed in fifteen F_1 s.

The relative heterosis for SLN varied from -28.97 (K-134 x JUG-43) to 23.89 (TIR-46 x JAL-6). Ten out of twenty eight F_1 s registered significant positive heterosis while eight F_1 s significant and negative heterosis. Standard heterosis ranged from -34.02 (TIR-46 x ICR-45) to 46.88 (ICR-45 x JUG-43). Significant positive heterosis over standard parent was observed in two F_1 s.

Inbreeding depression in F_2 generation ranged from -41.97 (JUG-37 x ICR-45) to 57.98 (K-134- x JAL-6). Inbreeding depression in positive

significant direction was recorded in seventeen F_2 s whereas significant negative inbreeding depression was observed in seven F_2 s. Only one F_2 , TIR-46 x TIR-10 recorded non-significant positive inbreeding depression while non-significant negative inbreeding depression was observed in four F_2 s.

4.5.2.3 Specific leaf area

Heterobeltiosis ranged from -4.94 (TIR-46 x JL-24) to 46.72 (TIR-10 x JL-24). Positive significant heterobeltiosis was observed in seventeen F_1 s. Only one F_1 , TIR-46 x JL-24 had significant negative heterobeltiosis. Fifteen F_1 s recorded significant positive relative heterosis. The highest significant positive relative heterosis was observed in F_1 , TIR-10 x JUG-43 (29.22). Four F_1 s exhibited significant negative relative heterosis. The lowest heterosis over mid parent was recorded by TIR-46 x JAL-6 (-8.85). Standard heterosis ranged from -9.85 (TIR-46 x ICR-45, ICR-45 x JAL-6 and ICR-45 x JL-24) to 36.42 (TIR-10 x JL-24). None of the crosses recorded significant heterosis over standard parent.

Inbreeding depression was significant in eighteen F_2 s. Inbreeding depression ranged from -40.89 (ICR-45 x JUG-43) to 30.98 (JUG-37 x JAL-6). Thirteen and five F_2 s recorded significant positive and negative inbreeding depression respectively. Five F_2 s each exhibited non-significant positive and negative inbreeding depression

Table 14 : Estimates of Heterosis and Inbreeding depression for SPAD chlorophyll meter reading in groundnut

Crosses	Rabi/2002			Kharif/2003			Inbreeding depression (%)
	Heterosis (%)			Heterosis (%)			
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	-3.48	-1.53	-1.90	-8.86**	-2.43	-8.00	-3.55
TIR-46 x ICR-45	-1.85	-0.82	-2.18	-12.10**	-3.91	-7.13	-3.05
TIR-46 x TIR-10	-2.33	-1.04	-2.18	-3.40	1.03	-7.19	-11.28**
TIR-46 x K-134	1.06	2.29	1.06	-8.58	-2.56	-8.59	-9.08**
TIR-46 x JAL-6	1.52	3.20	-0.91	2.16**	4.03	-7.13	-13.85**
TIR-46 x JUG-43	-3.34	0.66	2.48	-8.87	-3.63	-10.62	-8.52**
TIR-46 x JL-24	1.09	6.25**	-1.34	6.14	6.98**	-7.20	-3.44
JUG-37 x ICR-45	2.64	3.65*	4.33**	-10.94**	-8.90**	-5.89	-6.87*
JUG-37 x TIR-10	4.11*	4.84**	5.81**	-3.31	-0.92	-2.39	1.71
JUG-37 x K-134	1.11	1.93	2.76	-7.70**	-7.27**	-7.62	-7.88**
JUG-37 x JAL-6	4.04*	7.86**	5.73**	-9.65**	-4.92*	-8.61	-12.75**
JUG-37 x JUG-43	-4.66	0.54	4.39**	-5.62*	-4.38**	-4.73	-7.02*
JUG-37 x JL-24	20.71*	12.11**	6.73**	-6.12*	1.24	-5.23	-1.84
ICR-45 x TIR-10	5.66**	5.94**	5.88**	-12.38**	-8.21**	-7.41	-6.20*
ICR-45 x K-134	4.74**	4.92**	4.75**	-8.25**	-5.72**	-3.05	-1.72
ICR-45 x JAL-6	13.26**	10.20**	6.94**	-16.37**	-10.09**	-11.64	-11.76**
ICR-45 x JUG-43	-0.40	2.68	5.60**	-11.83**	-8.66**	-6.85	-6.63*
ICR-45 x JL-24	0.92	7.12**	0.57	-17.06**	-8.67**	-12.36	-4.48
TIR-10 x K-134	1.98	2.08	2.20	-2.98	-1.04	-2.99	3.30
TIR-10 x JAL-6	1.62	4.65**	1.85	-3.71	-1.05	-7.50	-1.34
TIR-10 x JUG-43	-2.27	0.48	3.60*	2.00	3.18	0.28	2.41
TIR-10 x JL-24	2.54	9.13**	2.76	-8.02**	-3.07	-11.64	-12.17**
K-134 x JAL-6	2.62	5.57**	2.63	-8.07**	-3.69	-8.07	-2.77
K-134 x JUG-43	-6.40**	-3.67**	-0.76	-3.63	-2.82	-3.64	1.58
K-134 x JL-24	-2.55	3.6*	-2.55	-8.21**	-1.44	-8.22	0.00
JAL-6 x JUG-43	-2.60	3.03	3.26	-3.47	0.31	-5.10	-5.28
JAL-6 x JL-24	5.69**	9.34**	0.21	2.56	5.25**	-6.76	-1.01
JUG-43 x JL-24	-3.14	5.79**	0.69	3.25	10.00**	1.53	4.80*
SE	0.89	0.77	0.89	1.18	1.02	1.18	1.24

* Significant at 5% level

** Significant at 1% level

BP = Better parent

MP = Mid parent

SP = Standard parent

Table 15 : Estimates of Heterosis and Inbreeding depression for specific leaf nitrogen in groundnut

Crosses	Rabi 2002			Kharif 2003			Inbreeding depression (%)
	Heterosis (%)			Heterosis (%)			
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	-49.04	-47.18	-43.41	-13.40**	3.39	-15.35	29.27**
TIR-46 x ICR-45	-29.67	-25.84	-18.97	-16.27**	-9.13*	-34.02	10.95*
TIR-46 x TIR-10	-30.02	-29.01	-25.72	-5.56	2.31	-26.14	1.72
TIR-46 x K-134	-33.13	-32.09	-30.87	-19.72**	-3.45	-19.72	19.08**
TIR-46 x JAL-6	-16.60	-7.50	-13.83	22.31**	23.89**	-17.01	10.99**
TIR-46 x JUG-43	-28.42	-26.94	-22.83	-30.17**	-17.55**	-33.61	-17.21**
TIR-46 x JL-24	-20.80	-14.61	-18.33	5.40	6.49	-30.29	-13.02**
JUG-37 x ICR-45	-33.68	-32.49	-23.47	-21.05**	-12.80**	-22.82	-41.97**
JUG-37 x TIR-10	-23.43	-21.74	-14.79	-15.33**	-5.82	-17.01	-4.52
JUG-37 x K-134	-33.40	-29.94	-26.05	-13.26**	-12.40*	-13.26	25.76**
JUG-37 x JAL-6	-28.36	-17.97	-20.26	3.76	22.58**	1.65**	-33.49**
JUG-37 x JUG-43	-20.39	-19.13	-11.58	16.65**	18.22**	14.10**	10.65**
JUG-37 x JL-24	-23.69	-14.96	-15.11	1.02	21.60**	-1.25	-11.81**
ICR-45 x TIR-10	-43.07	-40.79	-34.41	-0.03	0.75	-20.75	-1.78
ICR-45 x K-134	-40.34	-36.17	-31.19	-23.01**	-14.20**	-23.01	25.94**
ICR-45 x JAL-6	-41.37	-31.84	-32.48	6.83	15.20**	-15.35	27.66**
ICR-45 x JUG-43	-42.45	-40.51	-33.76	-20.51**	-13.27**	46.88**	35.80**
ICR-45 x JL-24	-43.65	-36.21	-35.05	-0.37	9.37*	-20.75	25.59**
TIR-10 x K-134	-37.43	-35.56	-12.22	-12.16**	-1.44	-12.16	41.38**
TIR-10 x JAL-6	-44.79	-37.98	-41.15	8.68*	16.34**	-14.93	29.37**
TIR-10 x JUG-43	-44.32	-43.96	-40.19	-22.36**	-14.68**	-26.14	22.16**
TIR-10 x JL-24	-43.90	-38.72	-40.51	-10.22*	-1.81	-29.87	28.34**
K-134 x JAL-6	-40.46	-34.80	-40.51	-11.98*	4.83	-11.98	57.98**
K-134 x JUG-43	-44.90	-42.90	-40.32	-30.60**	-28.97**	-30.60	20.80**
K-134 x JL-24	-44.25	-40.75	-44.05	-20.07**	-3.03	-20.07	-10.07**
JAL-6 x JUG-43	-32.67	-23.94	-27.65	-4.41	11.67**	-9.13	-1.23
JAL-6 x JL-24	-1.58	1.50	-13.18	12.77*	15.39**	-23.65	-19.19**
JUG-43 x JL-24	-16.60	-8.25	-9.97	-6.52	11.31**	-10.79	26.31**
SE	0.10	0.09	0.10	0.09	0.08	0.09	0.06

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

BP = Better parent
MP = Mid parent
SP = Standard parent

Table 16 : Estimates of Heterosis and Inbreeding depression for specific leaf area in groundnut

Crosses	Rabi 2002			Kharif 2003			Inbreeding depression (%)
	Heterosis (%)			Heterosis (%)			
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	52.63**	50.20**	73.60**	21.14**	-2.50	1.42	-16.39
TIR-46 x ICR-45	39.23**	37.01**	58.29*	3.69**	-2.40	-9.85	-31.86
TIR-46 x TIR-10	64.06**	51.93**	65.96*	12.39**	-3.44	4.50	0.59
TIR-46 x K-134	63.43**	50.34**	63.43*	2.58**	-8.19**	2.58	-2.90
TIR-46 x JAL-6	36.97**	38.19**	60.82*	-3.90**	-8.85**	7.03	1.42
TIR-46 x JUG-43	79.18**	56.08**	62.33*	7.13**	-5.27*	4.81	7.80
TIR-46 x JL-24	35.34**	34.29**	56.47*	-4.94**	-6.46**	13.65	-5.67
JUG-37 x ICR-45	30.97**	30.91**	48.83*	25.57	8.15**	4.311	4.60
JUG-37 x TIR-10	45.73**	37.26**	47.87	33.96**	26.46**	11.36	19.07
JUG-37 x K-134	65.41**	54.78**	65.40*	38.95**	26.15**	15.52	4.67
JUG-37 x JAL-6	30.86**	20.81**	49.34*	30.26	11.35**	8.29	30.98
JUG-37 x JUG-43	54.94**	37.40**	40.37	16.94	7.45*	-2.79	7.97
JUG-37 x JL-24	39.82**	38.68**	59.03*	28.32**	5.26*	6.68	22.91
ICR-45 x TIR-10	73.12**	63.14**	75.29**	30.61**	19.81**	21.45	22.35
ICR-45 x K-134	69.14**	58.34**	69.13	17.89**	12.40**	17.89	-3.00
ICR-45 x JAL-6	79.62**	64.64**	103.44**	0.63	-0.10	10.46	-19.98
ICR-45 x JUG-43	93.62**	71.78**	75.41**	12.58	6.11	10.14	-40.89
ICR-45 x JL-24	47.75**	46.48**	68.90*	9.07	4.41	19.72	-4.79
TIR-10 x K-134	71.58**	70.52**	71.57	16.80**	12.56**	8.61	1.07
TIR-10 x JAL-6	89.73**	63.67**	92.11**	24.55**	13.34**	15.81	-4.27
TIR-10 x JUG-43	81.91**	63.67**	84.18**	32.58**	29.22**	23.28	13.95
TIR-10 x JL-24	94.98**	82.07**	97.42**	46.72**	28.37**	36.42*	24.38
K-134 x JAL-6	63.55**	40.09**	63.16*	23.17**	16.54**	23.16	14.63
K-134 x JUG-43	75.09**	66.46**	58.63*	29.74**	28.32**	26.93	29.87
K-134 x JL-24	82.05**	68.87**	82.04**	22.34	11.44**	22.34	12.19
JAL-6 x JUG-43	50.42**	21.63**	36.28	8.95	1.90	6.59	15.36
JAL-6 x JL-24	2.50**	-4.86	18.50	6.97	3.18	19.13	7.22
JUG-43 x JL-24	9.95**	-3.39	-0.39	6.22**	-4.40	3.92	-8.20
SE	4.75	4.11	4.75	4.66	4.04	4.66	5.71

* Significant at 5% level

** Significant at 1% level

BP = Better parent

MP = Mid parent

SP = Standard parent

Table 17 : Estimates of Heterosis and Inbreeding depression for per cent reduction of Fv / Fm in groundnut

Crosses	Rabi 2002			Kharif 2003			Inbreeding depression (%)
	Heterosis (%)			Heterosis (%)			
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	-12.50**	-14.99**	11.56	-18.08**	-13.75**	3.33	28.66
TIR-46 x ICR-45	-2.84	-7.13*	23.88	-0.31	-8.78**	-8.45	40.52
TIR-46 x TIR-10	-12.84**	-11.99**	13.32	-21.09**	8.67**	-5.77	31.28
TIR-46 x K-134	37.33**	20.73**	37.33*	-12.79**	-16.56**	-20.03	34.41
TIR-46 x JAL-6	4.34	-3.84	13.67	-25.61**	25.13**	-4.26	52.36
TIR-46 x JUG-43	24.18*	4.57	15.15	-1.14	-6.52	-18.71	30.25
TIR-46 x JL-24	2.01	-2.87	18.19	25.55**	-0.40	-24.35	21.64
JUG-37 x ICR-45	-9.04**	-10.47**	22.77	-6.40**	-14.51**	-15.79	22.89
JUG-37 x TIR-10	-14.06**	-15.66**	11.75	-18.90**	10.92	-4.58	30.25
JUG-37 x K-134	21.36**	3.30	31.49	-27.71**	-31.25**	-34.96	1.02
JUG-37 x JAL-6	1.21	8.39*	32.18*	29.60**	5.53	-20.52	28.95
JUG-37 x JUG-43	27.13**	3.55	17.88	21.39**	15.92**	-0.19	39.34
JUG-37 x JL-24	1.31	-6.40*	17.38	12.09**	7.89	-18.97	16.70
ICR-45 x TIR-10	-12.81**	-15.80**	13.32	18.70**	2.80	-2.59	44.58
ICR-45 x K-134	26.44**	5.68	26.44	-5.71	-9.10*	-5.71	43.05
ICR-45 x JAL-6	8.55	-4.71	18.26	21.01**	9.76*	-7.37	19.91
ICR-45 x JUG-43	19.18**	-4.74	10.51	27.95**	10.93**	5.20	38.55
ICR-45 x JL-24	-17.37**	-24.95**	-4.26	21.37**	-12.83**	-26.92	-20.19
TIR-10 x K-134	13.59**	-1.24	13.58	19.27**	7.52	-2.12	-2.38
TIR-10 x JAL-6	4.78	-4.46	14.15	36.35**	22.76**	-11.99	5.01
TIR-10 x JUG-43	7.36	-10.62**	-0.46	17.12**	8.54*	-10.85	-8.01
TIR-10 x JL-24	15.93**	9.25**	34.29*	19.63**	31.50**	-6.45	22.99
K-134 x JAL-6	-0.57	-4.83	-0.57	46.99**	11.74*	-9.87	39.45
K-134 x JUG-43	-3.37*	-7.02	-0.10	19.04*	8.11*	-1.49	9.83
K-134 x JL-24	-0.21	-7.55*	-0.22	-4.32	-27.92**	-42.32	-67.67
JAL-6 x JUG-43	20.22**	10.55**	11.47	56.44**	33.68**	-4.06	-9.79
JAL-6 x JL-24	-15.94**	-18.53**	-8.42	30.0**	-40.83**	-63.54	-11.68
JUG-43 x JL-24	35.28**	20.27**	25.44	29.74**	49.04**	6.13	26.39
SE	2.94	2.55	2.94	3.05	2.64	3.05	2.27

* Significant at 5% level

** Significant at 1% level

BP = Better parent

MP = Mid parent

SP = Standard parent

Table 18 : Estimates of Heterosis and Inbreeding depression for root length in groundnut

Crosses	Rabi 2002			Kharif 2003			Inbreeding depression (%)
	Heterosis (%)			Heterosis (%)			
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	-20.67**	-19.32**	-18.52	1.58	5.40	-12.73	9.72
TIR-46 x ICR-45	-23.56**	-20.99**	-21.48	-2.52	6.37	-6.36	9.39
TIR-46 x TIR-10	-12.98*	-11.92*	-10.59	-22.37**	-18.07**	-30.59	-20.31
TIR-46 x K-134	-43.47**	-42.51**	-41.70	-22.12**	-13.47*	-22.14	-12.26
TIR-46 x JAL-6	7.91	9.69	-14.59*	-17.10**	-6.08	-13.32	-11.01
TIR-46 x JUG-43	-25.22**	-21.46**	-15.04	-18.84**	-10.28	-20.00	-8.71
TIR-46 x JL-24	42.55**	47.88**	46.44**	-7.67	2.93	-6.95	-10.10
JUG-37 x ICR-45	22.39**	24.40**	21.48**	-15.62*	-10.76	-21.00	-21.50
JUG-37 x TIR-10	17.00*	17.57**	13.92**	5.24	7.17	-5.77	2.73
JUG-37 x K-134	-17.04*	-16.73**	-17.03	-11.36	-4.49	-11.36	-13.85
JUG-37 x JAL-6	-4.88	-1.68	-1.38	2.46	12.67*	7.14	13.30
JUG-37 x JUG-43	7.17	14.39**	21.70**	-32.51**	-27.84**	-33.64	-45.89
JUG-37 x JL-24	-2.99	-1.02	-3.70	-12.63*	-5.53	-11.95	-6.20
ICR-45 x TIR-10	15.76*	18.24**	16.07*	-10.41	-7.19	-16.41	-7.04
ICR-45 x K-134	20.00**	22.42**	20.00**	-19.39**	-17.77**	-21.05	-14.66
ICR-45 x JAL-6	-11.40	-6.96	-5.93	-24.20**	-21.00**	-20.73	-15.49
ICR-45 x JUG-43	0.6	9.07	14.29*	-24.65**	23.77**	-25.90	-32.31
ICR-45 x JL-24	3.86	4.26	-0.22	-27.22**	-25.48**	-25.16	-39.26
TIR-10 x K-134	3.94	4.07	4.22	-11.36	-6.40	-11.36	-4.10
TIR-10 x JAL-6	-0.23	2.63	5.93	-36.23**	-31.25**	-33.32	-60.68
TIR-10 x JUG-43	-4.78	1.15	8.15	-3.08	1.53	-4.68	-33.07
TIR-10 x JL-24	13.30*	16.16*	13.56*	-32.83**	-28.92**	-32.41	-46.64
K-134 x JAL-6	-4.19	-1.32	-0.96	-41.01**	-39.70**	-38.32	-55.53
K-134 x JUG-43	-15.00*	-9.60	-3.48	-18.35**	-17.65**	-18.32	-23.56
K-134 x JL-24	4.69	7.21	4.67	-11.58*	-11.25	-10.91	-8.33
JAL-6 x JUG-43	15.65*	19.55**	31.33**	-27.65**	-25.02**	-23.95	-30.88
JAL-6 x JL-24	2.79	8.33	9.11	-7.97	6.27	-3.77	-2.52
JUG-43 x JL-24	-9.57	-1.65*	2.74	-8.27	7.15	-7.59	-1.64
SE	0.89	0.76	0.89	1.42	1.23	1.42	1.76

* Significant at 5% level

** Significant at 1% level

BP = Better parent

MP = Mid parent

SP = Standard parent

Table 19 : Estimates of Heterosis and Inbreeding depression for harvest index in groundnut

Crosses	Rabi 2002 Heterosis (%)			Kharif 2003 Heterosis (%)			Inbreeding depression (%)
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	-7.79	-5.96	4.44**	-15.09**	-14.56**	-15.09	5.19
TIR-46 x ICR-45	12.99*	19.18**	28.89**	-5.03	1.34	-5.03	16.56
TIR-46 x TIR-10	1.95	18.05**	15.55**	-24.53**	-9.09	-24.53	-23.33
TIR-46 x K-134	1.95	8.28	15.55**	-10.00	-9.72*	-10.0	8.33
TIR-46 x JAL-6	-18.18**	-13.10**	-6.67	-17.61**	-11.78**	-17.61	8.40
TIR-46 x JUG-43	-5.84	19.34**	6.67**	-27.67**	-12.21**	-27.67	-13.91
TIR-46 x JL-24	-7.14	7.12	6.67**	-11.94**	-19.45**	-11.94	-22.03
JUG-37 x ICR-45	2.70	6.29	13.33**	-40.76**	-37.16**	-41.51	-66.67
JUG-37 x TIR-10	-12.16**	0.00	-4.44	-37.58**	-25.19**	-37.74	-16.33
JUG-37 x K-134	2.70	7.04	13.33**	-39.37**	-38.80**	-39.37	-36.08
JUG-37 x JAL-6	-38.51**	-35.29**	-33.33	-38.22**	-34.24**	-39.37	-21.65
JUG-37 x JUG-43	-7.43	15.61*	2.22**	-52.87**	-43.08**	-52.83	-48.65
JUG-37 x JL-24	0.00	13.41*	8.89**	-50.32**	-46.39**	-51.42	-60.26
ICR-45 x TIR-10	21.74**	34.40**	26.67**	-22.30**	-11.48	-32.08	0.93
ICR-45 x K-134	13.77*	14.60*	15.55**	-22.50**	-17.06**	-22.50	0.81
ICR-45 x JAL-6	-5.80	-5.11	-4.44	-28.81**	-27.08**	-35.85	-30.89
ICR-45 x JUG-43	-2.17	18.94**	0	-30.22**	-19.83**	-39.62	-11.34
ICR-45 x JL-24	23.91**	36.25**	26.67**	-28.72**	-27.47**	-37.74	-29.29
TIR-10 x K-134	-8.09	0.81	-6.67	-34.38**	-20.75**	-34.38	7.62
TIR-10 x JAL-6	-13.24**	-4.84	-13.33	-40.58**	-32.51**	-49.06	-37.80
TIR-10 x JUG-43	25.89**	40.30**	4.44**	0.96	1.92	-33.96	-7.55
TIR-10 x JL-24	23.89**	24.44**	4.44**	-24.83**	-15.48**	-35.85	-0.99
K-134 x JAL-6	2.21	2.21	2.22*	-38.26**	-33.56**	-38.26	-61.62
K-134 x JUG-43	25.00**	51.00**	26.67**	-31.83**	-17.11**	-31.83	12.84
K-134 x JL-24	38.24**	51.00**	40.00**	-28.18**	-21.77**	-28.18	-17.39
JAL-6 x JUG-43	-2.94	17.33**	-2.22	-5.80	7.88	-18.87	22.31
JAL-6 x JL-24	-2.94	6.02	-2.22	-32.66**	-31.62**	-41.51	-5.38
JUG-43 x JL-24	-2.65	8.91	-17.78	-19.40**	-8.86	-32.08	-8.33
SE	0.03	0.03	0.03	0.03	0.02	0.03	0.03

* Significant at 5% level

BP = Better parent

** Significant at 1% level

MP = Mid parent

SP = Standard parent

Table 20 : Estimates of Heterosis and Inbreeding depression for Shell thickness area in groundnut

Crosses	Rabi 2002			Kharif 2003			Inbreeding depression (%)
	Heterosis (%)			Heterosis (%)			
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	-31.97**	-34.98**	10.43	-12.39**	-13.23**	4.88**	32.95
TIR-46 x ICR-45	-18.69**	-29.45**	-18.26	-3.90	-12.57**	-4.06	14.90
TIR-46 x TIR-10	-8.08**	-23.52**	-13.91	10.11**	-4.51	0.81**	29.96
TIR-46 x K-134	-25.60**	-35.82**	-26.09	20.45**	9.73**	20.33**	42.58
TIR-46 x JAL-6	21.09**	4.23	20.00**	11.94**	4.15	16.26**	27.72
TIR-46 x JUG-43	1.82	-17.70**	10.46	-8.64*	-14.27**	-4.88	23.13
TIR-46 x JL-24	15.41**	-6.15	4.35**	-12.39**	-24.34**	-20.32	8.02
JUG-37 x ICR-45	52.83**	25.94**	53.91**	18.79**	6.91*	18.69**	12.47
JUG-37 x TIR-10	50.12**	18.43**	40.87**	39.37**	19.81**	28.45**	21.60
JUG-37 x K-134	24.70**	2.13	28.69**	40.33**	26.48**	40.65**	33.15
JUG-37 x JAL-6	31.10**	7.13*	30.43**	27.43**	17.29**	32.52**	29.69
JUG-37 x JUG-43	41.34**	8.20**	26.09**	37.56**	24.95**	3.25**	28.03
JUG-37 x JL-24	48.21**	14.90**	33.91**	74.69**	49.15**	59.35**	46.69
ICR-45 x TIR-10	34.37**	29.47**	26.09**	7.43*	2.84	-1.63	15.15
ICR-45 x K-134	-10.99**	-11.45**	-11.31	-0.97	-0.85	-0.81	20.19
ICR-45 x JAL-6	45.77**	44.74**	45.21**	18.95**	18.48**	18.69**	24.09
ICR-45 x JUG-43	1.17	-5.00	-9.57	6.43	5.31	6.50**	23.44
ICR-45 x JL-24	27.85**	26.71**	14.78**	19.62**	14.02**	8.94**	21.96
TIR-10 x K-134	7.58*	4.21	0.86**	-6.38	-10.54**	-13.82	5.90
TIR-10 x JAL-6	13.27**	9.94**	6.09**	25.72**	17.70**	15.45**	26.22
TIR-10 x JUG-43	28.7**	25.53**	14.78**	41.98**	34.49**	30.08**	35.72
TIR-10 x JL-24	35.19**	32.57**	21.73**	3.57	3.19	-5.69	19.24
K-134 x JAL-6	-5.92	-6.10	-6.98	-0.57	-2.51	0	17.36
K-134 x JUG-43	-9.10**	-14.18**	20.86**	11.28**	10.47**	11.38**	26.71
K-134 x JL-24	31.39**	24.73**	18.26**	-6.28	-10.79**	-14.63	4.83
JAL-6 x JUG-43	12.74**	6.66*	0.86**	1.60	0.38	3.25**	9.00
JAL-6 x JL-24	37.02**	30.34**	23.48**	12.66**	5.05	2.44**	21.23
JUG-43 x JL-24	-0.77	-1.26	-11.30	16.14**	9.72**	5.69**	28.95
SE	0.03	0.03	0.03	0.04	0.04	0.04	0.04

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

BP = Better parent
MP = Mid parent
SP = Standard parent

Table 21 : Estimates of Heterosis and Inbreeding depression for oil per cent in groundnut

Crosses	Rabi 2002 Heterosis (%)			Kharif 2003 Heterosis (%)			Inbreeding depression (%)
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	-0.14	0.52	4.81	-4.75	0.98	-7.19	-5.62
TIR-46 x ICR-45	5.69	10.40**	9.49	-9.68*	-4.30	-11.99	2.27
TIR-46 x TIR-10	1.33	7.68*	4.99	-15.41**	-8.21	-17.57	-11.56
TIR-46 x K-134	7.02*	8.92**	10.88	-0.80	0.49	-0.81	3.50
TIR-46 x JAL-6	-8.68*	-4.59	-5.61	-4.83	-0.28	-7.27	1.47
TIR-46 x JUG-43	-4.97	-2.12	-1.53	-4.31	2.92	-6.75	-1.53
TIR-46 x JL-24	-6.33	-4.44	-2.95	-7.00	-6.81	-9.39	1.31
JUG-37 x ICR-45	-7.68*	-2.98	-3.12	5.91	5.97	-8.43	4.03
JUG-37 x TIR-10	4.03	11.22**	9.17	2.84	5.41	-11.19	-4.15
JUG-37 x K-134	-2.95	-0.61	1.85	-4.37	2.62	-4.38	-3.33
JUG-37 x JAL-6	-3.75	1.18	1.01	6.54	7.88	-5.68	7.38
JUG-37 x JUG-43	-0.45	3.17	4.45	7.73	6.08	-9.78	-2.39
JUG-37 x JL-24	1.68	4.39	6.72	-8.04	-2.68	-10.80	-8.12
ICR-45 x TIR-10	0.05	1.87	-5.18	0.16	-2.41	-17.73	-12.75
ICR-45 x K-134	3.71	6.50*	3.71	-4.21	2.47	-4.22	13.26
ICR-45 x JAL-6	4.53	14.51**	8.49	-2.77	-1.63	-13.92	-0.18
ICR-45 x JUG-43	3.36	4.87	0.85	8.72	6.99	-8.95	5.96
ICR-45 x JL-24	-13.81	-11.71**	-0.14	-8.87	-3.62	-11.56	4.64
TIR-10 x K-134	1.76	6.35	-0.41	-15.62**	-7.38	-15.63	-9.59
TIR-10 x JAL-6	9.38**	11.34**	3.59	-11.32*	-8.00	-21.52	-5.45
TIR-10 x JUG-43	-1.93	1.29	-4.32	13.17*	14.27**	-52.04	11.75
TIR-10 x JL-24	10.25**	-6.43	-10.69	-0.07	8.24	-3.27	11.95
K-134 x JAL-6	0.66	3.39	0.67	-11.88*	-6.63	-11.89	-3.81
K-134 x JUG-43	0.59	2.13	0.95	-7.80	0.34	-7.82	0.39
K-134 x JL-24	9.13*	9.40*	9.12	-5.04	3.68	-5.05	1.95
JAL-6 x JUG-43	-7.37*	-6.00	-9.62	-1.75	0.98	-13.02	3.50
JAL-6 x JL-24	9.53**	12.22**	8.97	-4.17	0.22	-6.99	8.92
JUG-43 x JL-24	-2.41	-1.46	-2.90	-12.78*	-8.37	-15.35	-16.59
SE	1.66	1.45	1.66	2.12	1.84	2.12	1.96

* Significant at 5% level

** Significant at 1% level

BP = Better parent

MP = Mid parent

SP = Standard parent

Table 22 : Estimates of Heterosis and Inbreeding depression for shelling per cent in groundnut

Crosses	Rabi 2002			Kharif 2003			Inbreeding depression (%)
	Heterosis (%)			Heterosis (%)			
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	0.93	8.46*	14.13	-4.63	-0.96	-3.78	-8.74
TIR-46 x ICR-45	1.39	4.53	14.65	-8.33	-7.26	-7.52	2.53
TIR-46 x TIR-10	0.00	9.09*	13.08	-6.50	-2.40	-5.18	-6.4
TIR-46 x K-134	-0.46	5.65	12.56	-9.72*	-9.30*	-8.93	0.00
TIR-46 x JAL-6	-4.17	0.49	8.37	-6.55	-3.82	-0.05	14.95
TIR-46 x JUG-43	0.00	2.61	13.08	-16.23**	-13.98**	-10.79	-4.71
TIR-46 x JL-24	-7.41	-5.21	4.71	-7.87	-7.123	-7.42	-6.03
JUG-37 x ICR-45	-3.94	0.26	2.09	-15.17**	-12.9**	-16.39	-2.23
JUG-37 x TIR-10	-4.30	-2.73	-6.81	-1.50	-1.5	-7.99	-3.05
JUG-37 x K-134	3.66	5.04	3.65	-7.01	-3.88	-7.06	13.07
JUG-37 x JAL-6	11.22*	14.14**	14.13	-7.88	-1.83	-1.46	3.79
JUG-37 x JUG-43	1.46	6.39	8.39	-10.53*	-4.67	-4.72	-6.37
JUG-37 x JL-24	-16.99**	-12.76**	-10.47	-12.68*	-9.93*	-13.13	-12.29
ICR-45 x TIR-10	-7.39	-1.83	-1.57	-7.58	-5.11	-8.93	6.67
ICR-45 x K-134	3.45	6.60	9.94	-3.27	-2.59	-3.32	11.59
ICR-45 x JAL-6	-9.86	-8.27	-4.19	-16.16**	-12.73**	-10.32	3.65
ICR-45 x JUG-43	-13.17**	-12.75**	-6.81	-20.18*	-17.08**	-14.99	-8.79
ICR-45 x JL-24	-7.77	-7.09	-0.53	-15.49**	-15.09**	-15.93	-15.00
TIR-10 x K-134	10.47*	13.75**	10.46	-17.29**	-14.49**	-17.33	-7.91
TIR-10 x JAL-6	-15.31**	-11.70*	-13.09	-19.65**	-14.22**	-14.07	-2.72
TIR-10 x JUG-43	-6.34	-0.26	0.51	-12.72*	-7.01	-7.06	-7.04
TIR-10 x JL-24	-4.85	1.55	2.60	-2.35	0.73	-2.86	5.77
K-134 x JAL-6	14.80**	16.28**	17.79	-15.28**	-12.42**	-9.39	-7.73
K-134 x JUG-43	-11.71*	-8.59**	-5.24	-25.00**	-22.62**	-20.13	-18.13
K-134 x JL-24	-19.42**	-16.37**	-13.09	-2.35	-2.58	-2.86	-1.82
JAL-6 x JUG-43	4.39	6.72	12.03	-11.40*	-11.60*	-5.66	18.32
JAL-6 x JL-24	-11.17*	-8.96*	4.19	-21.48**	-16.55**	-15.93	3.33
JUG-43 x JL-24	-27.18**	-27.01**	-21.47	-17.58**	-15.19**	-12.67	1.00
SE	3.47	3.00	3.47	3.52	3.05	3.52	3.30

* Significant at 5% level

** Significant at 1% level

BP = Better parent

MP = Mid parent

SP = Standard parent

Table 23 : Estimates of Heterosis and Inbreeding depression for sound mature kernel per cent in groundnut

Crosses	Rabi 2002			Kharif 2003			Inbreeding depression (%)
	Heterosis (%)			Heterosis (%)			
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	-7.25*	-2.99	-0.41	-8.75*	-7.59**	-14.11	-15.98
TIR-46 x ICR-45	-10.15**	-9.47**	-2.04	-11.69**	-10.25**	-14.11	0.00
TIR-46 x TIR-10	-2.67	4.72	4.51	-17.08**	-3.63	-21.97	-20.60
TIR-46 x K-134	-19.85**	-17.00**	-13.93	-4.10	-14.02**	-26.67	-12.30
TIR-46 x JAL-6	-6.87*	5.63	0	4.04	-5.94*	-19.21	9.71
TIR-46 x JUG-43	1.15	8.61**	8.61	-16.67**	-11.31**	-21.57	6.00
TIR-46 x JL-24	-11.83**	-10.81**	-5.32	-13.71**	-22.2**	-33.32	-8.24
JUG-37 x ICR-45	-6.77*	-1.78	1.65	-29.44**	-27.39**	-31.37	8.00
JUG-37 x TIR-10	-1.67	1.29	-3.69	-26.50**	-15.48**	-32.55	5.23
JUG-37 x K-134	4.51	5.59*	4.51	-13.33**	-21.21**	-33.73	1.78
JUG-37 x JAL-6	-0.42	8.43*	-2.05	1.01	-7.41**	-21.56	10.5
JUG-37 x JUG-43	6.28	9.25**	4.12	0.85	-5.17	-17.26	-16.59
JUG-37 x JL-24	0.39	3.84	5.34	-7.51*	9.51**	-7.45	29.66
ICR-45 x TIR-10	-10.15**	-2.65	-2.04	-35.48**	-23.99**	-37.26	-3.12
ICR-45 x K-134	-12.41**	-8.63**	-4.50	-5.05	-27.77**	-37.26	-20.00
ICR-45 x JAL-6	-9.02*	3.86	-0.81	-22.75**	-15.70**	-26.27	4.26
ICR-45 x JUG-43	-8.27*	-0.81	0	-37.50**	-28.98**	-36.08	-28.20
ICR-45 x JL-24	-18.05**	-16.48**	-10.65	-21.32**	-30.34**	-39.21	-27.10
TIR-10 x K-134	-7.79*	-4.05	-7.78	-14.36**	-9.24**	-34.51	5.39
TIR-10 x JAL-6	-11.56**	-6.35	-18.44	2.53	9.43**	-20.39	0.49
TIR-10 x JUG-43	-3.56	-3.77	-11.07	-5.21	4.17	-21.56	15.00
TIR-10 x JL-24	-17.58**	-12.27**	-13.53	-14.21**	-8.65**	-33.73	-31.36
K-134 x JAL-6	-10.25**	-1.35	-10.24	-6.06	-5.34**	-27.06	-18.28
K-134 x JUG-43	-9.43*	-5.96	-10.48	7.18*	2.96	-18.04	0.96
K-134 x JL-24	-20.70**	-18.8**	-16.79	0.00	0.51	-22.74	1.02
JAL-6 x JUG-43	7.96*	14.55**	-0.51	-15.15**	-17.85**	-34.12	-14.88
JAL-6 x JL-24	-11.33**	-0.44	-6.96	-2.53	-2.28	-24.32	2.07
JUG-43 x JL-24	-17.26**	-22.41**	-23.36	0.00	-3.43**	-22.74	-7.61
SE	2.83	2.45	2.83	3.19	2.77	3.19	3.14

* Significant at 5% level

** Significant at 1% level

BP = Better parent

MP = Mid parent

SP = Standard parent

Table 24 : Estimates of Heterosis and Inbreeding depression for No. of well filled and mature pods per plant in groundnut

Crosses	Rabi 2002			Kharif/2003			Inbreeding depression (%)
	Heterosis (%)			Heterosis (%)			
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	7.12	17.95	9.33	2.20	4.06*	20.74	27.15
TIR-46 x ICR-45	37.53	47.07**	14.55	-14.56	-11.52	0.97	-15.43
TIR-46 x TIR-10	-8.72	6.89*	-23.97	2.47	12.69	21.03	3.22
TIR-46 x K-134	5.41	15.02	5.42	18.13	27.98	39.53	32.56
TIR-46 x JAL-6	-8.52	15.55	30.61	43.68*	44.88*	68.74	34.23
TIR-46 x JUG-43	16.14	17.88	-0.30	2.75	7.94	21.42	16.04
TIR-46 x JL-24	-9.50	-7.43	-21.08	-21.43	-17.82	-7.21	-23.08
JUG-37 x ICR-45	8.44	26.82	10.64	-5.70	-4.06*	7.40	-21.15
JUG-37 x TIR-10	-18.54	3.25	-16.88*	-9.97	-2.62	2.53	-2.53
JUG-37 x K-134	-2.15	-1.17	-0.15	12.25	19.58	27.85	25.89
JUG-37 x JAL-6	-33.49**	-22.43	-6.89	-31.65	-32.30	-22.10	-16.25
JUG-37 x JUG-43	23.36	30.76*	22.81	-25.07	-22.56	-14.61	-3.42
JUG-37 x JL-24	28.64	38.75*	31.27	0.00	2.78	13.92	18.80
ICR-45 x TIR-10	52.91**	68.64**	10.85	4.42	11.50	14.89	-3.95
ICR-45 x K-134	4.90	21.65	4.92	-6.19	-1.70	3.21	5.97
ICR-45 x JAL-6	-12.43	16.17	25.04	-23.46	-21.38	-11.10	-6.20
ICR-45 x JUG-43	12.60	22.09	-3.35	-18.11	-17.37	-10.42	-21.74
ICR-45 x JL-24	54.07**	68.05**	32.03	-20.35	-19.52	-12.37	-4.81
TIR-10 x K-134	-18.75	2.23	-17.38	-21.75	-20.46	-21.81	-23.24
TIR-10 x JAL-6	-38.82**	-13.40	-12.67	-19.83	-12.50	-6.82	-2.09
TIR-10 x JUG-43	27.76	51.45**	9.63	4.86	10.05	11.98	17.97
TIR-10 x JL-24	33.72	59.44**	16.57	-9.04	-4.13*	-1.95	12.25
K-134 x JAL-6	-6.86*	9.53	33.45	-5.03	2.10	10.32	0.00
K-134 x JUG-43	48.31**	59.64**	48.35	-17.33	-14.60	-11.68	-5.88
K-134 x JL-24	43.24**	53.07**	43.28	17.70	-14.69	-11.39	-27.47
JAL-6 x JUG-43	5.31	-20.92	-12.42	-9.22	-5.39	1.07	26.15
JAL-6 x JL-24	0.39	-23.88	-12.47	-27.37	-24.64	-15.58	-31.92
JUG-43 x JL-24	30.23	31.25	13.53	-30.72	-30.41	-25.32	-31.74
SE	3.35	2.90	3.35	2.41	2.08	2.41	1.92

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

BP = Better parent
 MP = Mid parent
 SP = Standard parent

Table 25 : Estimates of Heterosis and Inbreeding depression for kernel yield per plant in groundnut

Crosses	Rabi 2002			Kharif 2003			Inbreeding depression (%)
	Heterosis (%)			Heterosis (%)			
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	-21.20*	-2.17	41.83	12.50	12.73	1.12	28.89
TIR-46 x ICR-45	48.99*	44.68**	54.85	-20.00	15.97	-28.08	13.54
TIR-46 x TIR-10	-12.23	0.11	-3.51	-10.83	-4.89	-19.89	-1.87
TIR-46 x K-134	-2.96	1.65	6.70	-5.62	-0.59	-5.62	48.81
TIR-46 x JAL-6	-1.48	7.36	29.67	19.17	24.35	7.08	44.06
TIR-46 x JUG-43	1.30	4.49	18.60	8.75	8.75	-2.25	32.57
TIR-46 x JL-24	-28.40	-24.38	-21.27	-5.42	-3.81	-14.94	11.01
JUG-37 x ICR-45	-28.07**	-8.85	29.47	5.44	10.53	-5.62	24.6
JUG-37 x TIR-10	-41.45**	-19.80	5.40	-18.41	-13.14	-26.96	4.10
JUG-37 x K-134	-40.0**	-22.85**	8.00	-14.23	-9.49	-14.27	36.24
JUG-37 x JAL-6	-35.06**	-24.98**	16.92	-15.48	-11.98	-24.38	19.80
JUG-37 x JUG-43	-37.11**	-23.80**	13.20	-35.00	-34.86*	-41.57	-19.87
JUG-37 x JL-24	-44.56**	-28.29**	-0.26	-11.30	-9.89	-20.56	34.43
ICR-45 x TIR-10	26.25	40.60**	31.42	-20.74	-19.44	-35.62	-4.07
ICR-45 x K-134	24.79	27.31**	29.93	-29.59	-22.31	-29.55	2.66
ICR-45 x JAL-6	-5.77	5.24*	24.07	-16.36	-15.79	-31.12	22.28
ICR-45 x JUG-43	-22.04	-17.45**	-8.72	-32.50	-29.10	-39.32	-1.23
ICR-45 x JL-24	5.83	8.90**	10.15	-46.55*	-44.77	-53.59	-29.03
TIR-10 x K-134	19.37	8.19**	5.40	-38.20*	-30.82	-38.20	3.64
TIR-10 x JAL-6	-1.08	-18.91**	-13.07	-13.64	-11.61	-28.88	33.68
TIR-10 x JUG-43	-33.94	21.69**	21.66	-16.67	-11.11	-25.06	23.00
TIR-10 x JL-24	3.89	13.77**	2.99	-15.52	-11.31	-26.63	18.88
K-134 x JAL-6	4.86	16.67**	35.13	-20.18	-12.53	-20.22	28.64
K-134 x JUG-43	47.64**	59.44**	73.06	-38.83*	-34.52*	-37.87	13.86
K-134 x JL-24	73.10**	52.08**	50.74	-20.97	-15.43	-21.01	20.85
JAL-6 x JUG-43	-22.73	-18.22**	1.69	-20.00	-16.52	-28.10	41.67
JAL-6 x JL-24	5.27	20.57**	38.59	-31.03	-29.20	-40.11	15.62
JUG-43 x JL-24	-16.11	2.11	9.95	-37.92*	-38.86*	-44.16	6.71
SE	2.94	2.55	2.94	1.46	1.26	1.46	1.05

* Significant at 5% level

** Significant at 1% level

BP = Better parent

MP = Mid parent

SP = Standard parent

Table 26 : Estimates of Heterosis and Inbreeding depression for pod yield per plant in groundnut

Crosses	Rabi 2002			Kharif 2003			Inbreeding depression (%)
	Heterosis (%)			Heterosis (%)			
	>BP	>MP	>SP	>BP	>MP	>SP	
TIR-46 x JUG-37	-22.12*	-2.0	39.16	19.61	20.28	26.91	45.96
TIR-46 x ICR-45	30.97**	32.34*	39.16	-20.44	-13.51	-15.56	1.74
TIR-46 x TIR-10	-3.31	8.81	0.61	-12.43	-7.58	-7.04	4.42
TIR-46 x K-134	9.04	11.21	14.25	19.89	23.47	27.26	35.94
TIR-46 x JAL-6	16.67	30.32*	53.59	11.60	24.31	18.47	34.65
TIR-46 x JUG-43	1.77	2.76	7.95	18.51	23.99	25.77	34.03
TIR-46 x JL-24	0.75	5.60	4.85	-6.08	-4.23	-0.35	15.88
JUG-37 x ICR-45	-34.46**	-17.67	18.00	11.73	20.85	17.24	16.75
JUG-37 x TIR-10	-29.16**	-2.22	27.55	-11.73	-7.33	-7.39	3.48
JUG-37 x K-134	-45.43**	-29.83**	1.74	6.98	9.58	12.31	41.51
JUG-37 x JAL-6	-32.55**	-22.07**	19.32	-22.91	-14.55	-19.09	12.32
JUG-37 x JUG-43	-34.03**	-16.98	18.81	-29.89	-27.03	-26.39	-9.96
JUG-37 x JL-24	-30.29**	-8.57	25.52	-6.42	-5.10	-1.76	37.31
ICR-45 x TIR-10	23.46	40.20**	31.17	-18.52	-15.92	-22.60	-11.36
ICR-45 x K-134	23.16	26.90	30.84	-21.42	-16.90	-21.46	-12.69
ICR-45 x JAL-6	-1.90	8.56	29.14	-5.26	-2.70	-15.57	19.79
ICR-45 x JUG-43	41.30**	41.4**	50.11	-33.03	-30.28*	-35.18	-13.12
ICR-45 x JL-24	21.09**	28.18*	17.07	-43.39**	-39.24**	-21.46	1.49
TIR-10 x K-134	-9.09	0.52	-9.12	-17.89	15.79	-17.94	10.36
TIR-10 x JAL-6	-19.88	-0.74	5.45	-15.12	-14.13	-19.35	-0.36
TIR-10 x JUG-43	4.87	19.03	11.28	-7.58	-6.73	-10.55	17.70
TIR-10 x JL-24	23.88*	35.31	17.07	-22.99	-20.24	-21.46	1.49
K-134 x JAL-6	-12.02	0.0	15.79	2.50	10.56	20.22	29.31
K-134 x JUG-43	62.63**	66.45**	72.92	-20.23	-18.93	-20.23	22.06
K-134 x JL-24	32.57**	40.37**	36.48	-12.93	-12.05	-11.17	22.11
JAL-6 x JUG-43	-28.9**	-20.5	-5.50	-8.00	-0.97	-10.29	27.74
JAL-6 x JL-24	0.71	17.26	32.58	-27.3	-20.44	-25.86	13.83
JUG-43 x JL-24	1.03	6.87	7.19	-39.37*	-37.76**	-38.17	-8.53
SE	3.55	3.08	3.55	1.88	1.63	1.88	1.65

* Significant at 5% level
** Significant at 1% level
BP = Better parent
MP = Mid parent
SP = Standard parent

Heterobeltiosis was maximum in the F_1 , JAL-6 x JUG-43 (56.44) and was minimum in JUG-37 x K-134 (-27.21). Seventeen F_1 s registered significant positive heterobeltiosis (Table 17). Seven F_1 s recorded significant negative heterobeltiosis. Relative heterosis for this trait ranged between -40.83 (JAL-6 x JL-24) and 49.04 (JUG-43 x JL-24). Twelve F_1 s recorded positive significant heterosis. Negative significant heterosis was observed in nine F_1 s. Standard heterosis ranged from -63.54 (JAL-6 x JL-24) to 6.13 (JUG-43 x JL-24). None of the crosses recorded significant heterosis over standard parent.

Inbreeding depression ranged from -67.67 (K-134 x JL-24) to 44.58 (ICR-45 x TIR-10). As many as twenty F_2 s registered significant positive inbreeding depression. Negative and non-significant inbreeding depression was observed in six F_2 s. Two F_2 s showed positive non-significant inbreeding depression.

4.5.2.5 Root length

Heterobeltiosis ranged between -41.01 (JUG-37 x TIR-10) and 5.24 (K-134 x JAL-6). Seventeen F_1 s registered negative and significant heterobeltiosis. Relative heterosis ranged from -39.70 (K-134 x JAL-6) to 23.77 (ICR-45 x JUG-43). Two F_1 s viz., JUG-37 x JAL-6 and ICR-45 x JUG-43 showed significant positive relative heterosis. Significant and negative relative heterosis observed in eleven F_1 s. Standard heterosis

ranged from -38.32 (K-134 x JAL-6) to 7.14 (JUG-37 x JAL-6). None of the F_1 s recorded significant heterosis over standard parent.

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The F_2 , TIR-10 x JAL-6 registered a minimum inbreeding depression of -60.68 per cent while JUG-37 x JAL-6 recorded the maximum (13.30). Out of twenty eight F_2 s, ten F_2 s exhibited significant negative inbreeding depression and four F_2 s expressed positive and non-significant inbreeding depression. Fourteen F_2 s registered non-significant negative inbreeding depression.

4.5.2.6 Harvest index

Heterobeltiosis ranged from -52.87 (JUG-37 x JUG-43) to 0.96 (TIR-10 x JUG-43). Out of 28 F_1 s, twenty four F_1 s recorded significant negative heterosis over better parent. Relative heterosis was minimum in the F_1 , JUG-37 x JL-24 (-46.39) and was maximum (7.88) in the F_1 , JAL-6 x JUG-43. Negative and significant relative heterosis was observed in twenty two F_1 s. Standard heterosis ranged from -52.83 (JUG-37 x JUG-43) to -5.03 (TIR-46 x ICR-45). None of the F_1 s recorded significant heterosis over standard parent.

Inbreeding depression for harvest index ranged from -66.67 to 22.31. The F_2 s which recorded the lowest and highest inbreeding depression are JUG-37 x ICR-45 and JAL-6 x JUG-43, respectively. Two and four F_2 s recorded significant and non-significant positive inbreeding depression

respectively. Eleven F_2 s each exhibited significant and non-significant negative inbreeding depression.

4.5.2.7 Shell thickness

The minimum and maximum heterobeltiosis observed for shell thickness are -12.39 (TIR-46 x JUG-37) and 41.98 (TIR-10 x JUG-43), respectively. As many as seventeen F_1 s recorded significant positive heterosis over better parent. Significant negative heterobeltiosis was observed in two F_1 s viz., TIR-46 x JUG-37 and TIR-46 x JL-24. Relative heterosis ranged from -24.34 to 49.15. The F_1 s, TIR-46 x JL-24 and JUG-37 x JL-24 recorded the lowest and highest relative heterosis respectively. Thirteen F_1 s registered significant positive relative heterosis while six F_1 s exhibited significant negative relative heterosis (Table 20). Standard heterosis ranged from -20.32 (TIR-46 x JL-24) to 59.35 (JUG-37 x JL-24). Significant positive heterosis over standard parent was observed in eighteen F_1 s.

Inbreeding depression ranged from 4.83 (K-134 x JL-24) to 46.69 (JUG-37 x JL-24). As many as twenty-seven F_2 s registered positive significant inbreeding depression and only one F_2 , K-134 x JL-24 exhibited non-significant positive inbreeding depression.

4.5.2.8 Oil per cent

The F_1 s namely, TIR-10 x K-134 and TIR-10 x JUG-43 recorded the lowest (-15.62) and the highest heterosis (13.17) over better parent

respectively. Significant positive heterobeltiosis was observed in one F_1 , TIR-10 x JUG-43. Six F_1 s exhibited significant negative heterobeltiosis. Relative heterosis ranged from -8.37 (JUG-43 x JL-24) to 14.27 (TIR-10 x JUG-43). One F_1 , TIR-10 x JUG-43 exhibited significant positive relative heterosis. Standard heterosis ranged from -52.04 (TIR-10 x JUG-43) to -0.81 (TIR-46 x K-134). None of the F_1 s recorded significant heterosis over standard parent.

Inbreeding depression ranged from -16.59 (JUG-43 x JL-24) to 13.26 (ICR-45 x K-134). Two crosses viz., TIR-10 x JL-24 and ICR-45 x K-134 recorded significant positive inbreeding depression. Three F_2 s exhibited significant negative inbreeding depression. Thirteen and ten F_2 s showed non-significant positive and negative inbreeding depression, respectively.

4.5.2.9 Shelling per cent

The lowest heterosis over better parent was observed in F_1 , K-134 x JUG-43 (25.00) and the highest in JUG-37 x TIR-10 (-1.50). Fifteen F_1 s recorded negative significant heterobeltiosis. Relative heterosis ranged from -22.62 (K-134 x JUG-43) to 0.73 (TIR-10 x JL-24). Significant negative relative heterosis was observed in fourteen F_1 s. Standard heterosis ranged from -20.13 (K-134 x JUG-43) to -0.05 (TIR-46 x JAL-6). None of the F_1 s recorded significant heterosis over standard parent.

The F_2 , K-134 x JUG-43 recorded the lowest inbreeding depression of -18.13 (K-134 x JUG-43). Highest inbreeding depression was observed in F_2 , JAL-6 x JUG-43 (18.32). Four F_2 s exhibited significant positive inbreeding depression and significant negative inbreeding depression was noticed in three F_2 s. Eight and thirteen F_2 s registered non-significant positive and negative inbreeding depression respectively.

4.5.2.10 Sound mature kernel per cent

The lowest heterobeltiosis was observed in F_1 , ICR-45 x JUG-43 (-37.50), while the highest in F_1 , K-134 x JUG-43 (7.18). One F_1 recorded significant positive heterobeltiosis. Significant negative heterobeltiosis was observed in sixteen F_1 s. Relative heterosis ranged from -30.34 (ICR-45 x JL-24) to 9.51 (JUG-37 x JL-24). Two F_1 s exhibited significant positive relative heterosis and twenty F_1 s recorded significant negative relative heterosis. Standard heterosis ranged from -39.21 (ICR-45 x JL-24) to -7.45 (JUG-37 x JL-24). None of the F_1 s recorded significant heterosis over standard parent.

The F_2 s, TIR-10 x JL-24 (-31.36) and JUG-37 x JL-24 (29.66) exhibited the minimum and maximum inbreeding depression respectively. Three F_2 s recorded significant positive inbreeding depression while significant negative inbreeding depression was observed in ten F_2 s. Twelve and three F_2 s registered non-significant negative and positive inbreeding depression respectively.

4.5.11 Number of well filled and mature pods per plant

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Estimates of heterosis over better parent ranged from -31.65 (JUG-37 x JL-24) to 43.68 (TIR-10 x JAL-6). Only one F_1 recorded significant positive heterobeltiosis. The minimum relative heterosis was observed in F_1 , JUG-37 x JAL-6 (-32.30) and maximum in F_1 , TIR-46 x JAL-6 (44.88). Two F_1 s, TIR-46 x JUG-37 and TIR-46 x JAL-6 recorded significant positive relative heterosis while significant and negative relative heterosis was observed in F_1 s, JUG-37 x ICR-45 and TIR-10 x JL-24. Standard heterosis ranged from -25.32 (JUG-43 x JL-24) to 68.74 (JUG-37 x JAL-6). None of the crosses recorded significant heterosis over standard parent.

Inbreeding depression ranged from -31.92 (JAL-6 x JL-24) to 34.23 (TIR-46 x JAL-6). Significant positive inbreeding depression was observed in two F_2 s (TIR-46 x K-134 and TIR-46 x JAL-6). Nine and seventeen F_2 s recorded non-significant positive and negative inbreeding depression, respectively.

4.5.12 Kernel yield per plant

The F_1 s, ICR-45 x JL-24 (-46.55) and TIR-46 x JAL-6 (19.17) recorded minimum and maximum heterobeltiosis, respectively. Four F_1 s exhibited significant negative heterobeltiosis. Relative heterosis ranged from -44.77 (ICR-45 x JL-24) to (24.35) TIR-46 x JAL-6. Only three F_1 s viz., JUG-37 x JUG-43, K-134 x JUG-43 and JUG-43 x JL-24

recorded significant negative relative heterosis. Standard heterosis ranged from -53.59 (ICR-45 x JL-24) to 7.08 (TIR-46 x JAL-6). None of the F_1 s recorded significant heterosis over standard parent.

Inbreeding depression ranged from -29.03 (ICR-45 x JL-24) to 48.81 (TIR-46 x K-134). Nine F_2 s recorded significant positive inbreeding depression. Thirteen and six F_2 s registered non-significant positive and negative inbreeding depression, respectively.

4.5.2.13 Pod yield per plant

Heterobeltiosis ranged from -43.39 (ICR-45 x JL-24) to 19.89 (TIR-46 x K-134). Two F_1 s, viz., JUG-43 x JL-24 and ICR-45 x JL-24 recorded significant negative heterobeltiosis. The minimum relative heterosis was observed in F_1 , ICR-45 x JL-24 (-39.24) and the maximum were in TIR-46 x JAL-26 (24.31). Three F_1 s, viz., ICR-45 x JUG-43, ICR-45 x JL-24 and JUG-43 x JL-24 recorded significant negative relative heterosis (Table 26). Standard heterosis ranged from -38.17 (JUG-43 x JL-24) to 27.26 (TIR-46 x K-134). None of the F_1 s recorded significant heterosis over standard parent.

Inbreeding depression ranged from -13.12 to 45.96. The lowest and highest inbreeding depression was observed in F_2 s, ICR-45 x JUG-43 and TIR-46 x JUG-37, respectively. Seven F_2 s recorded positive and significant inbreeding depression and sixteen crosses exhibited non-significant

positive inbreeding depression. Five F_2 s exhibited non-significant positive and negative inbreeding depression, respectively.

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4.6 VARIABILITY, HERITABILITY AND GENETIC ADVANCE

Genetic parameters in F_2 generation as phenotypic and genotypic coefficients of variation, heritability in broad sense, genetic advance and genetic advance as per cent of mean for thirteen characters were furnished in Table 27.

The phenotypic co-efficient of variation was higher than genotypic co-efficient of variation for all the attributes indicating the influence of environment. The genotypic coefficient of variation ranged from 3.26% to 27.25%. Moderate genotypic coefficient of variation was observed for specific leaf nitrogen (27.25%). Low genotypic coefficient of variation was seen for the rest of characters i.e., per cent reduction of Fv/Fm (20.39%), specific leaf area (16.81%), harvest index (12.87%), sound mature kernel per cent (12.71%), kernel yield per plant (10.93%), shell thickness (10.15%), number of well filled and mature pods per plant (8.06%), pod yield per plant (6.91%), root length (6.07%), shelling percent (6.41%), oil per cent (4.63%) and SPAD chlorophyll meter reading (3.26%).

Heritability in broad sense was estimated for all the characters and it ranged from 14 % (Pod yield per plant) to as high as 97 % (Per cent

Table 27 : Estimates of genetic parameters for 13 characters in 28 F₂s of groundnut

Character	Mean	PCV (%)	GCV (%)	h ² (%)	GA	GAM (%)
SPAD chlorophyll meter reading	44.55	4.74	3.26	47	1.99	4.48
Specific leaf nitrogen (g N /m ²)	1.97	27.68	27.25	90	1.01	51.43
Specific leaf area (cm ² /g)	163.33	17.58	16.81	91	54.11	33.13
Per cent reduction of Fv/Fm	50.65	22.04	20.39	97	22.67	44.75
Root length (cm)	20.99	13.38	6.07	20	1.19	5.68
Harvest index	0.42	15.05	12.87	73	0.10	22.67
Shell thickness (mm)	1.09	11.29	10.15	81	0.21	18.79
Oil per cent	41.39	7.07	4.63	43	2.59	6.24
Shelling per cent	66.48	8.97	6.41	55	6.29	9.45
Sound mature kernel per cent	66.38	13.96	12.71	83	15.82	23.29
Number of well filled and mature pods per plant	10.56	17.37	8.06	21	0.81	7.71
Kernel yield per plant (g)	5.92	18.47	10.93	35	0.79	13.33
Pod yield per plant (g)	9.15	18.31	6.91	14	0.49	5.38

reduction of Fv/Fm). High heritability was observed for the characters viz., per cent reduction of Fv/Fm (97%), specific leaf area (91%), specific leaf nitrogen (90%), sound mature kernel per cent (83%), harvest index (73%) and shell thickness (81%). Moderate heritability was noticed for characters viz., SPAD chlorophyll meter reading (47%), oil per cent (43%), shelling per cent (55%) and kernel yield per plant (35%). The low heritability was seen for pod yield per plant (14%) and number of well-filled and mature pods per plant (35%).

The range of genetic advance varied from 0.10 to 54.11. The highest genetic advance was recorded for specific leaf area (54.11), per cent reduction of Fv/Fm (22.67) and sound mature kernel per cent (15.82) whereas, lowest genetic advance was recorded for harvest index (0.10).

Genetic advance, expressed as percent of population mean (GAM) ranged from 4.48% to 51.43% (Table 27). High genetic advance, expressed as per cent of population mean was observed for specific leaf nitrogen (51.43%), per cent reduction of Fv/Fm (44.75%), specific leaf area (33.13%), sound mature kernel per cent (23.29%) and harvest index (22.67%). Moderate genetic advance, expressed as per cent of population mean was observed for shell thickness (18.79%) and kernel yield per plant (13.33%). Low genetic advance, expressed as per cent of population mean was recorded for characters viz., SPAD chlorophyll meter reading (4.48%), pod yield per plant (5.38%), root length (5.68), oil per cent

(6.24%), number of well-filled and mature pods per plant (7.71%) and shelling per cent (9.45%), 146

4.7 CHARACTER ASSOCIATION

Correlation coefficients at phenotypic (r_p) and genotypic level (r_g) were worked out between pairs of characters under study in parents, F_1 (Rabi, 2002; *kharif*, 2003) and F_2 (*kharif*, 2003) generations and are furnished in Tables 28 to 32. In general, the genotypic correlations between pairs of characters were higher in magnitude than the corresponding phenotypic correlations.

4.7.1 RABI - 2002

4.7.1.1 PARENTS

Pod yield per plant had significant positive association with shell thickness ($r_p = 0.582$, $r_g = 0.781$), harvest index ($r_g = 0.479$), oil per cent ($r_g = 0.595$), number of well filled and mature pods per plant ($r_g = 0.601$) and kernel yield per plant ($r_p = 0.948$, $r_g = 1.023$). The relationship of pod yield per plant with SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area and per cent reduction of F_v/F_m was found non-significant and positive, while its association with shelling per cent and sound mature kernel per cent was non-significant and negative (Table 28).

The kernel yield per plant exhibited significant and positive association with shell thickness ($r_p = 0.615$, $r_g = 0.751$), oil per cent ($r_p =$

Table 28 : Phenotypic (P) and genotypic (G) correlation coefficients for physiological, yield and yield component characters in parents (*Rabi-2002*)

Character		Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Pod yield per plant
SPAD chlorophyll meter reading	P	0.237	-0.587*	-0.104	0.375	-0.158	0.160	0.013	-0.170	-0.120	-0.191	0.178	0.132
	G	0.289	-0.682**	-0.121	0.883**	-0.192	0.172	-0.028	-0.328	-0.159	-0.281	0.220	0.180
Specific leaf nitrogen	P		0.214	0.485	-0.113	0.624*	0.465	0.062	0.174	0.374	-0.129	-0.018	0.027
	G		0.221	0.524*	-0.270	0.724**	0.456	0.107	0.298	0.431	-0.153	0.010	0.053
Specific leaf area	P			0.283	-0.124	0.491	0.287	0.107	0.141	-0.112	0.571*	0.245	0.313
	G			0.378	-0.564*	0.650**	0.311	0.044	0.234	-0.112	0.626**	0.336	0.385
Per cent reduction of Fv/Fm	P				-0.257	0.480	0.470	0.036	-0.107	0.394	-0.377	0.148	0.231
	G				-1.382**	0.585*	0.540*	0.051	-0.188	0.472	-0.392	0.172	0.233
Root length	P					-0.347	-0.126	0.167	0.052	-0.404	0.147	0.068	0.118
	G					-0.745**	-0.237	-0.666**	0.363	-0.957**	0.617*	0.312	-0.051
Harvest index	P						0.678**	0.424	0.066	0.252	0.243	0.425	0.4212
	G						0.780**	0.550*	0.029	0.335	0.292	0.373	0.497*
Shell thickness	P							0.591*	0.009	0.219	0.146	0.615*	0.582*
	G							0.894**	0.013	0.271	0.122	0.751**	0.781**
Oil per cent	P								0.292	0.204	0.112	0.501*	0.481
	G								0.344	0.594*	0.238	0.651**	0.595*
Shelling per cent	P									0.259	-0.059	-0.018	-0.045
	G									0.710**	0.024	-0.342	-0.457
Sound mature kernel per cent	P										-0.465	-0.138	-0.141
	G										-0.618*	-0.260	-0.232
No. of well filled pods per plant	P											0.477	0.463
	G											0.567**	0.601*
Kernel yield per plant	P												0.948**
	G												1.023**

* Significant at 5% level of probability

** Significant at 1% level of probability

0.501, $r_g = 0.654$), number of well-filled and mature pods per plant ($r_g = 0.567$) and pod yield per plant. Its relationship with SPAD chlorophyll meter reading, specific leaf area, per cent reduction of Fv/Fm, harvest index and root length was found to be non-significant and positive, while it had non-significant negative association with shelling per cent and sound mature kernel per cent 148

SPAD chlorophyll meter reading established a non-significant and positive relationship with specific leaf nitrogen, shell thickness, oil per cent, kernel yield per plant and pod yield per plant, while its association with root length ($r_g = 0.883$) was significant and positive. The association of it with specific leaf area ($r_p = -0.587$, $r_g = -0.682$) was found to be significant and negative. It had non significant negative association with per cent reduction of Fv/Fm, harvest index, shelling per cent, sound mature kernel per cent and number of well filled and mature pods per plant.

Specific leaf nitrogen possessed significant and positive association with per cent reduction of Fv/Fm ($r_g = 0.524$), harvest index ($r_p = 0.724$, $r_g = 0.624$), while it had non-significant positive relationship with specific leaf area, shell thickness, shelling per cent, oil per cent, sound mature kernel per cent, pod yield per plant and SPAD chlorophyll meter reading. Specific leaf nitrogen expressed non-significant and negative association with root length, number of well-filled and mature pods per plant and kernel yield per plant

Specific leaf area exhibited significant positive association with harvest index ($r_g = 0.650$) and number of well filled and mature pods per plant ($r_g = 0.626$), however it also had non-significant positive association with specific leaf nitrogen, per cent reduction of Fv/Fm, shell thickness, oil per cent, shelling per cent, kernel yield per plant and pod yield per plant. On the contrary, it had non-significant and negative association with sound mature kernel per cent. However its association with SPAD chlorophyll meter reading and root length ($r_g = -0.564$) was negative and significant. 149

The association between per cent reduction of Fv/Fm and specific leaf nitrogen, harvest index ($r_g = 0.585$), shell thickness ($r_g = 0.540$) was found to be significant and positive. It possessed significant and negative association with root length ($r_g = -1.382$) while it had weak positive relationship with specific leaf area, oil per cent, sound mature kernel per cent, kernel yield per plant and pod yield per plant. Non-significant negative association of it was recorded with SPAD chlorophyll meter reading, shelling per cent and number of well-filled and mature pods per plant

The association of root length with SPAD chlorophyll meter reading and number of well filled and mature pods per plant ($r_g = 0.617$) was found to be significant and positive, while its association with specific leaf area, per cent reduction of Fv/Fm, harvest index ($r_g = -0.745$), oil per cent ($r_g = -0.666$) and sound mature kernel per cent ($r_g = 0.957$) was significant

and negative. On contrary, it displayed non-significant negative association with specific leaf nitrogen and shell thickness. It possessed non-significant positive association with shelling per cent kernel yield per plant and pod yield per plant

Harvest index possessed significant and positive association with specific leaf nitrogen, specific leaf area, per cent reduction of Fv/Fm, shell thickness ($r_p = 0.678$, $r_g = 0.780$), oil per cent ($r_g = 0.550$) and pod yield per plant ($r_g = 0.479$) and non-significant positive association with shelling per cent, sound mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant, while it had weak negative relationship with SPAD chlorophyll meter reading. It had significant negative association with root length

The association of shell thickness with per cent reduction of Fv/Fm, harvest index, oil per cent ($r_p = 0.591$, $r_g = 0.894$), kernel yield per plant ($r_p = 0.615$, $r_g = 0.751$) and pod yield per plant ($r_p = 0.582$, $r_g = 0.781$) was highly significant and positive, whereas, its association with SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area, shelling per cent, sound mature kernel per cent, number of well filled and mature pods per plant cent was non-significant and positive. The relationship between shell thickness and root length was weak and negative.

Highly significant and positive relationship were observed between oil per cent and harvest index, shell thickness, sound mature kernel per cent

($r_g = 0.594$), kernel yield per plant ($r_p = 0.501$, $r_g = 0.651$) and pod yield per plant ($r_g = 0.595$). Oil per cent showed non-significant positive association with SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area and per cent reduction of Fv/Fm, while negative and non-significant association with shelling per cent and number of well-filled and mature pods per plant was observed. It showed significant negative association with root length

Shelling per cent per cent exhibited significant positive association with sound mature kernel per cent ($r_g = 0.710$). It had non-significant negative association with SPAD chlorophyll meter reading, per cent reduction of Fv/Fm, number of well filled and mature pods per plant, kernel yield per plant and pod yield per plant, however it also had non-significant positive association with rest of characters. (Table 28)

The relationship of sound mature kernel per cent with oil per cent and shelling per cent was significant and positive, while its association with other characters viz., specific leaf nitrogen, per cent reduction of Fv/Fm, harvest index and shell thickness was found to be positive but non-significant. It had negative but significant association with root length, number of well-filled and mature pods per plant ($r_g = -0.618$). Sound mature kernel per cent registered negative non-significant association with SPAD chlorophyll meter reading, specific leaf area and kernel yield per plant and pod yield per plant

Number of well filled and mature pods per plant established a significant and positive relationship with specific leaf area, root length, kernel yield per plant ($r_g = 0.567$) and pod yield per plant ($r_g = 0.601$) and significant negative relationship with sound mature kernel per cent, while its association with harvest index, shell thickness and oil per cent was non-significant and positive. It also expressed non-significant negative relation with rest of the characters. 152

4.7.1.2 F₁ GENERATION

Pod yield per plant had significant positive association with harvest ($r_p = 0.315$, $r_g = 0.310$), number of well filled and mature pods per plant ($r_p = 0.565$, $r_g = 0.616$) and kernel yield per plant ($r_p = 0.657$, $r_g = 0.687$) (Table 29). It had significant negative association with per cent reduction of Fv/Fm ($r_g = -0.445$) and shelling per cent ($r_g = -0.313$). The relationship of pod yield per plant with specific leaf area, oil per cent and sound mature kernel per cent was non-significant and positive, while its association with other characters was found to be negative but non-significant.

The kernel yield per plant exhibited significant and positive association with specific leaf nitrogen ($r_g = 0.417$), harvest index ($r_p = 0.414$, $r_g = 0.483$), oil per cent ($r_g = 0.286$) and sound mature kernel per cent ($r_p = 0.644$, $r_g = 0.666$). Its association with oil per cent and

Table 29 : Phenotypic (P) and genotypic (G) correlation coefficients for physiological, yield and yield component characters in F₁s (Rabi-2002)

Character		Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Pod yield per plant
SPAD chlorophyll meter reading	P	0.219	0.007	0.169	0.132	-0.312*	0.403**	-0.024	-0.133	0.159	-0.119	-0.268*	-0.160
	G	0.296*	0.085	0.390*	0.307*	-0.472**	0.577**	-0.116	-0.226	0.279*	0.006	-0.348**	-0.112
Specific leaf nitrogen	P		0.266*	0.378**	0.052	-0.012	0.327*	0.163	0.128	0.474**	-0.056	-0.0226	-0.019
	G		0.279*	0.438**	0.056	-0.017	0.331*	0.199	0.166	0.540**	-0.136	0.417**	-0.026
Specific leaf area	P			0.027	-0.118	0.253	0.074	-0.019	0.080	-0.004	0.114	-0.032	0.081
	G			0.029	-0.187	0.285*	0.076	-0.020	0.081	-0.005	0.221	-0.053	0.107
Per cent reduction of Fv/Fm	P				-0.119	-0.195	0.023	0.087	0.210	0.089	-0.151	-0.242	-0.245
	G				-0.152	-0.338*	0.024	0.056	0.247	0.103	-0.398**	-0.534**	-0.445**
Root length	P					-0.189	0.349**	-0.355**	-0.155	-0.015	-0.113	-0.150	-0.008
	G					-0.245	0.380**	-0.490**	-0.208	-0.013	-0.258	-0.407**	-0.126
Harvest index	P						-0.165	0.083	0.031	0.047	0.428**	0.414**	0.315*
	G						-0.209	0.070	0.035	0.057	0.433**	0.483**	0.310*
Shell thickness	P							-0.067	-0.259	0.221	0.075	-0.047	-0.009
	G							-0.074	-0.315*	0.239	0.095	-0.120	-0.036
Oil per cent	P								-0.048	0.055	-0.038	0.151	0.119
	G								-0.049	0.098	-0.166	0.286*	-0.084
Shelling per cent	P									0.386**	-0.146	0.080	-0.084
	G									0.504**	-0.259	0.088	-0.313*
Sound mature kernel per cent	P										-0.070	0.206	0.049
	G										-0.287*	-0.124	-0.014
No. of well filled pods per plant	P											0.644**	0.565**
	G											0.666**	0.616**
Kernel yield per plant	P												0.657**
	G												0.657**

* Significant at 5% level of probability

** Significant at 1% level of probability

shelling per cent was found to be non-significant and positive, while it had non-significant negative association with specific leaf area and shell thickness. The relationship of kernel yield per plant with SPAD chlorophyll meter reading ($r_p = -0.268$, $r_g = -0.348$), per cent reduction of Fv/Fm ($r_g = -0.534$) and root length ($r_g = -0.407$) was significant and negative

SPAD chlorophyll meter reading established a significant and positive relationship with specific leaf nitrogen ($r_g = 0.296$), per cent reduction of Fv/Fm ($r_g = 0.390$), root length ($r_g = 0.307$), shell thickness ($r_p = 0.403$, $r_g = 0.577$) and sound mature kernel per cent ($r_g = 0.275$), while its association with harvest index ($r_p = -0.312$, $r_g = -0.4720$) and kernel yield per plant ($r_p = -0.268$, $r_g = -0.348$) was significant and negative. SPAD chlorophyll meter reading expressed non-significant and negative association with oil per cent, shelling per cent, number of well filled and mature pods per plant and pod yield per plant (Table 29)

Specific leaf nitrogen exhibited significant positive association with SPAD chlorophyll meter reading, specific leaf area ($r_p = 0.266$, $r_g = 0.279$), per cent reduction of Fv/Fm ($r_p = 0.378$, $r_g = 0.438$), shell thickness ($r_p = 0.327$, $r_g = 0.331$) sound mature kernel per cent ($r_p = 0.474$, $r_g = 0.540$) and kernel yield per plant ($r_g = 0.471$), however it also had non-significant positive association with harvest index, oil per cent and shelling per cent. On contrary, it had non-significant and negative association with root

length, number of well filled and mature pods per plant and pod yield per plant .

The association of specific leaf area with specific leaf nitrogen and harvest index ($r_g = 0.285$) was found to be significant and positive, while its weak positive association was observed with SPAD chlorophyll meter reading, per cent reduction of Fv/Fm, shell thickness, shelling per cent, number of well filled and mature pods per plant and pod yield per plant. On contrary, it displayed non-significant negative association with root length, oil per cent, sound mature kernel per cent and kernel yield per plant

Per cent reduction of Fv/Fm had positive significant association with SPAD chlorophyll meter reading and specific leaf nitrogen and significant negative association with harvest index ($r_g = -0.338$), number of well filled and mature pods per plant ($r_g = -0.398$), kernel yield per plant ($r_g = -0.534$) and pod yield per plant ($r_g = -0.445$). Non-significant positive association of per cent reduction of Fv/Fm was observed with shell thickness, oil per cent, shelling per cent and sound mature kernel per cent, while its non-significant and negative association was observed with root length

The relationship of root length with SPAD chlorophyll meter reading and shell thickness ($r_p = 0.349$, $r_g = 0.380$) was significant and positive while its association with specific leaf nitrogen was found to be positive but non-significant. It had negative but significant association with oil per cent ($r_p = -0.355$, $r_g = -0.490$) and kernel yield per plant ($r_g = -0.407$). On

contrary it had non-significant and negative correlation with specific leaf area, per cent reduction of F_v/F_m , harvest index, shelling per cent, sound mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant (Table 29)

Harvest index showed significant and positive association with specific leaf area, number of well filled and mature pods per plant ($r_p = 0.428$, $r_g = 0.433$), kernel yield per plant ($r_p = 0.414$, $r_g = 0.483$) and pod yield per plant ($r_p = 0.315$, $r_g = 0.310$) and non-significant positive association was observed with oil per cent, shelling per cent and sound mature kernel per cent. It had weak negative relationship with specific leaf nitrogen, root length and shell thickness. It had negative but significant association with SPAD chlorophyll meter reading and percent reduction of F_v/F_m

The shell thickness exhibited significant and positive association with SPAD chlorophyll meter reading, specific leaf nitrogen, root length and significant negative association with shelling per cent ($r_g = -0.315$). Its relationship with specific leaf area, per cent reduction of F_v/F_m , sound mature kernel per cent, number of well filled and mature pods per plant was found to be non-significant and positive, while it had non-significant negative association with harvest index, oil per cent, kernel yield per plant and pod yield per plant.

Oil per cent established a significant and positive relationship with specific leaf nitrogen, per cent reduction of Fv/Fm, harvest index, sound mature kernel per cent and kernel yield per plant ($r_g = 0.286$), while its association with SPAD chlorophyll meter reading, specific leaf area, shell thickness, shelling percent, number of well-filled and mature pods per plant was non-significant and negative. It had positive and non-significant association with pod yield per plant

Shelling per cent expressed significant and positive association with sound mature kernel per cent ($r_p = 0.386$, $r_g = 0.504$), while it had non-significant and positive relationship with rest of the characters. It also registered significant negative association with shell thickness and pod yield per plant ($r_{g\Delta} = 0.313$) and non-significant negative association with SPAD chlorophyll meter reading, root length, oil per cent and number of well filled and mature pods per plant

Sound mature kernel per cent exhibited significant positive association with-SPAD chlorophyll meter reading, specific leaf nitrogen and shelling per cent, however, it also had non-significant positive association with per cent reduction of Fv/Fm, harvest index, shell thickness, oil per cent and pod yield per plant. On contrary, it had non-significant and negative association was observed with specific leaf area, root length and kernel yield per plant. However its association with number

of well filled and mature pods per plant ($r_g = -0.287$) was significant and negative 158

The association of number of well filled and mature pods per plant with harvest index, kernel yield per plant ($r_p = 0.644$, $r_g = 0.6660$ and pod yield per plant ($r_p = 0.565$, $r_g = 0.616$) was found to be significant and positive, while its weak positive association was observed with specific leaf area, root length and shell thickness. On contrary, it displayed non-significant negative association with SPAD chlorophyll meter reading, specific leaf nitrogen, shelling per cent and oil per cent.

4.7.2 KHARIF - 2003

4.7.2.1 PARENTS

Pod yield per plant had significant positive association with kernel yield per plant ($r_p = 0.757$) (Table 30). The relationship of pod yield per plant with oil per cent, shelling per cent, number of well filled and mature pods per plant and sound mature kernel per cent was non-significant and positive, while its association with other characters viz., SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area, per cent reduction of F_v/F_m , root length ($r_p = -0.465$), harvest index and shell thickness were found to be negative but non-significant.

The kernel yield per plant exhibited significant and positive association with number of well-filled and mature pods per plant ($r_p = 0.616$). Its relationship with specific leaf nitrogen, per cent

Table 30 : Phenotypic (P) and genotypic (G) correlation coefficients for physiological, yield and yield components characters in parents (*Kharif-2003*)

Character		Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Pod yield per plant
SPAD chlorophyll meter reading	P	0.466	-0.636**	0.709**	0.073	-0.023	0.079	-0.243	-0.202	0.214	-0.245	-0.172	-0.181
	G	0.702**	-0.661**	0.785**	0.046	***	0.031	-0.620*	-0.382	0.335	***	***	***
Specific leaf nitrogen	P		-0.324	0.634**	0.032	-0.232	-0.165	-0.043	0.178	0.033	-0.061	0.136	-0.062
	G		-0.426	0.802**	0.214	***	0.038	0.123	0.007	0.019	***	***	***
Specific leaf area	P			-0.276	0.103	-0.141	-0.192	0.395	0.309	0.188	0.142	-0.053	-0.107
	G			-0.291	0.070	***	-0.356	0.711**	0.662**	0.181	***	***	***
Per cent reduction of Fv/Fm	P				-0.255	-0.071	0.245	-0.089	-0.226	0.440	-0.145	0.007	-0.058
	G				-0.430	***	0.318	-0.036	-0.339	0.595*	***	***	***
Root length	P					0.012	-0.391	-0.035	0.307	-0.308	-0.100	-0.239	-0.465
	G					***	-1.248**	-0.043	1.068**	-0.517*	***	***	***
Harvest index	P						0.434	-0.248	-0.064	-0.283	0.068	0.161	-0.087
	G						**	***	***	***	***	***	***
Shell thickness	P							-0.078	-0.101	0.337	0.203	0.052	-0.053
	G							-0.171	-0.578*	0.628**	***	***	***
Oil per cent	P								0.063	-0.043	-0.006	0.057	0.214
	G								0.234	0.100	***	***	***
Shelling per cent	P									0.135	0.595**	0.335	0.001
	G									-0.173	***	***	***
Sound mature kernel per cent	P										0.415	0.087	0.083
	G										***	***	***
No. of well filled pods per plant	P											0.616*	0.338
	G											***	***
Kernel yield per plant	P												0.757**
	G												***

* Significant at 5% level of probability

** Significant at 1% level of probability

*** indicates values are almost equal to zero

reduction of Fv/Fm, harvest index, shell thickness, oil per cent, shelling per cent and sound mature kernel per cent was found to be non-significant and positive, while it had non-significant negative association with SPAD chlorophyll meter reading, specific leaf area and root length. 160

SPAD chlorophyll meter reading established a significant and positive relationship with specific leaf nitrogen ($r_g = 0.702$), per cent reduction of Fv/Fm ($r_g = 0.709$, $r_g = 0.785$), while its association with specific leaf area ($r_p = -0.636$, $r_g = -0.661$) was significant and negative. SPAD chlorophyll meter reading expressed non-significant and negative association with harvest index, shelling per cent, number of well filled and mature pods per plant, kernel yield per plant and pod yield per plant, while it had non-significant and positive relationship with rest of the characters.

Specific leaf nitrogen exhibited significant positive association with per cent reduction of Fv/Fm ($r_p = 0.634$, $r_g = 0.802$) and SPAD chlorophyll meter reading, however, it also had non-significant positive association with root length, shell thickness, shelling per cent, sound mature kernel per cent and kernel yield per plant. On contrary, it had non-significant and negative association with specific leaf area ($r_g = -0.426$), harvest index, oil per cent, number of well filled and mature pods per plant and pod yield per plant.

The association of specific leaf area with oil per cent ($r_g = 0.711$) and shelling per cent ($r_g = 0.662$) was found to be significant and positive,

while its weak positive association was observed with root length, sound mature kernel per cent and number of well filled and mature pods per plant. On contrary, it displayed non-significant negative association with specific leaf nitrogen, per cent reduction of Fv/Fm, harvest index, shell thickness, kernel yield per plant and pod yield per plant.

Percent reduction of Fv/Fm had positive significant association with sound mature kernel per cent ($r_g = 0.595$), SPAD chlorophyll meter reading and specific leaf nitrogen. Non-significant positive association of per cent reduction of Fv/Fm was recorded with shell thickness and kernel yield per plant, while its non-significant and negative association was observed with specific leaf area, root length, harvest index, oil per cent, shelling per cent, number of well filled and mature pods per plant and pod yield per plant.

The relationship of root length with shelling per cent was ($r_g = 1.068$) significant and positive, while its association with other characters viz., SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area and harvest index was found to be positive but non-significant. It had negative but significant association with shell thickness ($r_g = -1.243$) and sound mature kernel per cent ($r_g = -0.517$). On contrary it had non-significant and negative correlation with per cent reduction of Fv/Fm, oil per cent, number of well filled and mature pods per plant, kernel yield per plant and pod yield per plant

Harvest index possessed non- significant and positive association with root length, shell thickness, number of well filled and mature pods per plant and kernel yield per plant. Non-significant and negative association of it was observed with SPAD chlorophyll meter reading, per cent reduction of Fv/Fm, oil per cent, specific leaf area, specific leaf nitrogen, shelling per cent and sound mature kernel per cent.

The shell thickness exhibited significant and positive association with sound mature kernel per cent ($r_g = 0.628$) and significant negative association with root length and shelling per cent ($r_g = -0.578$). It's relationship with SPAD chlorophyll meter reading, specific leaf nitrogen, per cent reduction of Fv/Fm, harvest index, number of well filled and mature pods per plant and kernel yield per plant was found to be non-significant and positive, while it had non-significant negative association with specific leaf area, oil per cent and pod yield per plant.

Oil per cent established a significant and positive relationship with specific leaf area and significant negative relationship with SPAD chlorophyll meter reading, while its association with specific leaf nitrogen, per cent reduction of Fv/Fm, root length, harvest index, shell thickness and number of well filled and mature pods per plant was non-significant and negative. It had positive and non-significant association with rest of the characters

Shelling per cent expressed significant and positive association with specific leaf area, root length and number of well filled and mature pods per plant ($r_p = 0.595$), while it had non-significant and positive relationship with rest of the characters viz., specific leaf nitrogen, oil per cent, kernel yield per plant and pod yield per plant. It also registered significant negative association with shell thickness and non-significant negative association with SPAD chlorophyll meter reading, per cent reduction of Fv/Fm, harvest index and sound mature kernel per cent

Sound mature kernel per cent exhibited significant positive association with per cent reduction of Fv/Fm and shell thickness, however, it also had non-significant positive association with SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area, oil per cent, shelling per cent, number of well filled and mature pods per plant, kernel yield per plant and pod yield per plant. On contrary, it had non-significant and negative association with harvest index. However its association was observed significant but negative with root length

The association of number of well filled and mature pods per plant with shelling per cent and kernel yield per plant ($r_p = 0.616$) was found to be significant and positive, while its weak positive association was observed with specific leaf area, harvest index, shell thickness, sound mature kernel per cent and pod yield per plant. On contrary, it displayed non-significant negative association with SPAD chlorophyll meter

reading, specific leaf nitrogen, per cent reduction of Fv/Fm, root length and oil per cent . 164

4.7.2.2 F₁ GENERATION

Pod yield per plant established a significant and positive relationship with root length ($r_g = 0.332$), harvest index ($r_p = 0.332$, $r_g = 0.435$), oil per cent ($r_p = 0.364$, $r_g = 0.372$), shelling per cent ($r_g = 0.424$), sound mature kernel per cent ($r_g = 0.341$), number of well filled and mature pods per plant ($r_p = 0.768$, $r_g = 0.773$) and kernel yield per plant ($r_p = 0.920$, $r_g = 1.007$), while its association with SPAD chlorophyll meter reading ($r_g = -0.265$), specific leaf nitrogen ($r_p = -0.259$), specific leaf area ($r_g = -0.398$) and per cent reduction of Fv/Fm ($r_p = -0.398$) was significant and negative (Table 31). Pod yield per plant expressed non-significant and positive association with shell thickness.

Kernel yield per plant exhibited significant positive association with root length ($r_g = 0.334$), harvest index ($r_p = 0.334$, $r_g = 0.540$), oil per cent ($r_g = 0.333$), root length ($r_g = 0.334$), shelling per cent ($r_g = 0.634$), sound mature kernel per cent ($r_g = 0.463$), number of well filled and mature pods per plant ($r_p = 0.741$, $r_g = 0.861$) and pod yield per plant. However it also had significant negative association with SPAD chlorophyll meter reading ($r_g = -0.386$), specific leaf nitrogen ($r_g = -0.506$) and specific leaf area

Table 31 : Phenotypic (P) and genotypic (G) correlation coefficients for physiological, yield and yield components characters in F₁s (*Kharif- 2003*)

Character		Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Pod yield per plant
SPAD chlorophyll meter reading	P	0.016	-0.143	0.245	0.158	0.034	0.126	-0.114	-0.045	0.060	-0.080	-0.092	-0.105
	G	0.034	-0.156	0.369**	0.519**	-0.137	0.222	-0.121	-0.258	0.150	-0.282*	-0.386**	-0.265*
Specific leaf nitrogen	P		0.080	-0.075	0.002	-0.584**	0.464**	-0.031	0.116	0.044	-0.918	-0.225	-0.259**
	G		0.091	-0.076	-0.006	-0.679**	0.478**	-0.094	0.231	0.055	-0.534**	-0.506**	-0.447
Specific leaf area	P			-0.214	-0.071	-0.167	-0.277*	0.118	-0.047	-0.249	-0.140	-0.259	-0.317
	G			-0.255	-0.076	-0.101	-0.301*	0.204	-0.087	-0.336*	-0.286*	-0.382**	-0.398**
Per cent reduction of Fv/Fm	P				-0.266**	0.104	-0.004	-0.222	0.057	0.013	0.042	-0.042	-0.398**
	G				-0.318*	0.178	0.002	-0.479**	0.094	0.022	0.089	-0.056	-0.062
Root length	P					0.132	0.108	0.233	0.029	0.116	-0.189	0.132	0.052
	G					0.199	0.104	0.236	0.176	0.198	0.289*	0.334*	0.332*
Harvest index	P						-0.423**	0.135	0.252	0.045	0.289*	0.334*	0.332*
	G						-0.053**	0.314	0.487**	0.015	0.706**	0.540**	0.435**
Shell thickness	P							0.088	-0.013	0.328*	0.147	0.064	0.104
	G							0.191	0.020	0.392**	0.281*	0.055	0.121
Oil per cent	P								0.214	-0.055	0.315*	0.055	0.364**
	G								0.502**	0.050	0.143	0.333*	0.372**
Shelling per cent	P									0.045	0.124	0.326	0.146
	G									0.151	0.928**	0.634**	0.424**
Sound mature kernel per cent	P										0.086	0.155	0.167
	G										0.257	0.463**	0.341**
No. of well filled pods per plant	P											0.741**	0.768**
	G											0.861**	0.773**
Kernel yield per plant	P												0.920**
	G												1.007**

* Significant at 5% level of probability
** Significant at 1% level of probability

($r_g = -0.382$). On contrary, it had non-significant and negative association with shell thickness. **166**

SPAD chlorophyll meter reading had significant positive association with per cent reduction of Fv/Fm ($r_g = 0.369$) and root length ($r_g = 0.519$). The relationship of SPAD chlorophyll meter reading with specific leaf nitrogen, harvest index, shell thickness and sound mature kernel per cent was non-significant and positive, while its association with other characters viz., specific leaf area, oil per cent and shelling per cent were found to be negative but non-significant. SPAD chlorophyll meter reading had significant and negative association with number of well-filled and mature pods per plant ($r_g = -0.282$), kernel yield per plant ($r_g = -0.386$) and pod yield per plant ($r_g = -0.265$).

The specific leaf nitrogen exhibited significant and positive association with shell thickness ($r_p = 0.464$, $r_g = 0.478$). Specific leaf nitrogen also registered significant negative association with harvest index ($r_p = -0.584$, $r_g = -0.679$), number of well-filled and mature pods per plant ($r_g = -0.534$), kernel yield per plant ($r_g = -0.506$) and pod yield per plant ($r_p = -0.259$). Its relationship with SPAD chlorophyll meter reading, specific leaf area, shelling per cent and sound mature kernel per cent was found to be non-significant and positive, while it had non-significant negative association with per cent reduction of Fv/Fm, oil per cent and root length.

the association of specific leaf area with shell thickness ($r_p = -0.277$, $r_g = -0.301$), sound mature kernel per cent ($r_g = -0.336$), number of well filled and mature pods per plant ($r_g = -0.286$), kernel yield per plant ($r_g = -0.382$) and pod yield per plant ($r_g = -0.398$) was found to be significant and negative, while its weak positive association was observed with specific leaf nitrogen and oil per cent. On contrary, it displayed non-significant negative association with SPAD chlorophyll meter reading, root length, per cent reduction of Fv/Fm, harvest index and shelling per cent

Per cent reduction of Fv/Fm had positive significant association with SPAD chlorophyll meter reading and negative significant association with root length ($r_p = -0.266$, $r_g = -0.318$), oil per cent ($r_g = -0.479$) and pod yield per plant ($r_p = -0.398$). Non-significant positive association of per cent reduction of Fv/Fm was observed with shelling per cent, sound mature kernel per cent and number of well filled and mature pods per plant, while its non-significant and negative association was seen with specific leaf nitrogen, specific leaf area, shell thickness and kernel yield per plant,

Root length established a significant and positive relationship with SPAD chlorophyll meter reading, kernel yield per plant ($r_g = 0.334$) and pod yield per plant ($r_g = 0.332$) and significant negative relationship with percent reduction of Fv/Fm, number of well-filled and mature pods per plant ($r_g = -0.289$) while its association with specific leaf nitrogen and

specific leaf area was non-significant and negative. It had positive and non- 168
significant association with rest of the characters

The association of harvest index with number of well filled and mature pods per plant ($r_p = 0.289$, $r_g = 0.706$), shelling per cent ($r_g = 0.478$), kernel yield per plant ($r_p = 0.334$, $r_g = 0.540$) and pod yield per plant ($r_p = 0.332$, $r_g = 0.435$) was found to be significant and positive, while its weak positive association was observed with oil per cent, root length and sound mature kernel per cent. On contrary, it displayed non-significant negative association with specific leaf area. Harvest index expressed significant negative association with specific leaf nitrogen ($r_p = -0.584$, $r_g = -0.679$) and shell thickness ($r_p = -0.423$, $r_g = -0.653$).

The shell thickness exhibited significant and positive association with sound mature kernel per cent ($r_g = 0.328$, $r_g = 0.392$), specific leaf nitrogen and number of well filled and mature pods per plant ($r_g = 0.281$) and significant negative association with specific leaf area and harvest index. Its relationship with SPAD chlorophyll meter reading, root length, oil per cent, pod yield per plant, shelling per cent and kernel yield per plant was found to be non-significant and positive, while it had non-significant negative association with per cent reduction of F_v/F_m and shelling per cent.

Oil per cent expressed significant and positive association with shelling per cent ($r_g = 0.502$), number of well filled and mature pods per

plant ($r_p = 0.315$), kernel yield per plant ($r_g = 0.333$) and pod yield per plant ($r_p = 0.364$, $r_g = 0.372$), while it had non-significant and positive relationship with specific leaf area, root length, harvest index, shell thickness and sound mature kernel per cent. It also registered significant negative association with per cent reduction of Fv/Fm and non-significant negative association with SPAD chlorophyll meter reading and specific leaf nitrogen (Table 31).

Shelling per cent exhibited significant positive association with harvest index, oil per cent, number of well filled and mature pods per plant ($r_g = 0.928$), kernel yield per plant ($r_g = 0.634$) and pod yield per plant ($r_g = 0.424$), however, it also had non-significant positive association with specific leaf nitrogen, per cent reduction of Fv/Fm, root length, shell thickness and sound mature kernel per cent. On contrary, it had non-significant and negative association with SPAD chlorophyll meter reading and specific leaf area.

The relationship of sound mature kernel per cent with shell thickness, kernel yield per plant ($r_g = 0.463$) and pod yield per plant ($r_g = 0.341$) was significant and positive, while its association with other characters viz., SPAD chlorophyll meter reading, specific leaf nitrogen, per cent reduction of Fv/Fm, root length, oil per cent, shelling per cent, number of well filled and mature pods per plant and harvest index was found to be positive but non-significant.

Number of well filled and mature pods per plant established a significant and positive relationship with root length, harvest index, shell thickness, oil per cent, shelling per cent, kernel yield per plant ($r_p = 0.741$, $r_g = 0.861$) and pod yield per plant ($r_p = 0.768$, $r_g = 0.773$) and significant negative relationship with SPAD chlorophyll meter reading, specific leaf nitrogen, root length and specific leaf area, while its association with per cent reduction of Fv/Fm and sound mature kernel per cent was non-significant and positive.

4.7.2.3 F₂ GENERATION

Pod yield per plant had significant positive association with harvest index ($r_g = 0.592$), number of well-filled and mature pods per plant ($r_p = 0.639$, $r_g = 0.321$) and kernel yield per plant ($r_p = 0.613$, $r_g = 0.792$). The relationship of pod yield per plant with per cent reduction of Fv/Fm ($r_p = -0.332$, $r_g = -0.884$) and root length ($r_g = -0.389$) was significant and negative while its association with other characters viz., SPAD chlorophyll meter reading, specific leaf nitrogen, shell thickness and shelling per cent was found to be positive but non-significant (Table 32). On contrary it had non-significant and negative correlation with specific leaf area, oil per cent and sound mature kernel per cent.

The kernel yield per plant exhibited significant and positive association with harvest index ($r_g = 0.481$), shelling per cent ($r_p = 0.445$,

Table 32. Phenotypic (r) and genotypic (G) correlation coefficients for physiological, yield and yield component characters in F_2 s (Kharif- 2003)

Character		Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Pod yield per plant
SPAD chlorophyll meter reading	P	-0.035	-0.281	-0.305*	0.006	0.089	0.204	0.134	-0.088	0.022	0.061	0.207	0.238
	G	0.075	-0.475**	-0.476**	-0.135	-0.055	0.236	0.089	-0.229	-0.004	-0.250	0.038	0.129
Specific leaf nitrogen	P		0.085	0.002	-0.029	-0.023	0.299*	-0.145	-0.225	-0.209	0.157	0.023	0.045
	G		0.094	-0.000	-0.064	-0.005	0.364**	-0.171	-0.279*	-0.225	0.384**	0.106	0.183
Specific leaf area	P			-0.033	-0.019	0.017	-0.285*	-0.232	-0.028	0.216	0.131	0.022	-0.019
	G			-0.046	-0.055	0.130	-0.311	-0.409**	-0.098	0.236	0.365**	0.038	0.154
Per cent reduction of Fv/Fm	P				0.288*	-0.378**	0.057	-0.171	-0.133	-0.113	-0.311*	-0.287*	-0.332*
	G				0.673**	-0.432**	0.006	-0.259	-0.158	-0.116	-0.564**	-0.516**	-0.884**
Root length	P					-0.156	0.157	-0.282*	-0.232	-0.226	-0.079	-0.237	-0.110
	G					-0.329*	0.445**	-0.778**	-0.488**	-0.538**	-0.357**	-0.490**	-0.389**
Harvest index	P						-0.100	-0.077	-0.618	-0.312*	-0.008	-0.033	0.102
	G						-0.079	0.296*	0.392**	0.106	0.666**	0.481**	0.592**
Shell thickness	P							-0.077	-0.168	-0.312*	-0.007	-0.033	0.102
	G							-0.259*	-0.325*	-0.420**	-0.072	-0.110	0.025
Oil per cent	P								0.292*	0.094	0.027	0.075	-0.085
	G								0.331*	0.072	0.125	0.221	-0.208
Shelling per cent	P									0.437**	-0.006	0.445**	0.007
	G									0.591**	0.044	0.682**	0.242
Sound mature kernel per cent	P										-0.153	0.147	-0.061
	G										-0.218	0.218	-0.004
No. of well filled pods per plant	P											0.505**	0.639**
	G											0.463**	0.321*
Kernel yield per plant	P												0.613**
	G												0.792**

* Significant at 5% level of probability

** Significant at 1% level of probability

$r_g = 0.682$), number of well filled and mature pods per plant ($r_p = 0.505$, $r_g = 0.463$) and pod yield per plant. Its relationship with SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area, oil per cent and sound mature kernel per cent was found to be non-significant and positive, while it had significant negative association with per cent reduction of Fv/Fm ($r_p = -0.287$, $r_g = -0.516$) and root length ($r_g = -0.490$) and non-significant and negative association with shell thickness .

SPAD chlorophyll meter reading established a non-significant and positive relationship with specific leaf nitrogen, shell thickness, oil per cent, kernel yield per plant and pod yield per plant, while its association with root length, harvest index, shelling per cent, sound mature kernel per cent and number of well filled and mature pods per plant was non-significant but negative. The association of it with specific leaf area ($r_g = -0.475$) and per cent reduction of Fv/Fm ($r_p = -0.305$, $r_g = -0.476$) was found to be significant and negative.

Specific leaf nitrogen possessed significant and positive association with shell thickness ($r_p = 0.299$, $r_g = 0.364$) and number of well-filled and mature pods per plant ($r_g = 0.384$), while it had significant negative relationship with shelling per cent ($r_g = -0.279$). Specific leaf nitrogen expressed non-significant and negative association with root length, per cent reduction of Fv/Fm, harvest index, oil per cent and sound mature

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kernel per cent, while it had non-significant and positive association with rest of the characters. 173

Specific leaf area exhibited significant positive association with number of well filled and mature pods per plant ($r_g = 0.365$), however it also had non-significant positive association with specific leaf nitrogen, harvest index, sound mature kernel per cent and kernel yield per plant. On contrary, it had non-significant and negative association with per cent reduction of F_v/F_m , root length and shelling per cent. However its association with SPAD chlorophyll meter reading, shell thickness ($r_p = -0.285$) and oil per cent ($r_g = -0.409$) was negative and significant.

The association between per cent reduction of F_v/F_m and root length ($r_p = 0.288$, $r_g = 0.673$) was found to be significant and positive. It possessed significant and negative association with SPAD chlorophyll meter reading, harvest index ($r_p = -0.378$, $r_g = 0.432$), number of well filled and mature pods per plant ($r_p = -0.311$, $r_g = -0.564$), kernel yield per plant ($r_p = -0.287$, $r_g = -0.516$) and pod yield per plant ($r_p = -0.332$, $r_g = -0.884$), it had weak positive relationship with shell thickness, it's non-significant and negative association was observed with specific leaf nitrogen, specific leaf area, oil per cent, shelling per cent and sound mature kernel per cent.

The association of root length with per cent reduction of F_v/F_m and shell thickness ($r_g = 0.445$) was found to be significant and positive, while

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its significant and negative association was observed with harvest index ($r_g = -0.329$), oil per cent ($r_p = -0.282$, $r_g = -0.778$), shelling per cent ($r_g = -0.488$), sound mature kernel per cent ($r_g = -0.538$), number of well filled and mature pods per plant ($r_g = -0.357$), kernel yield per plant ($r_g = -0.490$) and pod yield per plant ($r_g = -0.389$). On contrary, it displayed non-significant negative association with SPAD chlorophyll meter reading, specific leaf nitrogen and specific leaf area.

Harvest index possessed significant and positive association with oil per cent ($r_g = 0.296$), shelling per cent ($r_g = 0.392$), number of well filled and mature pods per plant ($r_g = 0.666$), kernel yield per plant ($r_g = 0.481$) and pod yield per plant ($r_g = 0.592$) and non-significant positive association with specific leaf area, while it had weak negative relationship with the rest of the characters (Table 32). It had significant negative association with per cent reduction of Fv/Fm, root length and sound mature kernel per cent ($r_g = -0.312$)

The association of shell thickness with specific leaf nitrogen, root length was highly significant and positive whereas It's correlation with specific leaf area, oil per cent ($r_g = -0.259$), shelling per cent ($r_g = -0.325$) and sound mature kernel per cent ($r_p = -0.312$, $r_g = -0.420$) was significant and negative. The relationship between shell thickness and SPAD chlorophyll meter reading, per cent reduction of Fv/Fm and pod yield per

plant was weak and positive and with the rest of characters it is non-significant and negative . 175

Highly significant and positive relationship were observed between oil per cent, harvest index and shelling per cent ($r_p = 0.292$, $r_g = 0.331$). Oil per cent showed non-significant positive association with specific leaf nitrogen, per cent reduction of Fv/Fm, sound mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant, while negative and non-significant association with SPAD chlorophyll meter reading and pod yield per plant was observed. It showed negative significant association with specific leaf area, root length and shell thickness

Shelling per cent per cent exhibited significant positive association with harvest index, oil per cent, sound mature kernel per cent ($r_p = 0.437$, $r_g = 0.591$) and kernel yield per plant ($r_p = 0.445$, $r_g = 0.682$). It had significant negative association with specific leaf nitrogen, root length and shell thickness, however, it also had non-significant positive association with number of well filled and mature pods per plant and pod yield per plant .On contrary, it had non-significant and negative association with SPAD chlorophyll meter reading, specific leaf area and per cent reduction of Fv/Fm.

The relationship of sound mature kernel per cent with shell thickness, shelling per cent was significant and positive, while it's

association with other characters viz., oil per cent, specific leaf area and kernel yield per plant was found to be positive but non-significant. It had negative but significant association with root length, harvest index and shell thickness. Sound mature kernel per cent registered negative non-significant association with SPAD chlorophyll meter reading, specific leaf nitrogen, per cent reduction of Fv/Fm, number of well filled and mature pods per plant and pod yield per plant 176

Number of well filled and mature pods per plant established a significant and positive relationship with specific leaf nitrogen, specific leaf area and harvest index and significant negative relationship with per cent reduction of Fv/Fm and root length, while its association with oil per cent, shelling per cent and kernel yield per plant was non-significant and positive. It also expressed non-significant negative relation with rest of the characters.

4.8 PATH COEFFICIENTS

The phenotypic and genotypic path coefficients for yield in parents, F₁s and F₂s were given in Tables 33 to 37 separately season - wise (*rabi* 2002 and *kharif* 2003). Though, values of both phenotypic and genotypic path coefficients were given in tables, presentation (results and discussion) is based on phenotypic path coefficients only.

4.8.1.1 PARENTS

The maximum positive direct contribution to pod yield per plant was from kernel yield per plant (0.938) followed by per cent reduction of Fv/Fm (0.213). The direct effects of specific leaf nitrogen, oil per cent and number of well filled and mature pods per plant and kernel yield per plant were found to be positive. The highest direct negative effect to pod yield per plant was from harvest index (-0.185), shell thickness (-0.138) followed by specific leaf area, sound mature kernel per cent, shelling per cent, SPAD chlorophyll meter reading and root length.

SPAD chlorophyll meter reading exerted positive indirect effect through shelling per cent, sound mature kernel per cent and kernel yield per plant. On contrary, its highest negative indirect effect was through specific leaf area, per cent reduction of Fv/Fm, shell thickness and number of well-filled and mature pods per plant (Table 33).

Specific leaf nitrogen had a positive indirect effect through per cent reduction of Fv/Fm and oil per cent and negative indirect effect through SPAD chlorophyll meter reading, shell thickness, shelling per cent, sound mature kernel per cent and number of well filled and mature pods per plant.

Specific leaf area showed positive indirect effect through specific leaf nitrogen, per cent reduction of Fv/Fm, oil per cent, sound mature kernel per cent, number of well filled and mature pods per plant and kernel

Table 3.3 : Path coefficients for seed yield to characters (1966-1967)

Character	SPAD chlorophyll meter reading	Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Correlation with seed yield per plant
SPAD chlorophyll meter reading	P	-0.030	0.036	-0.018	0.005	0.023	-0.021	0.004	0.011	0.003	-0.026	0.199	0.132
Specific leaf nitrogen	G	-0.095	0.057	0.193	-0.026	-0.006	-0.063	-0.007	0.041	0.012	-0.093	0.206	0.180
Specific leaf area	P	-0.007	0.153	0.006	-0.002	-0.122	-0.063	0.010	-0.010	-0.000	-0.017	-0.014	0.027
Per cent reduction of Fv/Fm	G	-0.028	0.199	-0.063	0.008	0.021	-0.168	0.028	-0.038	-0.033	-0.050	0.035	0.053
Root length	P	0.018	0.033	0.029	-0.002	-0.100	-0.039	0.010	-0.008	0.003	0.076	0.253	0.313
Harvest index	G	0.065	0.044	-0.283	0.017	0.019	-0.114	0.011	-0.029	0.009	0.206	0.315	0.385
Shell thickness	P	0.003	0.075	0.009	-0.004	-0.087	-0.067	0.004	0.005	-0.009	-0.052	0.116	0.231
Oil per cent	G	0.016	0.104	-0.017	0.041	0.017	-0.198	0.013	0.024	-0.036	-0.129	0.161	0.233
Shelling per cent	P	-0.011	-0.018	-0.004	0.013	0.059	0.019	0.033	-0.005	0.011	0.015	0.052	0.118
Sound mature kernel per cent	G	-0.084	-0.054	0.159	-0.029	-0.022	0.088	-0.172	-0.045	0.072	0.203	0.293	-0.051
No. of well filled pods per plant	P	0.004	0.101	0.016	-0.004	-0.185	-0.101	0.067	-0.005	-0.007	0.037	0.387	0.421
Kernel yield per plant	G	0.018	0.144	-0.184	0.022	-0.209	-0.286	0.142	-0.004	-0.025	0.096	0.350	0.497*
	P	-0.005	0.070	0.008	-0.001	-0.135	-0.138	0.096	-0.000	-0.005	0.019	0.604	0.582**
	G	-0.016	0.091	-0.088	0.007	0.023	-0.367	0.230	-0.016	-0.021	0.040	0.705	0.781**
	P	-0.001	0.010	0.003	0.003	-0.077	-0.083	0.160	-0.018	-0.005	0.016	0.475	0.481
	G	0.003	0.021	-0.012	0.019	0.016	-0.328	0.258	-0.043	-0.045	0.078	0.611	0.595**
	P	0.006	0.027	0.004	-0.019	-0.016	-0.001	0.048	-0.059	-0.006	-0.006	0.015	-0.045
	G	0.031	0.059	-0.066	-0.062	0.000	-0.005	0.089	-0.126	-0.054	0.008	-0.321	-0.457
	P	0.004	0.058	-0.003	0.085	-0.053	-0.030	0.034	-0.016	-0.023	-0.064	-0.140	-0.141
	G	0.015	0.086	0.032	0.157	0.010	-0.099	0.135	-0.089	-0.076	-0.204	-0.244	-0.232
	P	0.006	-0.109	0.017	-0.083	-0.052	-0.020	0.019	0.003	0.011	0.132	0.452	0.463
	G	0.027	-0.030	-0.177	-0.130	0.009	-0.045	0.061	-0.003	0.047	0.330	0.531	0.601*
	P	-0.006	-0.002	0.008	0.025	-0.076	-0.089	0.081	-0.001	0.004	0.064	0.938	0.948**
	G	-0.021	0.000	-0.095	0.057	0.011	-0.276	0.168	0.043	0.020	0.186	0.939	1.023**

Residual effect : (P) 0.0719 : (G) 0.196

Diagonal (Bold) are direct effects

* Significant at 5% level of probability
 ** Significant at 1% level of probability

yield per plant, while through shell thickness and shelling per cent it showed negative indirect effect.

Per cent reduction of F_v/F_m exhibited positive indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, oil per cent, shelling per cent and kernel yield per plant and negative indirect effect through shell thickness, sound mature kernel per cent and number of well filled and mature pods per plant.

Root length had positive indirect effect through shell thickness, sound mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant and negative indirect effect through SPAD chlorophyll meter reading, per cent reduction of F_v/F_m , specific leaf nitrogen and shelling per cent.

Harvest index had positive indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, per cent reduction of F_v/F_m , oil per cent, number of well filled and mature pods per plant and kernel yield per plant and negative indirect effect through shell thickness, shelling per cent and sound mature kernel per cent.

The shell thickness exerted positive indirect effect through specific leaf nitrogen, per cent reduction of F_v/F_m , oil per cent, number of well filled and mature pods per plant and kernel yield per plant. On contrary, its highest negative indirect effect was through SPAD chlorophyll meter reading, shelling per cent and sound mature kernel per cent.

Oil per cent had positive indirect effect through specific leaf ¹⁸⁰nitrogen, per cent reduction of Fv/Fm, root length, number of well filled and mature pods per plant and kernel yield per plant and negative indirect effect through shell thickness, shelling per cent and sound mature kernel per cent.

Shelling per cent showed positive indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen and oil per cent, while through per cent reduction of Fv/Fm, shell thickness and sound mature kernel per cent it showed negative indirect effect.

Sound mature kernel per cent exhibited positive indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, per cent reduction of Fv/Fm and oil per cent and negative indirect effect through shell thickness, shelling per cent, number of well filled and mature pods per plant and kernel yield per plant.

The character, number of well filled and mature pods per plant had positive indirect effect through oil per cent and kernel yield per plant and negative indirect effect through specific leaf nitrogen, per cent reduction of Fv/Fm and shell thickness

Kernel yield per plant exerted positive indirect effect through per cent reduction of Fv/Fm, oil per cent, sound mature kernel per cent and number of well filled and mature pods per plant. On contrary, its highest

negative direct effect was through SPAD chlorophyll meter reading and shell thickness.

4.8.1.2 F₁ GENERATION

The maximum positive direct effect contribution to pod yield per plant was from kernel yield per plant (0.552) followed by number of well-filled and mature pods per plant (0.241). The direct effects of specific leaf nitrogen, specific leaf area, root length, oil per cent, shelling per cent and sound mature kernel per cent were found to be positive. The highest direct negative effect to pod yield per plant was from shell thickness (-0.168) followed by harvest index (-0.072), SPAD chlorophyll meter reading, per cent reduction of Fv/Fm and harvest index (Table 34)

SPAD chlorophyll meter reading exerted positive indirect effect through specific leaf nitrogen, specific leaf area, root length, harvest index, shelling per cent and sound mature kernel per cent. On contrary, its negative indirect effect was through per cent reduction of Fv/Fm, shell thickness, oil per cent, number of well filled and mature pods per plant and kernel yield per plant.

Specific leaf nitrogen had a positive indirect effect through SPAD chlorophyll meter reading, per cent reduction of Fv/Fm, shell thickness, shelling per cent, number of well filled and mature pods per plant and kernel yield per plant. Specific leaf nitrogen had negative indirect effect

Table 34 : Path coefficients for pod yield in F₁s (Rabi – 2002)

Character		SPAD chlorophyll meter reading	Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Correlation with pod yield per plant
SPAD chlorophyll meter reading	P	-0.003	0.032	0.001	-0.018	0.020	0.023	-0.068	-0.002	0.019	0.014	-0.029	-0.148	-0.160
	G	3.658	0.888	-0.124	-1.413	-0.818	-0.884	0.022	0.173	-0.322	-1.033	-0.018	-0.235	-0.112
Specific leaf nitrogen	P	-0.001	0.146	0.025	-0.040	0.008	0.001	-0.055	0.011	-0.018	0.041	-0.013	-0.125	-0.019
	G	1.083	2.999	-0.408	-1.587	-0.149	-0.032	-0.130	-0.297	0.237	-1.998	0.404	-0.292	-0.026
Specific leaf area	P	-0.000	0.039	0.094	-0.003	-0.101	-0.018	-0.013	-0.001	-0.011	-0.001	0.027	-0.017	0.081
	G	0.312	0.838	-1.459	-0.071	0.498	0.534	0.003	0.009	0.101	0.004	-0.624	-0.038	0.107
Per cent reduction of Fv/Fm	P	-0.001	0.056	0.003	-0.016	-0.019	0.015	-0.004	0.006	-0.029	0.008	-0.036	-0.136	-0.245
	G	1.428	1.314	-0.029	-3.621	0.404	-0.634	0.001	-0.084	0.323	-0.382	1.179	-0.375	-0.445**
Root length	P	-0.001	0.008	-0.011	0.013	0.156	0.012	-0.058	-0.025	0.022	-0.001	-0.027	-0.079	-0.008
	G	1.124	0.168	-0.273	0.550	-2.661	-0.459	0.015	0.731	-0.296	-0.049	0.765	-0.286	-0.126
Harvest index	P	0.001	-0.002	0.024	0.021	-0.026	-0.072	0.028	0.006	-0.005	0.004	0.103	0.227	0.315*
	G	-1.726	-0.050	-0.416	1.225	0.653	-1.873	-0.008	-0.105	0.014	-0.205	-1.282	0.339	0.310*
Shell thickness	P	-0.001	0.048	0.007	-0.003	0.054	0.012	-0.168	-0.005	0.037	0.019	0.019	-0.025	-0.009
	G	2.112	0.992	-0.103	-0.085	-1.101	-0.931	0.039	0.111	-0.449	-0.885	-0.282	-0.084	-0.036
Oil per cent	P	0.000	0.024	-0.002	-0.009	-0.055	-0.006	0.012	0.069	0.008	0.005	-0.009	0.084	0.119
	G	-0.424	0.597	0.009	-0.204	1.305	0.132	-0.003	-1.489	-0.059	-0.363	0.492	0.201	0.192
Shelling per cent	P	0.001	0.019	0.008	-0.022	-0.024	-0.002	0.044	-0.004	0.142	0.033	-0.035	0.041	-0.084
	G	-0.827	0.499	-0.104	-0.895	0.552	0.018	-0.012	0.062	1.425	-1.863	0.769	0.062	-0.313*
Sound mature kernel per cent	P	-0.001	0.069	-0.001	-0.009	-0.002	-0.003	-0.037	0.004	-0.055	0.086	-0.017	0.015	0.048
	G	1.022	1.620	0.002	-0.374	-0.036	0.104	0.009	-0.146	0.712	-3.697	0.851	-0.087	-0.015
No. of well filled pods per plant	P	0.000	-0.008	0.011	0.016	-0.018	-0.031	-0.013	-0.003	0.021	-0.006	0.241	0.355	0.565**
	G	0.022	-1.409	-1.307	1.439	0.687	0.812	0.004	0.247	-0.639	1.061	2.964	0.397	0.616**
Kernel yield per plant	P	0.001	-0.033	-0.003	0.026	-0.022	-0.209	0.008	0.011	-0.011	0.002	0.155	0.552	0.657**
	G	-1.272	-1.249	0.078	1.935	1.084	0.905	-0.005	-0.426	0.125	0.459	-1.677	0.701	0.657**

Residual effect (P) 0.4618, (G) 0.305 Diagonal values (Bold) are direct effects

* Significant at 5% level of probability

** Significant at 1% level of probability

through specific leaf area, root length, harvest index, oil per cent, sound mature kernel per cent and kernel yield per plant.

Specific leaf area showed positive indirect effect through specific leaf nitrogen and number of well filled and mature pods per plant, while through SPAD chlorophyll meter reading, per cent reduction of Fv/Fm, root length, harvest index, oil per cent, sound mature kernel per cent and kernel yield per plant it showed negative indirect effect.

Per cent reduction of Fv/Fm exhibited positive indirect effect through specific leaf nitrogen, specific leaf area, harvest index, sound mature kernel per cent and oil per cent on pod yield per plant and negative indirect effect through SPAD chlorophyll meter reading, root length, shelling per cent, number of well filled and mature pods per plant and kernel yield per plant.

The character root length had positive indirect effect through specific leaf nitrogen, per cent reduction of Fv/Fm, harvest index and shelling per cent and negative indirect effect through SPAD chlorophyll meter reading, specific leaf area, shell thickness, oil per cent, sound mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant.

Harvest index had positive indirect effect through SPAD chlorophyll meter reading, specific leaf area, per cent reduction of Fv/Fm, shell thickness, oil per cent, sound mature kernel per cent and number of well

filled and mature pods per plant and negative indirect effect through specific leaf nitrogen, root length, shelling per cent and kernel yield per plant .

The shell thickness exerted positive indirect effect through specific leaf nitrogen, specific leaf area, root length, harvest index, shelling per cent, sound mature kernel per cent and number of well filled and mature pods per plant. On contrary, its negative indirect effect was through SPAD chlorophyll meter reading, per cent reduction of F_v/F_m , oil per cent and kernel yield per plant .

Oil per cent had a positive indirect effect through specific leaf nitrogen, shell thickness, shelling per cent, sound mature kernel per and kernel yield per plant and negative indirect effect through SPAD chlorophyll meter reading, specific leaf area, per cent reduction of F_v/F_m , root length, harvest index and number of well filled and mature pods per plant.

Shelling per cent showed positive indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area, shell thickness, sound mature kernel per cent and kernel yield per plant , while through per cent reduction of F_v/F_m , root length, harvest index, oil per cent and number of well filled and mature pods per plant it showed negative indirect effect.

Sound mature kernel per cent exhibited positive indirect effect through specific leaf nitrogen, oil per cent and kernel yield per plant and negative indirect effect through SPAD chlorophyll meter reading, specific leaf area, per cent reduction of F_v/F_m , root length, harvest index, shell thickness, shelling per cent and number of well filled and mature pods per plant.

The character number of well filled and mature pods per plant had positive indirect effect through specific leaf area, per cent reduction of F_v/F_m , shelling per cent and kernel yield per plant and negative indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, root length, harvest index, shell thickness, oil per cent and sound mature kernel per cent.

Kernel yield per plant exerted positive indirect effect through SPAD chlorophyll meter reading, per cent reduction of F_v/F_m , shell thickness, oil per cent, sound mature kernel per cent and number of well filled and mature pods per plant. On contrary, its negative indirect effect was through specific leaf nitrogen, specific leaf area, root length harvest index and shelling per cent.

4.8.2 KHARIF-2003

4.8.2.1 PARENTS

The maximum positive direct effect contribution to pod yield per plant was from kernel yield per plant (0.768) followed by oil per cent

Table 35 : Path coefficients for pod yield in parents (*Kharif* - 2003)

Character		SPAD chlorophyll meter reading	Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Correlat ion with Pod yield per plant
SPAD chlorophyll meter reading	P	-0.392	-0.213	0.301	0.197	-0.017	0.001	-0.030	-0.064	-0.024	0.052	0.061	-0.132	-0.181
Specific leaf nitrogen	P	-0.183	-0.456	0.193	0.176	-0.007	0.014	0.063	-0.011	0.021	0.008	0.015	0.105	-0.062
Specific leaf area	P	0.249	0.148	-0.598	-0.077	-0.024	0.009	0.074	0.104	0.037	0.046	-0.035	-0.040	-0.107
Per cent reduction of Fv/Fm	P	-0.278	-0.289	0.165	0.277	0.059	0.004	-0.094	-0.024	-0.027	0.107	0.036	0.005	-0.058
Root length	P	-0.029	-0.014	-0.061	-0.071	-0.232	-0.001	0.150	-0.009	0.036	-0.075	0.025	-0.184	-0.465
Harvest index	P	0.009	0.106	0.084	-0.019	-0.003	-0.061	-0.167	-0.066	-0.007	-0.069	-0.017	0.123	-0.087
Shell thickness	P	-0.031	0.075	0.115	0.068	0.091	-0.027	-0.384	-0.021	-0.012	0.082	-0.050	0.040	-0.053
Oil per cent	P	0.950	0.019	-0.236	-0.025	0.008	0.015	0.030	0.264	0.008	-0.011	0.001	0.044	0.214
Shelling per cent	P	0.079	-0.081	-0.185	-0.063	-0.071	0.004	0.039	0.017	0.119	0.033	-0.146	0.258	0.001
Sound mature kernel per cent	P	-0.084	-0.015	-0.113	0.122	0.071	0.017	-0.130	-0.011	0.016	0.244	-0.102	0.067	0.083
No. of well filled pods per plant	P	0.096	0.028	-0.085	-0.040	0.023	-0.004	-0.078	-0.002	0.071	0.101	-0.246	0.473	0.338
Kernel yield per plant	P	0.067	-0.062	0.031	0.002	0.056	-0.010	-0.020	0.015	0.039	0.021	-0.152	0.768	0.757**

Residual effect (P) 0.16093 Diagonal values (Bold) are direct effects

* Significant at 5% level of probability

** Significant at 1% level of probability

(0.264). The direct effects of per cent reduction of Fv/Fm, shelling per cent and sound mature kernel per cent were found to be positive (Table 35). The highest negative direct effect to pod yield per plant was from specific leaf area (-0.598) followed by specific leaf nitrogen (-0.456), SPAD chlorophyll meter reading, root length, harvest index, shell thickness and number of well filled and mature pods per plant.

SPAD chlorophyll meter reading exerted positive indirect effect through specific leaf area, per cent reduction of Fv/Fm, harvest index, sound mature kernel per cent and number of well filled and mature pods per plant. On contrary, its negative indirect effect was through specific leaf nitrogen, root length, shell thickness, oil per cent, shelling per cent and kernel yield per plant.

Specific leaf nitrogen had a positive indirect effect through specific leaf area, per cent reduction of Fv/Fm, harvest index, shell thickness, shelling per cent, sound mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant and negative indirect effect through SPAD chlorophyll meter reading, root length and oil per cent

Specific leaf area showed positive indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, harvest index, shell thickness, oil per cent, shelling per cent and sound mature kernel per cent, while through per cent reduction of Fv/Fm, root length, number of well

filled and mature pods per plant and kernel yield per plant it showed negative indirect effect.

Per cent reduction of Fv/Fm exhibited positive indirect effect through specific leaf area, root length, harvest index, sound mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant and negative indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, shell thickness, oil per cent and shelling per cent.

The character root length had positive indirect effect through shell thickness, shelling per cent and number of well filled and mature pods per plant and negative indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area, per cent reduction of Fv/Fm, harvest index, oil per cent, sound mature kernel per cent and kernel yield per plant.

Harvest index had positive indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area and kernel yield per plant and negative indirect effect through per cent reduction of Fv/Fm, root length, shell thickness, oil per cent, shelling per cent, sound mature kernel per cent and number of well filled and mature pods per plant

The shell thickness exerted positive indirect effect through specific leaf nitrogen, specific leaf area, per cent reduction of Fv/Fm, root length, sound mature kernel per cent and kernel yield per plant . On contrary, its

negative indirect effect was through SPAD chlorophyll meter reading, harvest index, oil per cent, shelling per cent and number of well filled and mature pods per plant

Oil per cent had a positive indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, root length, harvest index, shell thickness, shelling per cent, number of well filled and mature pods per plant and kernel yield per plant and negative indirect effect through specific leaf area, per cent reduction of F_v/F_m and sound mature kernel per cent

Shelling per cent showed positive indirect effect through SPAD chlorophyll meter reading, harvest index, shell thickness, oil per cent, sound mature kernel per cent and kernel yield per plant, while through specific leaf nitrogen, specific leaf area, per cent reduction of F_v/F_m , root length, and number of well filled and mature pods per plant it showed high negative indirect effect.

Sound mature kernel per cent exhibited positive indirect effect through per cent reduction of F_v/F_m , root length, harvest index, shelling per cent, and kernel yield per plant and negative indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area, shell thickness, oil per cent and number of well filled and mature pods per plant.

The character number of well filled and mature pods per plant had positive indirect effect through SPAD chlorophyll meter reading, specific

leaf nitrogen, root length, shelling per cent, sound mature kernel per cent and kernel yield per plant and negative indirect effect through specific leaf area, per cent reduction of Fv/Fm, harvest index, shell thickness and oil per cent.

Kernel yield per plant exerted positive indirect effect through SPAD chlorophyll meter reading, specific leaf area, per cent reduction of Fv/Fm, root length, oil per cent, shelling per cent and sound mature kernel per cent. On contrary, its negative direct effect was through specific leaf nitrogen, harvest index, shell thickness and number of well filled and mature pods per plants.

4.8.2.2 F₁ GENERATION

The maximum positive direct effect contribution to pod yield per plant was from kernel yield per plant (0.789) followed by number of well-filled and mature pods per plant (0.132). The direct effects of specific leaf nitrogen, per cent reduction of Fv/Fm, shell thickness, oil per cent and, sound mature kernel per cent were found to be positive. The highest negative direct effect to pod yield per plant was from shelling per cent (-0.169) closely followed by harvest index (-0.066), SPAD chlorophyll meter reading, specific leaf area and root length in the order of their relative importance (Table 36).

Table 36 : Path coefficients for pod yield in *Pis (Kharif - 2003)*

Character	SPAD chlorophyll meter reading	Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Correlation with Pod yield per plant
Character	0.024	0.029	0.042	0.076	0.140	0.113	-0.013	-0.031	-0.012	0.019	-0.024	-0.077	-0.265*
SPAD chlorophyll meter reading	0.360	0.002	-0.000	0.003	-0.000	-0.038	0.010	-0.003	-0.020	0.001	-0.026	-0.178	-0.259
Specific leaf nitrogen	0.001	0.865	-0.025	-0.016	-0.002	0.362	-0.027	-0.024	0.099	0.007	-0.046	-0.101	-0.447**
Specific leaf area	0.012	0.000	-0.010	0.000	0.003	-0.008	-0.006	0.011	0.008	-0.004	-0.018	-0.205	-0.317*
Per cent reduction of Fv/Fm	0.003	-0.079	-0.270	-0.052	-0.021	0.083	0.017	0.052	-0.041	-0.044	-0.025	-0.076	-0.398**
Root length	0.056	-0.000	0.024	-0.039	0.011	0.007	-0.000	-0.022	-0.009	0.000	0.006	-0.033	-0.062
Harvest index	0.006	0.066	0.069	0.206	-0.086	-0.148	-0.000	-0.123	0.044	0.002	0.008	-0.011	-0.017
Shell thickness	0.133	0.000	0.008	0.010	-0.042	0.089	0.024	0.023	-0.005	0.002	-0.006	0.044	0.041
Oil per cent	0.004	0.005	0.021	-0.665	0.270	-0.165	-0.006	0.061	0.083	0.026	0.016	0.026	0.052
Shelling per cent	0.187	-0.000	0.013	-0.004	-0.006	-0.006	-0.009	0.013	-0.043	0.001	0.039	0.264	0.332*
Sound mature kernel per cent	0.000	0.587	0.027	0.037	0.054	-0.827	0.029	0.001	0.229	0.002	0.061	0.107	0.435**
No. of well filled pods per plant	0.049	0.001	0.031	0.000	-0.005	-0.028	0.022	0.009	0.002	0.005	0.019	0.051	0.104
Kernel yield per plant	0.003	-0.413	0.081	0.001	0.028	0.416	-0.057	0.049	0.010	0.015	0.024	0.011	0.121
Residual effect	0.080	-0.000	-0.012	0.009	-0.009	0.001	0.002	0.097	-0.036	-0.000	0.042	0.623	0.364**
	0.003	0.001	-0.056	-0.098	0.064	-0.259	-0.011	0.257	0.237	0.007	0.012	0.095	0.372**
	0.044	0.000	0.005	-0.002	-0.001	0.017	-0.000	0.021	-0.169	0.001	0.016	0.258	0.146
	0.001	-0.183	0.024	0.019	0.048	-0.403	-0.001	0.129	0.472	0.019	0.080	0.126	0.424**
	0.093	0.000	0.027	-0.001	-0.005	0.003	0.007	-0.005	-0.008	0.015	0.012	0.123	0.167
	0.002	-0.048	0.091	0.005	0.054	-0.012	-0.022	0.013	0.072	0.129	0.022	0.093	0.341**
	0.054	-0.000	0.015	-0.002	0.002	0.019	0.003	0.031	-0.021	0.001	0.132	0.585	0.768**
	0.002	0.462	0.078	0.018	-0.051	-0.584	-0.016	0.036	0.438	0.033	0.036	0.172	0.773**
	0.102	-0.000	0.029	0.002	-0.002	0.022	0.001	0.032	-0.055	0.020	0.098	0.789	0.920**
	0.002	-0.437	0.103	-0.012	0.036	-0.447	-0.003	0.122	0.299	0.060	0.074	0.199	1.007**
	0.139												

Diagonal values (Bold) are direct effects

(G) 0.223

* Significant at 5% level of probability.
 ** Significant at 1% level of probability

Table 36 : Path coefficients for pod yield in F₁s (*Kharif - 2003*)

Character	SPAD chlorophyll meter reading	Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Correlation with Pod yield per plant
SPAD chlorophyll meter reading	P -0.024 G -0.360	0.000 -0.029	0.016 0.042	-0.009 0.076	-0.007 0.140	0.002 0.113	0.003 -0.013	-0.011 -0.031	0.008 -0.012	0.001 0.019	-0.011 -0.024	-0.073 -0.077	-0.105 -0.265*
Specific leaf nitrogen	P -0.001 G -0.012	0.002 0.865	-0.000 -0.025	0.003 -0.016	-0.000 -0.002	-0.038 0.562	0.010 -0.027	-0.003 -0.024	-0.020 0.099	0.001 0.007	-0.026 -0.046	-0.178 -0.101	-0.259 -0.447**
Specific leaf area	P 0.003 G 0.056	0.000 -0.079	-0.010 -0.270	0.000 -0.052	0.003 -0.021	-0.008 0.083	-0.006 0.017	0.011 0.052	0.008 -0.041	-0.004 -0.044	-0.018 -0.025	-0.205 -0.076	-0.317* -0.398**
Per cent reduction of Fv/Fm	P -0.006 G -0.133	-0.000 0.066	0.024 0.069	-0.039 0.206	0.011 -0.086	0.007 -0.148	-0.000 -0.000	-0.022 -0.123	-0.009 0.044	0.000 0.002	0.006 0.008	-0.033 -0.011	-0.062 -0.017
Root length	P -0.004 G -0.187	0.000 0.005	0.008 0.021	0.010 -0.665	-0.042 0.270	0.089 -0.165	0.024 -0.006	0.023 0.061	-0.005 0.083	0.002 0.026	-0.006 0.016	0.044 0.026	0.041 0.052
Harvest index	P -0.000 G 0.049	-0.000 0.587	0.013 0.027	-0.004 0.037	-0.006 0.054	-0.066 -0.827	-0.009 0.029	0.013 0.001	-0.043 0.229	0.001 0.002	0.039 0.061	0.264 0.107	0.332* 0.435**
Shell thickness	P -0.003 G -0.080	0.001 -0.413	0.031 0.081	0.000 0.001	-0.005 0.028	-0.028 0.416	0.022 -0.057	0.009 0.049	0.002 0.010	0.005 0.015	0.019 0.024	0.051 0.011	0.104 0.121
Oil per cent	P 0.003 G 0.044	-0.000 0.001	-0.012 -0.056	0.009 -0.098	-0.009 0.064	0.001 -0.259	0.002 -0.011	0.097 0.257	-0.036 0.237	-0.000 0.007	0.042 0.012	0.623 0.095	0.364** 0.372**
Shelling per cent	P 0.001 G 0.093	0.000 -0.183	0.005 0.024	-0.002 0.019	-0.001 0.048	0.017 -0.403	-0.000 -0.001	0.021 0.129	-0.169 0.472	0.001 0.019	0.016 0.080	0.258 0.126	0.146 0.424**
Sound mature kernel per cent	P -0.002 G -0.054	0.000 -0.048	0.027 0.091	-0.001 0.005	-0.005 0.054	0.003 -0.012	0.007 -0.022	-0.005 0.013	-0.008 0.072	0.015 0.129	0.012 0.022	0.123 0.093	0.167 0.341**
No. of well filled pods per plant	P 0.002 G 0.102	-0.000 0.462	0.015 0.078	-0.002 0.018	0.002 -0.051	0.019 -0.584	0.003 -0.016	0.031 0.036	-0.021 0.438	0.001 0.033	0.132 0.086	0.585 0.172	0.768** 0.773**
Kernel yield per plant	P 0.002 G 0.139	-0.000 0.437	0.029 0.103	0.002 -0.012	-0.002 0.036	0.022 -0.447	0.001 -0.003	0.032 0.122	-0.055 0.299	0.020 0.060	0.098 0.074	0.789 0.199	0.920** 1.007**
Residual effect	(P) 0.090 , (G) 0.223	Diagonal values (Bold) are direct effects											

* Significant at 5% level of probability.
** Significant at 1% level of probability

SPAD chlorophyll meter reading exerted positive indirect effect through specific leaf area, shell thickness, harvest index, sound mature kernel per cent and shelling per cent. On contrary, its negative indirect effect was through specific leaf nitrogen, per cent reduction of Fv/Fm, root length, oil per cent, shelling per cent and number of well filled and mature pods per plant and kernel yield per plant.

Specific leaf nitrogen had a positive indirect effect through per cent reduction of Fv/Fm, shell thickness and sound mature kernel per cent and negative indirect effect through SPAD chlorophyll meter reading, harvest index, oil per cent, shelling per cent, number of well filled and mature pods per plant and kernel yield per plant.

Specific leaf area showed positive indirect effect through SPAD chlorophyll meter reading, root length, oil per cent, shelling per cent, while through harvest index, shell thickness, sound mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant it showed negative indirect effect.

Per cent reduction of Fv/Fm exhibited positive indirect effect through specific leaf area, root length, harvest index and number of well filled and mature pods per plant and negative indirect effect through SPAD chlorophyll meter reading, oil per cent, shelling per cent, sound mature kernel per cent and kernel yield per plant.

The character root length had positive indirect effect through specific leaf area, per cent reduction of F_v/F_m , harvest index, shell thickness, oil per cent, sound mature kernel per cent and kernel yield per plant and negative indirect effect through SPAD chlorophyll meter reading, shelling per cent and number of well filled and mature pods per plant.

Harvest index had positive indirect effect through specific leaf area, oil per cent, sound mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant and negative indirect effect through SPAD chlorophyll meter reading, per cent reduction of F_v/F_m , root length, shell thickness and shelling per cent.

The shell thickness exerted positive indirect effect through specific leaf nitrogen, specific leaf area, oil per cent, shelling per cent, sound mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant. On contrary, its negative indirect effect was through SPAD chlorophyll meter reading, per cent reduction of F_v/F_m , root length and harvest index.

Oil per cent had a positive indirect effect through SPAD chlorophyll meter reading, harvest index, shell thickness, number of well filled and mature pods per plant and kernel yield per plant and negative indirect effect through specific leaf area, per cent reduction of F_v/F_m , root length, shelling per cent and sound mature kernel per cent.

Shelling per cent showed positive indirect effect through SPAD chlorophyll meter reading, specific leaf area, harvest index, oil per cent, sound mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant, while through per cent reduction of F_v/F_m and root length it showed high negative indirect effect.

Sound mature kernel per cent exhibited positive indirect effect through specific leaf area, harvest index, shell thickness, number of well filled and mature pods per plant and kernel yield per plant and negative direct effect through SPAD chlorophyll meter reading, per cent reduction of F_v/F_m , root length, oil per cent and shelling per cent.

The character number of well filled and mature pods per plant had positive indirect effect through SPAD chlorophyll meter reading, specific leaf area, root length, harvest index, shell thickness, oil per cent, sound mature kernel per cent and kernel yield per plant and negative indirect effect through per cent reduction of F_v/F_m and shelling per cent.

Kernel yield per plant exerted positive indirect effect through SPAD chlorophyll meter reading, specific leaf area, per cent reduction of F_v/F_m , harvest index, oil per cent, sound mature kernel per cent and number of well filled and mature pods per plant. On contrary, its negative indirect effect was through root length, shelling per cent and shell thickness.

4.8.2.3 F₂ GENERATION

The maximum positive direct effect contribution to pod yield per plant was from kernel yield per plant (0.479) followed by number of well-filled and mature pods per plant (0.398) (Table 37). The direct effects of SPAD chlorophyll meter reading, shell thickness and sound mature kernel per cent were found to be positive. The highest negative direct effect to pod yield per plant was from per cent reduction of Fv/Fm (-0.114) followed by specific leaf area (-0.073), specific leaf nitrogen, root length, harvest index, oil per cent and shelling per cent.

SPAD chlorophyll meter reading exerted positive indirect effect through specific leaf nitrogen, specific leaf area, per cent reduction of Fv/Fm (0.035), shell thickness, shelling per cent, number of well filled and mature pods per plant and kernel yield per plant (0.099). On contrary, its negative indirect effect was through oil per cent.

Specific leaf nitrogen had a positive indirect effect through root length, harvest index, shell thickness, oil per cent, shelling per cent (0.047), number of well filled and mature pods per plant and kernel yield per plant and negative indirect effect through SPAD chlorophyll meter reading and specific leaf area.

Specific leaf area showed positive indirect effect through per cent reduction of Fv/Fm, root length, oil per cent, shelling per cent, sound mature kernel per cent number of well filled and mature pods per plant

Table 37 : Path coefficients for pod yield in F_{2s} (Kharif – 2003)

Character		SPAD chlorophyll meter reading	Specific leaf nitrogen	Specific leaf area	Per cent reduction of Fv/Fm	Root length	Harvest index	Shell thickness	Oil per cent	Shelling per cent	Sound mature kernel per cent	No. of well filled pods per plant	Kernel yield per plant	Correlation with Pod yield per plant
SPAD chlorophyll meter reading	P	0.033	0.004	0.021	0.035	-0.000	-0.003	0.029	-0.014	0.018	0.000	0.025	0.099	0.238
	G	6.767	-0.075	-1.939	-1.409	-0.212	0.174	0.276	0.145	-1.724	0.006	-1.558	-0.324	0.129
Specific nitrogen	P	-0.001	-0.017	-0.006	-0.000	0.001	0.001	0.030	0.015	0.047	-0.000	0.063	0.011	0.045
	G	0.507	-0.997	0.383	-0.000	-0.101	0.015	0.426	-0.276	-2.097	0.335	2.403	-0.414	0.183
Specific leaf area	P	-0.009	-0.009	-0.073	0.004	0.001	-0.004	-0.029	0.024	0.006	0.008	0.053	0.010	-0.019
	G	-3.215	-0.093	4.081	-0.137	-0.086	-0.412	-0.364	-0.662	-0.737	-0.351	2.281	-0.147	0.154
Per cent reduction of Fv/Fm	P	-0.010	-0.000	0.002	-0.114	-0.008	0.013	0.006	0.018	0.028	-0.004	-0.124	-0.138	-0.323*
	G	-3.221	0.000	-0.180	2.962	1.054	1.365	0.078	-0.419	-1.190	0.172	-3.521	2.023	-0.884**
Root length	P	0.000	0.003	0.002	-0.033	-0.028	0.005	0.016	0.030	0.048	-0.009	-0.031	-0.114	-0.110
	G	-0.914	0.064	-0.324	1.993	1.568	1.038	0.522	-1.259	-3.668	0.801	-2.231	1.922	-0.389**
Harvest index	P	0.003	0.002	-0.008	0.043	0.004	-0.034	-0.010	-0.015	-0.056	0.002	0.139	0.161	0.102
	G	-0.372	0.005	0.532	-1.279	-0.515	-3.160	-0.093	0.479	2.946	-0.158	4.093	-1.885	0.592**
Shell thickness	P	0.007	-0.032	0.021	-0.007	-0.004	0.004	0.101	0.008	0.035	-0.012	-0.003	-0.016	0.102
	G	1.596	-0.363	-1.271	0.916	0.698	0.250	1.172	-0.419	-2.445	0.625	-0.448	0.432	0.025
Oil per cent	P	0.005	0.016	0.017	0.019	0.008	-0.005	-0.008	-0.015	-0.061	0.004	-0.011	0.036	-0.085
	G	0.605	0.170	-1.669	-0.766	-1.219	-0.936	-0.304	1.619	2.487	-0.107	0.779	-0.866	-0.028
Shelling per cent	P	-0.003	0.025	0.002	0.015	0.006	-0.009	-0.017	-0.031	-0.028	0.017	-0.002	0.213	0.007
	G	-1.552	0.278	-0.401	-0.469	-0.765	-1.239	-0.381	0.536	7.514	-0.881	0.276	-2.674	0.242
Sound kernel per cent	P	0.001	0.022	-0.016	0.013	0.006	-0.003	-0.032	-0.010	-0.091	0.038	-0.061	0.071	-0.061
	G	-0.029	0.224	0.962	-0.342	-0.843	-0.336	-0.492	0.117	4.443	-1.489	-1.364	-0.854	-0.004
No. of well filled pods per plant	P	0.002	-0.017	-0.009	0.035	0.002	-0.012	-0.010	0.003	0.001	-0.006	0.398	0.242	0.639**
	G	-1.688	-0.384	1.489	-1.670	0.560	-2.071	-0.084	0.202	0.332	0.325	6.245	-1.815	0.321*
Kernel yield per plant	P	0.007	-0.002	-0.002	0.033	0.007	-0.012	-0.003	-0.008	-0.093	0.006	0.201	0.479	0.613**
	G	0.559	-0.105	0.153	-1.529	-0.769	-1.519	-0.129	0.357	2.126	-0.240	2.892	3.920	0.792**
Residual effect (P) 0.394, (G) 0.423 Diagonal values(Bold) are direct effects														

* Significant at 5% level of probability

** Significant at 1% level of probability

(0.053) and kernel yield per plant while through SPAD chlorophyll meter reading, specific leaf nitrogen, harvest index and shell thickness (0.029) it showed negative indirect effect.

Per cent reduction of Fv/Fm exhibited positive indirect effect through specific leaf area, harvest index, shell thickness, oil per cent and shelling per cent and negative indirect effect through SPAD chlorophyll meter reading, root length, sound mature kernel per cent, number of well filled and mature pods per plant (0.124) and kernel yield per plant (0.138).

The character root length had positive indirect effect through specific leaf nitrogen, specific leaf area, harvest index, shell thickness, oil per cent, shelling per cent, and negative indirect effect through per cent reduction of Fv/Fm, number of well filled and mature pods per plant, sound mature kernel per cent and kernel yield per plant (0.114).

Harvest index had positive indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, per cent reduction of Fv/Fm, sound mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant and negative indirect effect through specific leaf area, root length, shell thickness, oil per cent and shelling per cent

The shell thickness exerted positive indirect effect through SPAD chlorophyll meter reading, specific leaf area, harvest index, oil per cent and shelling per cent. On contrary, its negative indirect effect was through specific leaf nitrogen, per cent reduction of Fv/Fm, root length, sound

mature kernel per cent, number of well filled and mature pods per plant and kernel yield per plant

Oil per cent had a positive indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area, per cent reduction of F_v/F_m , root length, sound mature kernel per cent and kernel yield per plant and negative indirect effect through harvest index, shell thickness, shelling per cent and number of well filled and mature pods per plant

Shelling per cent showed positive indirect effect through specific leaf nitrogen, specific leaf area, per cent reduction of F_v/F_m , root length, sound mature kernel per cent and kernel yield per plant, while through SPAD chlorophyll meter reading, harvest index, shell thickness, oil per cent and number of well filled and mature pods per plant it showed negative indirect effect.

Sound mature kernel per cent exhibited positive indirect effect through SPAD chlorophyll meter reading, specific leaf nitrogen, per cent reduction of F_v/F_m , root length and kernel yield per plant and negative direct effect through specific leaf area, harvest index, shell thickness, oil per cent, shelling per cent and number of well filled and mature pods per plant.

The character number of well filled and mature pods per plant had positive indirect effect through SPAD chlorophyll meter reading, per cent reduction of F_v/F_m , root length, oil per cent, shelling per cent and kernel

yield per plant and negative indirect effect through specific leaf nitrogen, specific leaf area, harvest index, shell thickness and sound mature kernel per cent

Kernel yield per plant exerted positive indirect effect through SPAD chlorophyll meter reading, per cent reduction of F_v/F_m , root length, sound mature kernel per cent and number of well filled and mature pods per plant. On contrary, its negative direct effect was through specific leaf nitrogen, specific leaf area, harvest index, shell thickness, oil per cent and shelling per cent.

Chapter - V

Discussion

CHAPTER - V

DISCUSSION

Groundnut (*Arachis hypogaea* L.) is the major oilseed crop of India. It occupies a total area of 8.2 million hectares in the country with a production of 6.2 million tones. Though India ranks second in the production, its productivity is appallingly low hovering around 1000 kg ha⁻¹ (FAO, 2001). With an expected rise in population by 2025 to about 1.4 billion, India might require doubling the production than the present level to remain self sufficient. Although this looks achievable under irrigated conditions enhancing the area under irrigation seems to have intrinsic problem, since the major constraint is non-availability of water. Further, more than 80% area of groundnut is under rainfed conditions where soil type and water availability predominantly constrain productivity.

An estimated 30-60% reduction in potential crop yields is often attributed to abiotic stresses, of which, moisture stress is predominant. Paul Kramer (1981) opined that crop losses due to water shortage was greater than those from all other causes together. Therefore, development of drought tolerant varieties under rainfed conditions plays an important role to achieve potential productivity in this crop. But development of varieties tolerant to drought is difficult, since drought resistance is not a simple response, and it is

mostly conditioned by a number of component responses which interact with each other and may differ for different situations. Therefore, to formulate an efficient breeding programme for developing drought resistant varieties, it is essential to understand the mode of inheritance of physiological traits. Drought tolerance is quantitatively inherited with complex physiological traits, thus its genetic basis has received limited attention and the development of drought resistant varieties has been slow. Williams *et al.* (1969) indicated that inheritance of drought resistance is controlled by partial or complete dominance. Identification of traits that improve the plants ability to exploit soil water and withstand drought and introgression of these into agronomically superior variety is important.

Though an array of drought tolerant traits has been identified, SPAD chlorophyll meter reading, specific leaf nitrogen, specific leaf area, root length and harvest index are perhaps the most important physiological traits that determine plant productivity under drought.

The relevance of these traits has been adequately explained by a number of researchers. According to Nageswara Rao *et al.* (2001) SPAD chlorophyll meter reading (SCMR) could be used as a rapid, low cost, non-destructive technique to screen large breeding populations for specific leaf area (SLA) or specific leaf nitrogen (SLN) since a definite relationship was

observed between SPAD chlorophyll meter reading, specific leaf nitrogen and specific leaf area in groundnut.

Rucker *et al.* (1995) while studying traits to improve drought avoidance in peanut, indicated that the plant with large root system (long roots) has maintained its yield potential even under drought conditions. Further recent studies have shown considerable genetic variability for traits like Carbon isotope discrimination, SCMR, SLA and SLN in groundnut (Sharma and Varshney 1995; Nageswara Rao *et al.*, 1993; Wright 1996 and Shashidhar, 2002).

The results are discussed under the following sub-heads.

- a. *per se* performance.
- b. Combining ability
- c. Heterosis and inbreeding depression
- d. Genetic variability, heritability and genetic advance.
- e. Character association
- f. Path coefficients.

5.1 *Per se* performance of parents, F₁s and F₂s.

Out of the eight parents used in the study, JUG-43 showed the highest *per se* performance for SCMR, per cent reduction of Fv/Fm, root length and shell thickness during *rabi* (Table 5). In the same season, the genotype, JUG-

37 recorded the highest *per se* performance for oil per cent, kernel yield per plant and pod yield per plant. The parental genotype, TIR-46 exhibited the highest *per se* performance for specific leaf nitrogen and SMK per cent during *rabi*. However, the situation is quite different during *kharif*. The genotype, JAL-6 showed the highest *per se* performance for root length, shelling per cent and SMK per cent. The parent, K-134 recorded the highest *per se* performance for SLN, harvest index and kernel yield. The genotypes, ICR-45 for SPAD chlorophyll meter reading and TIR-46 for pod yield per plant and number of well filled and mature pods per plant exhibited the highest *per se* performance during *kharif*.

Among the F_1 s, K-134 x JUG-43 was distinct for its highest mean values for per cent reduction of Fv/Fm, number of well filled and mature pods per plant, kernel yield per plant and pod yield per plant during *rabi* (Table 6). Other F_1 s, involving K-134 as one of parents showing highest *per se* performance are K-134 x JAL-6 for shelling per cent, K-134 x JL-24 for harvest index and TIR-46 x K-134 for both shell thickness and oil per cent. The F_1 s involving JL-24 as one of parents viz., JUG-43 x JL-24 for both specific leaf nitrogen and specific leaf area and F_1 , ICR-45 x JAL-6 for SCMR showed the highest *per se* performance during *rabi*.

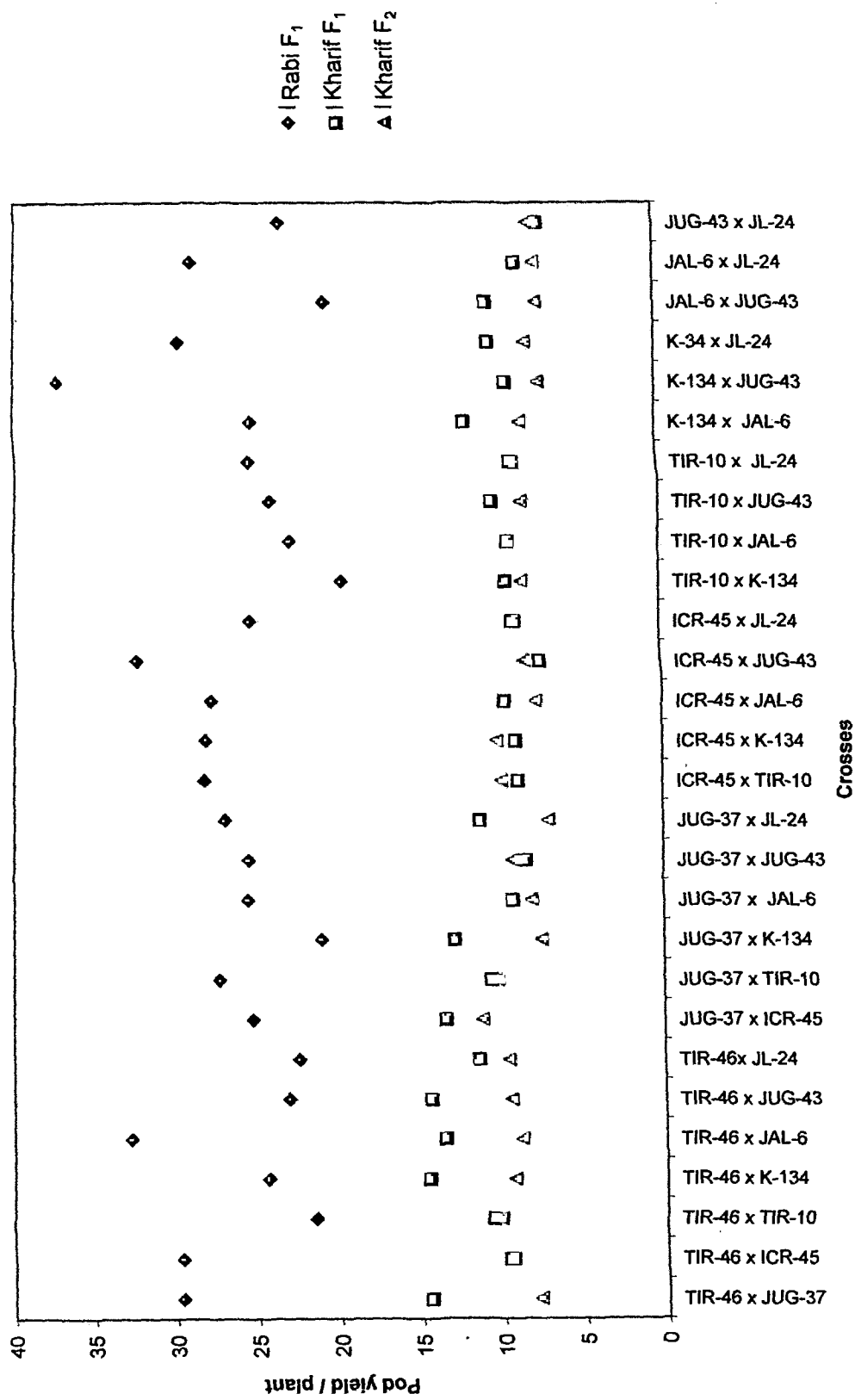
It was found that water deficits can give harvest index as low as zero Boyle *et al.* (1991), hence, the maintenance of the harvest index is of crucial importance when water is in short supply (Boyer, 1996). The parents viz., TIR-46 and ICR-45 included in the study with high SCMR, pod yield and number of well filled and mature pods per plant imparted high *per se* performance for harvest index and also specific leaf area (TIR-46 x ICR-45). The parental genotypes viz., TIR-46 and JAL-6 and its F₁, TIR-46 x JAL-6 were remarkable for their higher shelling per cent, number of well filled and mature pods per plant and kernel yield per plant.

Hubick *et al.* (1986) suggested selection for genotypic differences in rooting ability as an alternate strategy for improving drought resistance of groundnuts. In the present study, the parent, JAL-6 and F₁, JUG-37 x JAL-6 had comparatively higher root length.

JL-24 as one of the parents in cross combinations showed the highest *per se* performance for various physiological and yields attributes. JUG-37 x JL-24 for SMK per cent; TIR-46 x JL-24 for oil per cent; JAL-6 x JL-24 per cent reduction of Fv/Fm; JUG-43 x JL-24 for SCMR and TIR-46 x JL-24 for shell thickness. The F₁, TIR-46 x K-134 a combination of K-134 had high *per se* performance for pod yield per plant.

Among the F₂s, JUG-37 x JAL-6 was distinct for its highest mean values for specific leaf nitrogen and harvest index during *khariif*. Other F₂s,

Fig. 1 : Mean pod yield of F₁s and F₂s



involving TIR-46 as one of parents showing highest *per se* performance are TIR-46 x K-134 for shell thickness and shelling per cent, TIR-46 x JAL-6 for SPAD chlorophyll meter reading and per cent reduction of Fv/Fm, TIR-46 x TIR-10 for kernel yield per plant and TIR-46 x JUG-37 for sound mature kernel per cent (Table 7). The F₂s involving JUG-37 as one of parents viz., JUG-37 x ICR-45 for both number of well filled and mature pods per plant and pod yield per plant and JUG-37 x K-134 for oil per cent showed the highest *per se* performance during *kharif*.

It is clear from *per se* performance of parents and F₁s that no parent imparted usually high yielding ability to all the crosses in which it occurred, however the highest yield F₁s can be predicted on the basis of parentage to some extent.

Identification of promising parents that would nick well and throw up desirable segregants in segregating generations is important in improvement of crop plants. Combining ability studies help in identification of promising parents and estimates of heterosis help in identification of favourable cross combinations that would produce better progeny in succeeding generations.

General combining ability is associated with genes which are additive in effects and specific combining ability is attributed primarily to deviations from the additive scheme caused by dominance and epistasis (Rojas and Sprague, 1952). Many earlier investigations revealed that both *gca* and *sca*

were found to be significant for yield and its components in groundnut and that *gca* variance was usually of greater magnitude than *sca* variance (Labana *et al.*, 1981; Swe and Branch, 1986). Further, several investigations on combining ability indicated divergent results. Combining ability and gene action varied with the type of breeding material studied. While direct selection for yield can be effective (White *et al.*, 1994) the limitations of this approach are high resource investment and poor repeatability of the results due to the large G x E interaction for yield (Cooper and Hammer, 1996).

The strong negative relationship between WUE and SLA suggests that the genotypes with lower SLA (thicker leaves) had greater WUE and greater photosynthetic capacity and assimilate more carbon per unit leaf area (Wright *et al.*, 1994). Hence SLA could be used as a rapid and inexpensive tool to identify genotypes with high WUE, where mass spectrometer facilities are not available. However, SLA is influenced by environmental factors such as temperature and water deficit, which affect cell elongations and multiplication (Nageswara Rao and Wright, 1994).

A recent study of Nageswara Rao *et al.* (2001) has shown significant correlations between the SCMR, SLA and SLN in groundnut and concluded that SCMR could be used as a rapid, low cost, non-destructive technique to screen SLN or SLA. Later Bindu Madhava *et al.* (2003) further studied the relationship of SCMR with WUE. In groundnut, variation in WUE is primarily

controlled by differences in chloroplast and RuBisCo contents that constitute the major pool of nitrogen in the plant, since SCMR is a measure of leaf nitrogen status, it could be considered as an estimates of TE as well. In their study, they found a strong positive relationship between SCMR and SLN and an inverse relationship between SCMR and SLA.

5.2 Combining ability

The estimates of component variances suggested that the estimates of specific combining ability variance components were higher than estimates of general combining ability variance components for almost all the traits viz., SCMR, SLN, SLA, per cent reduction of Fv/Fm, root length, harvest index, shell thickness, shelling per cent, sound mature kernel per cent, pod yield per plant, number of well filled pods per plant and kernel yield per plant in both the seasons (*rabi* 2002 and *kharif* 2003) indicating the preponderance of non-additive gene action in the inheritance these characters. However, oil per cent recorded higher *gca* variance than *sca* variance in *rabi* and reverse is the case during *kharif*, indicating the importance of both additive and non-additive gene actions in the inheritance of oil per cent (Table 9). The traits, pod yield and oil per cent appear to be more influenced by additive gene action as the variance ratio was found to be more than unity for these traits. Similar results

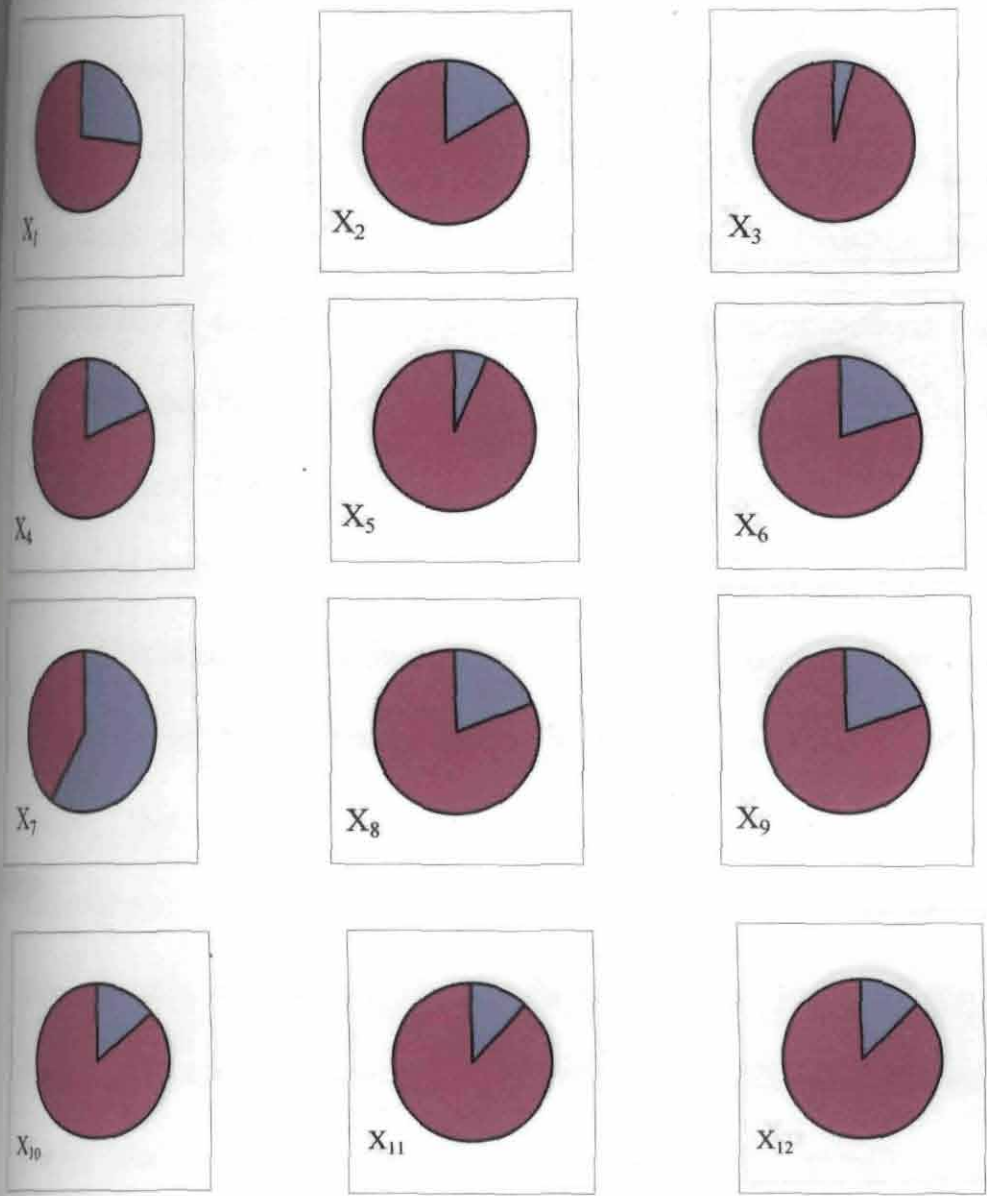
were reported by earlier workers (Manoharan *et al.*, 1985; Basu *et al.*, 1986 and Bansal *et al.*, 1992).

From the variance ratios obtained for the traits, SCMR (*kharif* and *rabi*), shell thickness (*rabi*) and per cent reduction of Fv / Fm (*kharif*) seems to be equally influenced by both additive and non-additive gene actions as the ratio is nearer to unity (Fig. 2 and 3)

The traits SLN, SLA, harvest index, root length, shelling per cent, SMK per cent, number of well filled and mature pods per plant, kernel yield per plant showed very low variance ratio which indicates the dominant role of non-additive gene action in the inheritance of these characters. These findings are in agreement with the reports of earlier workers i.e., Garet (1976) Hamid *et al.*, (1981), Nadaf *et al.*, (1988) and Varman (2000) for shelling per cent, Mathur *et al.*, (2000) for SMK per cent ; for number of well filled and mature pods per plant (Labana *et al.*, 1981; Dwivedi *et al.*, 1989 and Varman, 2000) and Singh and Labana (1980), Vijayabhaskar Reddy (1984), Sateera Banu (1992) and Upadhyaya *et al.*, (1992) for kernel yield per plant and Vasanthi *et al.*, (2004) for specific leaf area .

JUG-37 and JUG-43 in both seasons, ICR-45 in *rabi* and K-134 in *harif* were found to be good general combiners with significant *gca* effects and high *per se* performance for SCMR. From *sca* effects and *per se* performance the F₁s, JUG-37 x JAL-6 (H x L), JUG-37 x JL-24 (H x L),

Fig. 1: Ratio of *gca* and *sca* variance for 12 characters in groundnut (*rabi*, 2002)



■ gca variance
■ sca variance

Fig.3: Ratio of *gca* and *sca* variance for 12 characters in groundnut (*kharif*, 2003)



■ *gca* variance
 ■ *sca* variance

ICR-45 x JAL-6 (H x L) and TIR-10 x JL-24 (H x L) were found to be promising combinations as they showed significant positive *sca* effects with high *per se* performance and significant positive heterobeltiosis and relative heterosis during *rabi*. During *kharif* TIR-46 x JL-24 (L x L), TIR-46 x JAL-6 (L x L), JAL-6 x JL-24 (L x L) and JUG-43 x JL-24 (H x L) exhibited significant positive *sca* effects with high mean performance and positive heterobeltiosis and relative heterosis. The cross combinations that showed high *sca* and higher *per se* performance was either H x L or L x L combinations. These results indicate the role of inter-allelic interactions in displaying higher *sca* and high *per se* performance.

This also could be due to genetic interaction between favourable alleles contributed by the parents involved. The recurrent selection and diallel mating system, that provide an opportunity for selection, recombination and accumulation of the desired genes and also to exploit fixable and non-fixable type of genes in later generations, should be employed for improvement of SCMR in these combinations. Vasanthi *et al.*, (2004) and Seethala Devi (2004) also reported non-additive gene action for SCMR in segregating generation of groundnut.

Parents JUG-37 and JUG-43 during both seasons and TIR-46 in *rabi* and K-134 in *kharif* were found to be good general combiners with high *per se* performance for specific leaf nitrogen. The F₁s, TIR-46x JAL-46 (H x L), K-

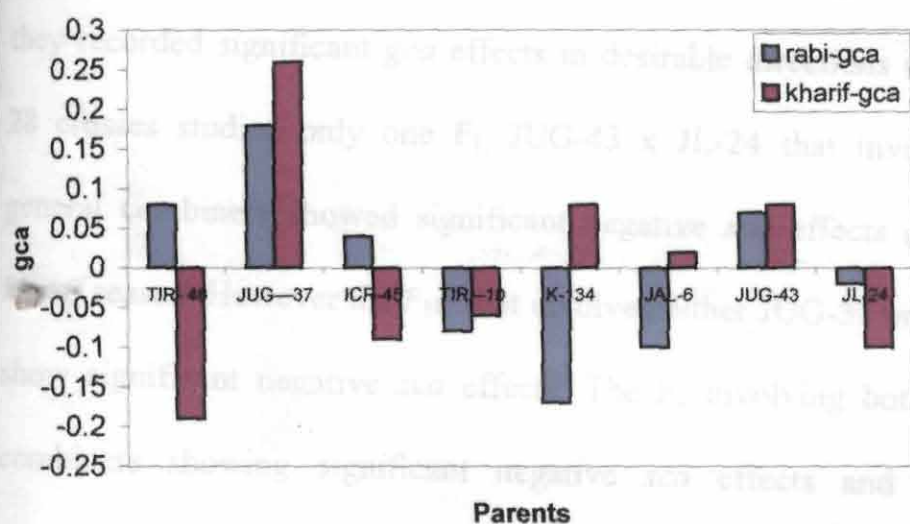
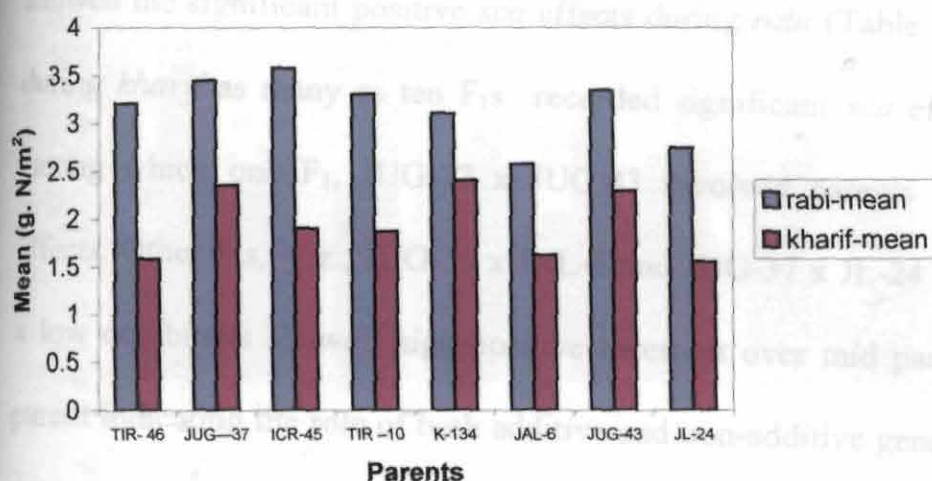


Fig. 4 : Relative gca and *per se* performance of parents for specific leaf nitrogen

134 x JL-24, (L x L), JAL-6 x JL-24 (L x L) and JUG-37 x JL-24 (H x L) showed the significant positive *sca* effects during *rabi* (Table 11) . However, during *kharif* as many as ten F_1 s recorded significant *sca* effects for SLN, among which one F_1 , JUG-37 x JUG-43 involved parents with high *gca* effects. Other F_1 s, viz., JUG-37 x JAL-6 and JUG-37 x JL-24 involving high x low combiners showed high positive heterosis over mid parent and better parent indicating the role of both additive and non-additive gene effects in the expression of this character.

For SLA, the genotypes JUG-43 and JUG-37 in both seasons JL-24 during *rabi* and TIR-46 in *kharif* were found to be best general combiners as they recorded significant *gca* effects in desirable directions (Fig. 5). Among 28 crosses studied only one F_1 , JUG-43 x JL-24 that involved two good general combiners showed significant negative *sca* effects during *rabi* and *kharif* season. However the F_1 s that involved either JUG-37 or TIR-46 did not show significant negative *sca* effects. The F_1 involving both good general combiners showing significant negative *sca* effects and non-significant negative relative heterosis indicating the operation of additive gene action and is a cause for heterosis. Simple conventional breeding programmes like pedigree method can exploit this particular cross. Jayalakshmi *et al.*, (1999) and Nigam *et al.*, (2001) also reported additive gene action for SLA in

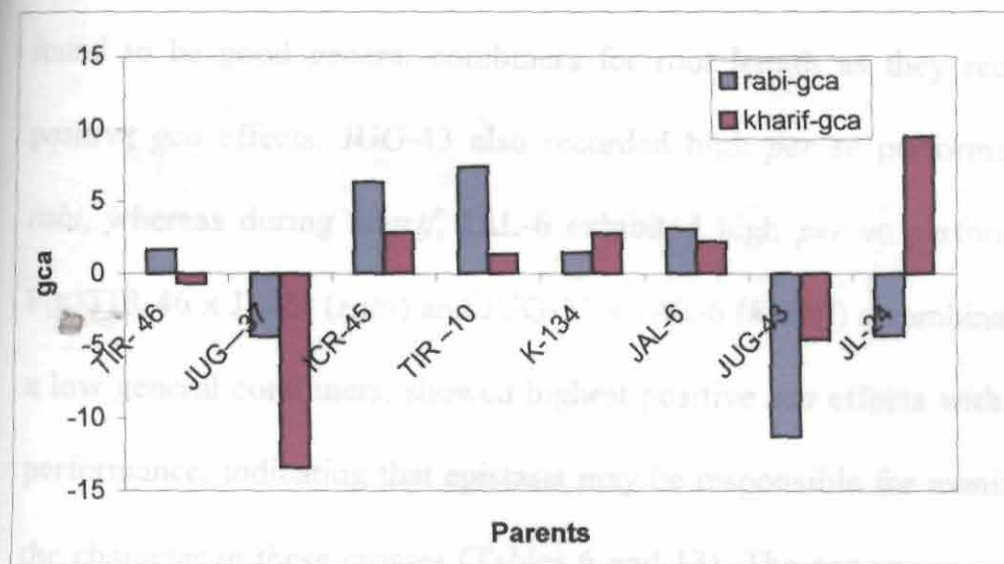
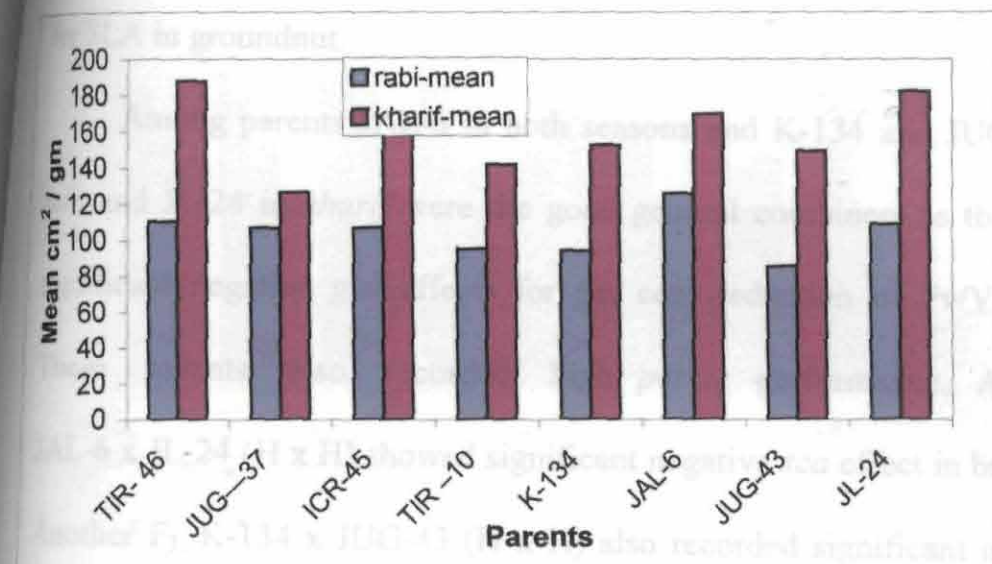


Fig. 5 : Relative gca and per se performance of 8 parents for specific leaf area

groundnut, however Vasanthi *et al.*, (2004) reported non-additive gene action for SLA in groundnut.

Among parents JAL-6 in both seasons and K-134 and JUG-43 during *rabi* and JL-24 in *kharif* were the good general combiners as they recorded significant negative *gca* effects for per cent reduction of Fv/Vm (Fig. 6). These parents also recorded high *per se* performance. Among F_1 s, JAL-6 x JL-24 (H x H) showed significant negative *sca* effect in both seasons. Another F_1 , K-134 x JUG-43 (H x H) also recorded significant negative *sca* effects during *rabi*.

Parents, JAL-6 and JUG-43 during *rabi* and JL-24 in *kharif* were found to be good general combiners for root length as they recorded high positive *gca* effects. JUG-43 also recorded high *per se* performance during *rabi*, whereas during *kharif*, JAL-6 exhibited high *per se* performance. The F_1 s, TIR-46 x JL-24 (*rabi*) and JUG-37 x JAL-6 (*kharif*) a combination of low x low general combiners, showed highest positive *sca* effects with high mean performance, indicating that epistasis may be responsible for manifestation of the character in these crosses (Tables 6 and 13). The *sca* variance component was greater than *gca* variance indicating importance of non-additive gene action. Since, non-additive gene action was found predominant, breeding method involving selection, intermating the selections and reselection may help to improve this character. Rucker *et al.* (1995) in identification of

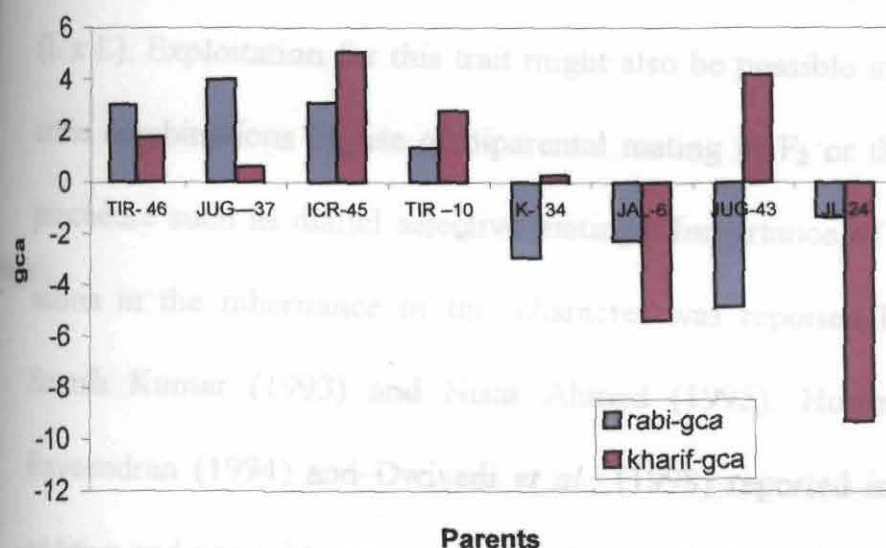
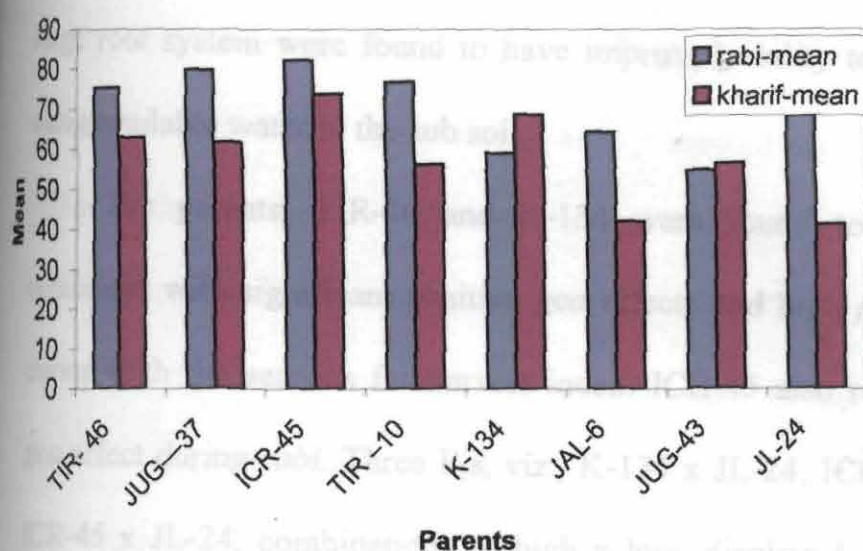


Fig. 6 : Relative gca and per se performance of 8 parents for per cent reduction of Fv / Fm

genotypes possessing traits tolerant to drought concluded that genotypes with large root system were found to have improved ability to avoid drought by using available water in the sub soil.

The parents, TIR-46 and K-134 were found to be good general combiners with significant positive *gca* effects and high *per se* performance during both the seasons for harvest index. ICR-45 also recorded significant *gca* effect during *rabi*. Three F_1 s, viz., K-134 x JL-24, ICR-45 x TIR-10 and ICR-45 x JL-24, combinations of high x low, displayed significant positive *sca* effects with high mean and heterosis during *rabi*. The other F_1 , that recorded the highest significant positive *sca* effects in *kharif* is JAL-6 x JUG-43 (L x L). Exploitation for this trait might also be possible in H x L and L x L cross combinations by use of biparental mating in F_2 or the use of selection procedure such as diallel selective matings. Importance of non-additive gene action in the inheritance of this character was reported by Makne (1992), Suresh Kumar (1993) and Nisar Ahmed (1995). However, Varman and Raveendran (1994) and Dwivedi *et al.*, (1998) reported importance of both additive and non-additive gene action for harvest index in groundnut.

Among parents TIR-46 and K-134 in both seasons and JUG-43 in *rabi* and JL-24 in *kharif* were found to be good general combiners with significant *gca* effects and *per se* performance in desirable direction. Thus, these parents are of considerable use in obtaining genotypes with thin shell. The F_1 s, TIR-46

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JUG-37 (H x L), TIR-46 x ICR-45 (H x L) and TIR-46 x K-134 (H x H) during *rabi* and crosses JUG-37 x JL-24 (L x H), TIR-46 x JUG-37 (H x L) and K-134 x JL-24 (H x H) during *kharif* showed significant negative *sca* effects with high *per se* performance and heterosis in desirable direction indicating operation of non-additive gene action (Table 11 and 13).

Among the parents TIR-46, JUG-37 and K-134 in *rabi* recorded significant *gca* effects and *per se* performance for oil per cent. K-134 also recorded significant *gca* effect during *kharif* (Table 12). Among F_1 s, JAL-6 x JL-24 (L x L) and TIR-10 x JUG-43 (L x L) exhibited significant positive *sca* effects during *rabi* and *kharif*, respectively. These F_1 s also recorded significant positive heterosis. Besides these, two more F_1 s, ICR-45 x JAL-6 (L x L) and TIR-46 x ICR-45 (L x L) in *rabi*, one more F_1 , TIR-10 x JL-24 (L x L) during *kharif* also recorded significant positive *sca* effects. These findings suggest that epistasis may be responsible for manifestation of this character. Estimates of *gca* and *sca* components of variances revealed the importance of additive gene action in *rabi* and non-additive gene action in *kharif*. Layrisse *et al.* (1980), Basu *et al.*, (1986), Skyes and Michaels (1986), Bansal *et al.*, (1992) reported additive gene action for oil per cent. Contrary to this several studies reported non-additive gene action for oil per cent (Basu *et al.* (1987), Makne and Bhale (1987), Francis and Ramalingam (1999), Varman (2000) and Ali *et al.* (2001).

Among parents only one parent TIR-46 recorded significant positive *gca* effects in *rabi*, whereas none of the parents showed significant positive *gca* effect in *kharif* for shelling per cent. The F₁s, JUG-37 x JAL-6 and TIR-10 x K-134, a combination of low x low only showed significant positive *sca* effects, indicating that epistasis may be responsible for manifestation of the character in these crosses. Since, these crosses involved both poor combiners exhibiting positive *sca* effects indicating non-additive gene action. The results are in agreement with those reported by Hamid *et al.*, (1981), Nadaf *et al.*, (1988) and Varman (2000).

Parents TIR-46 and JUG-37 in both seasons and ICR-45 in *rabi* only were found to be good general combiners for sound mature kernel percentage with significant positive *gca* effects. Among F₁s, the JUG-37 x JL-24 (H x L) in both seasons and TIR-46 x JUG-43 (H x L) JAL-6 x JUG-43 (L x L) in *rabi* and K-134 x JUG-43 (L x L), TIR-10 x JAL-6 (L x L) in *kharif* showed significant positive *sca* effects. The F₁s with high mean involving H x L and L x L general combiners as parents can be improved by integrating pedigree and bulk method with recurrent selection and diallel selective mating system to fix both additive and non-additive gene actions. Suneetha *et al.*, (2004) and Dasaradha Ramireddy and Suneetha (2004) in a study of 25 F₁s made L x T fashion reported non-additive gene action for SMK per cent in groundnut.

Among parents only one parent TIR-46 recorded significant positive *gca* effect in *kharif*. In *rabi* none of the parents recorded significant positive *gca* effect for number of well filled and mature pods per plant. Among F_1 s, K-134 x JUG-43 (H x L), ICR-45 x JL-24 (L x L), K-134 x JL-24 (L x L) during *rabi* and TIR-46 x JAL-6 (H x L) in *kharif* exhibited significant positive *sca* effects. A combination of high x low and low x low general combiners indicate operation of non-additive gene action in controlling this character. The results are in close agreement with the finds of Labana *et al.*, (1981), Manoharan *et al.*, (1985), Nadaf *et al.*, (1988), Suresh Kumar (1993), Francis and Ramalingam (1999), Varman (2000), Manivel *et al.*, (2003) and Mothilal *et al.*, (2004) in groundnut.

In respect of kernel yield per plant, JUG-37 and K-134 were found to be the best general combiners in *rabi* and *kharif*, respectively. These two parents recorded highest significant positive *gca* effects coupled with high *per se* performance in respective seasons (Table 7). Among F_1 s, K-134 x JUG-43 exhibited high significant positive *sca* effect coupled with high *per se* performance and heterosis during *rabi*. Heterosis in a cross combination involving both the parents with high *gca* indicate operation of additive gene action in controlling this character. High *sca* effect in the F_1 , JUG-37 x ICR-45 may be due to both additive and non-additive gene actions as the cross involved high and low *gca* parents. Additive gene action in the inheritance of

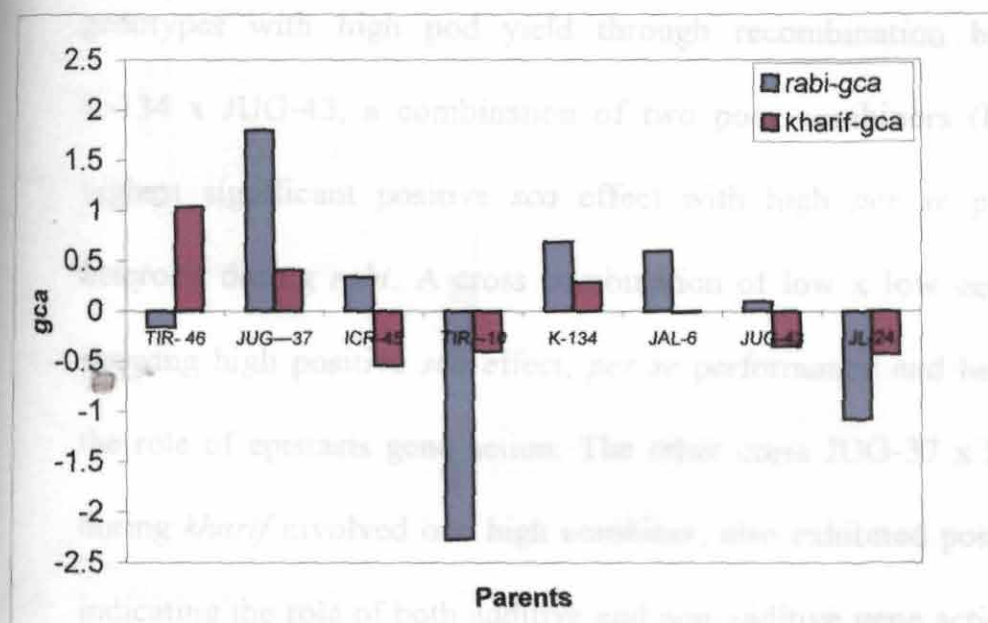
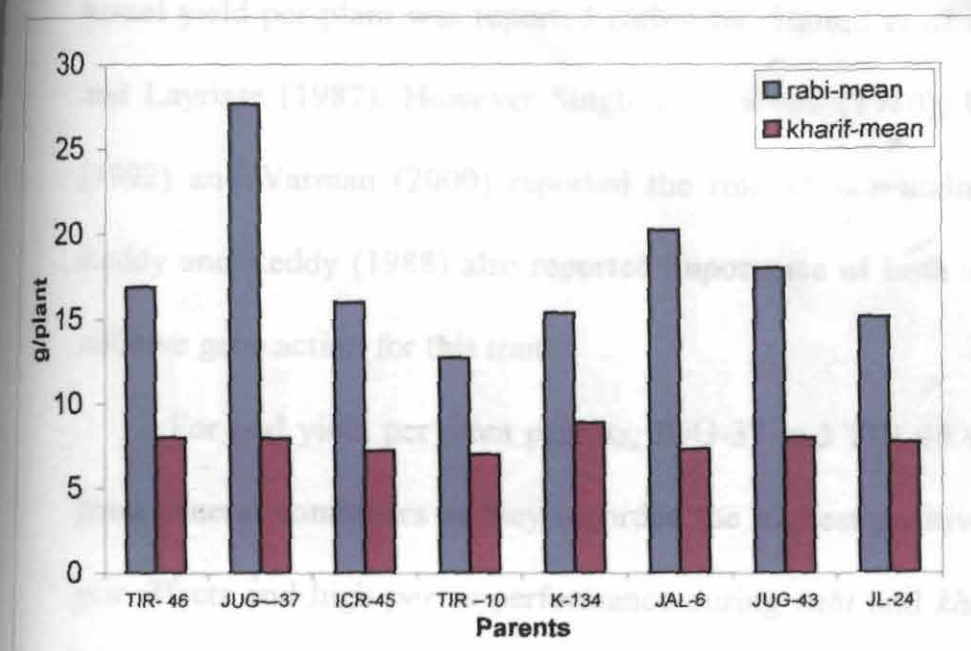


Fig. 7 : Relative gca and per se performance of 8 parents for kernel yield per plant

kernel yield per plant was reported earlier by Hamid *et al.* (1981) and Nava and Layrisse (1987). However Singh and Labana (1980), Uapdhyaya *et al.* (1992) and Varman (2000) reported the role of non-additive gene action. Reddy and Reddy (1988) also reported importance of both additive and non-additive gene action for this trait.

For pod yield per plant parents, JUG-37 and TIR-46 were found to be good general combiners as they recorded the highest positive and significant *gca* effects and high *per se* performance during *rabi* and *kharif*, respectively (Fig. 8). Thus these parents are of considerable use in development of genotypes with high pod yield through recombination breeding. The F₁, K-134 x JUG-43, a combination of two poor combiners (L x L), showed highest significant positive *sca* effect with high *per se* performance and heterosis during *rabi*. A cross combination of low x low general combiners showing high positive *sca* effect, *per se* performance and heterosis, indicate the role of epistasis gene action. The other cross JUG-37 x ICR-45 (H x L) during *kharif* involved one high combiner, also exhibited positive *sca* effects indicating the role of both additive and non-additive gene actions. Since, non-additive gene action was found predominant, breeding method involving selection, intermating the selections and reselection may be help to improve this trait. Nadaf *et al.* (1988) reported importance of additive gene action for pod yield per plant. On the contrary, the importance of non-additive gene

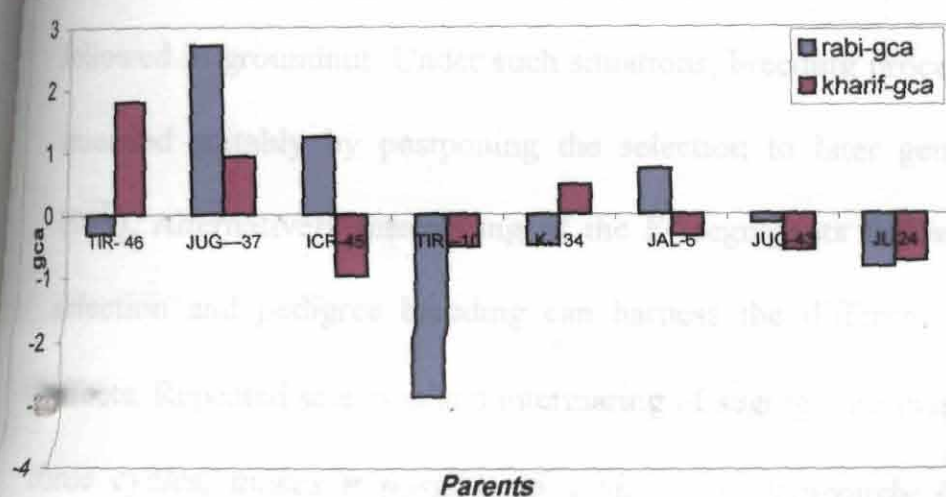
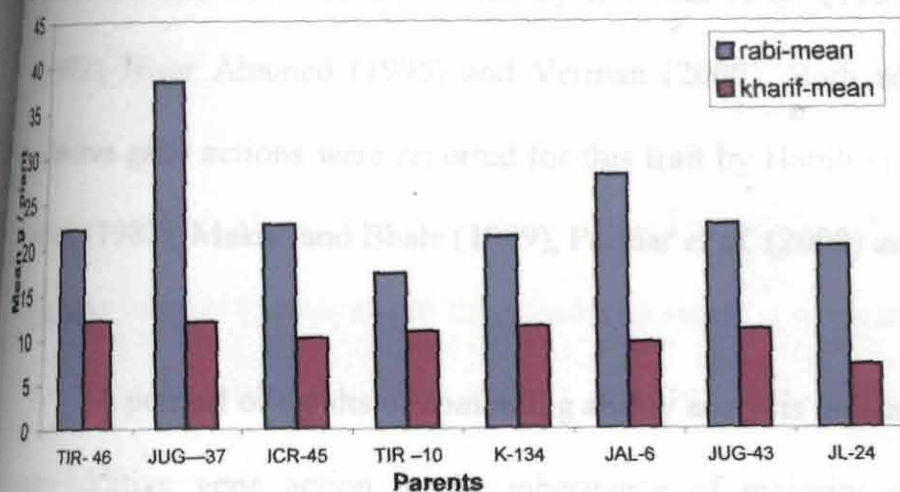


Fig. 8 : Relative gca and per se performance of 8 parents for pod yield per plant

action for this trait was mentioned by Dwivedi *et al.* (1989), Sateera Banu (1992), Nisar Ahamed (1995) and Verman (2000). Both additive and non-additive gene actions were reported for this trait by Habib *et al.* (1985), Basu *et al.* (1987), Makne and Bhale (1989), Parmar *et al.* (2000) and Mothilal *et al.* (2004).

A perusal of results of combining ability analysis indicated considerable non-additive gene action in the inheritance of majority of the attributes studied. The non-fixable dominance deviation and epistatic effects are likely to hinder improvement through simple pedigree selection, which is commonly followed in groundnut. Under such situations, breeding procedures have to be amended suitably by postponing the selection to later generations (Baker, 1968). Alternatively intermating of the F_2 segregants followed by recurrent selection and pedigree breeding can harness the different kinds of gene - effects. Repeated selection and intermating of segregating materials for two or three cycles, makes it possible to achieve simultaneously improvement in kernel yield and other physiological attributes. Monteverde - Penso and Wyne (1998) suggested that, where hybridization is difficult recurrent selection with minimal crossing followed by single seed descent may be practiced for obtaining better results. Halward *et al.* (1990) found that recurrent selection was effective for improving both yield and agronomic characters in the broad based groundnut population.

5.3 Heterosis and inbreeding depression

Heterosis in F_1 generation expressed in terms of superiority over the better / mid parent/standard parent is of direct relevance not only for developing hybrids in cross-pollinated crops, but also in self pollinated crops because heterotic crosses help the breeder to select appropriate crosses which would lead to desirable transgressive segregants in advanced generations (Arunachalam *et al.*, 1984). Stokes and Hull (1930) first observed the manifestation of heterosis for different traits in groundnut. Since then, several investigators reported heterosis for yield and its components in groundnut (Higgins, 1940; Layrisse *et al.*, 1980; Deshmukh *et al.*, 1985 and Dwivedi *et al.*, 1994). According to the available evidence, heterosis in groundnut is related to the parental genetic diversity. The reproductive biology of groundnut is such that it prevents the direct exploitation of heterosis in commercial F_1 hybrids. In groundnut the heterosis generally results from dominance and overdominance and will disappear with inbreeding, however, if heterosis is due to epistatic gene action particularly by additive x additive of epistasis or to repulsion phase linkage of loci exhibiting partial or complete dominance, it should be possible through selection to fix alleles at the interacting or linked loci to preserve the heterotic effect (Isleib and Wynne, 1983).

Table 38 : Best parents and F₁s (based on *per se* performance, combining ability and heterosis) for 13 characters in groundnut (Rabi - 2002)

Character	Best parent - based on			Best cross - based on			Best heterotic crosses-based on		
	Per se performance	gca effects	Per se performance	Sca effects	Heterobeltiosis	Relative heterosis	Standard heterosis		
SPAD chlorophyll meter reading	JUG-43	JUG-43	ICR-45 x JAL-6	JUG-37 x JL-24	JUG-37 x JL-24	JUG-37 x JL-24	ICR-45 x JAL-6		
	JUG-37	JUG-37	JUG-37 x JL-24	ICR-45 x JAL-6	ICR-45 x JAL-6	ICR-45 x JAL-6	JUG-37 x JL-24		
	TIR-10	ICR-45	ICR-45 x TIR-10	JUG-37 x JAL-6	JAL-6 x JL-24	JAL-6 x JL-24	JUG-37 x TIR-10		
Specific leaf nitrogen	ICR-45	JUG-37	JUG-43 x JL-24	K-134 x JL-24*	All non-significant and negative			JUG-43 x JL-24	
	JUG-43	TIR-46	TIR-10 x K-134	JAL-6 x JL-24				JUG-37 x JUG-43	JUG-37 x JUG-43
	JUG-37	JUG-43	JUG-37 x JUG-43	JUG-37 x JL-24				TIR-10 x K-134	TIR-10 x K-134
Specific leaf area	K-134	JUG-43	JUG-43 x JL-24	JUG-43 x JL-24	JAL-6 x JL-24	JAL-6 x JL-24	ICR-45 x JAL-6		
	TIR-10	JUG-37	JAL-6 x JL-24	JUG-37 x TIR-10	JUG-43 x JL-24	JUG-43 x JL-24	TIR-10 x JAL-6		
	JUG-43	JL-24	JAL-6 x JUG-43	JAL-6 x JUG-43	JUG-37 x JAL-6	JUG-37 x JAL-6	TIR-46 x K-134		
Per cent reduction of Fv/Fm	JUG-43	JUG-43	K-134 x JUG-43	ICR-45 x JL-24	ICR-45 x JL-24	ICR-45 x JL-24	JUG-37 x JAL-6		
	K-134	K-134	JAL-6 x JL-24	JAL-6 x JL-24	JAL-6 x JL-24	JAL-6 x JL-24	TIR-10 x JL-24		
	JAL-6	JAL-6	TIR-10 x K-134	TIR-46 x JUG-37	JUG-37 x TIR-10	ICR-45 x TIR-10	JUG-37 x JAL-6		
Root length	JUG-43	JUG-43	TIR-46 x JL-24	TIR-46 x JL-24	TIR-46 x JL-24	TIR-46 x JL-24	TIR-46 x JL-24		
	JAL-6	JAL-6	JAL-6 x JUG-43	ICR-45 x K-134	JUG-37 x ICR-45	JUG-37 x ICR-45	JAL-6 x JUG-43		
	TIR-46	JL-24	JUG-37 x JUG-43	JUG-37 x ICR-45	ICR-45 x K-134	ICR-45 x K-134	JUG-37 x JUG-43		
Harvest Index	TIR-46	TIR-46	K-134 x JL-24	K-134 x JL-24	K-134 x JL-24	K-134 x JL-24	K-134 x JL-24		
	JUG-37	ICR-45	K-134 x JUG-43	ICR-45 x TIR-10	TIR-10 x JUG-43	TIR-10 x JUG-43	TIR-46 x ICR-45		
	ICR-45	K-134	ICR-45 x JL-24	ICR-45 x JL-24	K-134 x JUG-43	K-134 x JUG-43	ICR-45 x TIR-10		
Shell thickness	JUG-43	JUG-43	TIR-46 x K-134	TIR-46 x JUG-37	TIR-46 x JUG-37	TIR-46 x JUG-37	JUG-37 x ICR-45		
	JL-24	K-134	TIR-46 x ICR-45	TIR-46 x ICR-45	TIR-46 x K-134	TIR-46 x K-134	JUG-37 x TIR-10		
	TIR-10	TIR-46	TIR-46 x TIR-10	TIR-46 x K-134	TIR-46 x ICR-45	TIR-46 x ICR-45	JUG-37 x JL-24		
Oil per cent	JUG-37	JUG-37	TIR-46 x ICR-45	JAL-6 x JL-24	TIR-10 x JL-24	ICR-45 x JAL-6	JUG-37 x K-134		
	TIR-46	K-134	JUG-37 x ICR-45	ICR-45 x JAL-6	JAL-6 x JL-24	JAL-6 x JL-24	JUG-37 x ICR-45		
	K-134	TIR-46	JUG-37 x TIR-10	TIR-46 x ICR-45	TIR-10 x JAL-6	TIR-10 x JAL-6	JUG-37 x TIR-10		
Shelling per cent	TIR-46	TIR-46	TIR-46 x ICR-45	K-134 x JAL-6	K-134 x JAL-6	K-134 x JAL-6	K-134 x JAL-6		
	JUG-43	K-134	K-134 x JAL-6	JUG-37 x JAL-6	JUG-37 x JAL-6	JUG-37 x JAL-6	TIR-46 x ICR-45		
	JL-24	JAL-6	ICR-45 x JAL-6	TIR-10 x K-134	TIR-10 x K-134	TIR-10 x K-134	TIR-46 x JUG-37		
Sound mature kernel per cent	ICR-45	TIR-46	TIR-46 x JUG-43	TIR-46 x JUG-43	JAL-6 x JUG-43	JAL-6 x JUG-43	TIR-46 x JUG-43		
	TIR-46	JUG-37	JUG-37 x JL-24	JAL-6 x JUG-43	JUG-37 x JUG-43	JUG-37 x JUG-43	JUG-37 x JL-24		
	JL-24	ICR-45	JUG-37 x K-134	JUG-37 x JL-24	JUG-37 x K-134	TIR-46 x JUG-43	TIR-46 x TIR-10		
Number of well filled and mature pods per plant	JAL-6	JAL-6	K-134 x JUG-43	K-134 x JUG-43	JUG-37 x K-134	ICR-45 x JL-24	K-134 x JUG-43		
	JUG-37	K-134	K-134 x JL-24	ICR-45 x JL-24	ICR-45 x TIR-10	ICR-45 x TIR-10	K-134 x JL-24		
	K-134	JL-24	K-134 x JAL-6	K-134 x JL-24	K-134 x JUG-43	K-134 x JUG-43	K-134 x JAL-6		
Kernel yield per plant	JUG-37	JUG-37	K-134 x JUG-43	K-134 x JUG-43	K-134 x JL-24	K-134 x JL-24	K-134 x JUG-43		
	JAL-6	K-134	JUG-37 x TIR-10	K-134 x JL-24	TIR-46 x ICR-45	TIR-46 x ICR-45	TIR-46 x ICR-45		
	JUG-43	JAL-6	TIR-46 x ICR-45	TIR-46 x ICR-45	K-134 x JUG-43	K-134 x JUG-43	K-134 x JL-24		
Pod yield per plant	JUG-37	JUG-37	K-134 x JUG-43	K-134 x JUG-43	K-134 x JUG-43	K-134 x JUG-43	K-134 x JUG-43		
	JAL-6	ICR-45	TIR-46 x JAL-6	TIR-46 x JAL-6	ICR-45 x JUG-43	ICR-45 x JUG-43	TIR-46 x JAL-6		
	ICR-45	JAL-6	JUG-37 x JUG-43	ICR-45 x JUG-43	K-134 x JL-24	K-134 x JL-24	ICR-45 x JUG-43		

Table 39 : Best parents and F₁ (based on *per se* performance, combining ability, heterosis and inbreeding depression) for 13 characters in groundnut (Kharif - 2003)

Character	Best parent – based on		Best cross – based on		Best heterotic cross based on			Cross with lowest inbreeding depression
	Per se performance	gca effects	Per se performance	Sca effects	Heterobeltiosis	Relative heterosis	Standard heterosis	
SPAD chlorophyll meter reading	ICR-45	JUG-43	JUG-43 x JL-24	JUG-43 x JL-24	TIR-46 x JAL-6	JUG-43 x JL-24	JUG-43 x JL-24	TIR-46 x JAL-6
	JUG-37	JUG-37	TIR-10 x JUG-43	TIR-46 x JL-24	TIR-46 x JL-24	JAL-6 x JL-24	TIR-10 x JUG-43	JUG-37 x JAL-6
	K-134	K-134	JUG-37 x TIR-10	JAL-6 x JL-24	JUG-43 x JL-24	JAL-6 x JL-24	JUG-37 x TIR-10	TIR-10 x JL-24
Specific leaf nitrogen	K-134	JUG-37	JUG-37 x JUG-43	JUG-37 x JL-24	TIR-46xJAL-6	TIR-46xJAL-6	ICR-45 x JUG-43	JUG-37 x ICR-45
	JUG-37	K-134	JUG-37 x JAL-6	JUG-37 x JL-24	JUG-37 x JUG-43	JUG-37 x JAL-6	JUG-37 x JUG-43	JUG-37 x JAL-6
	JUG-43	JUG-43	JUG-37 x JL-24	JUG-37 x JAL-6	TIR-46 x JL-24	JUG-37 x JL-24	JUG-37 x JAL-6	JAL-6 x JL-24
Specific leaf area	JUG-37	JUG-37	JUG-37 x JUG-43	JUG-43 x JL-24	TIR-46xJAL-6	TIR-46 x JL-24	TIR-10 x JL-24 K-	ICR-45 x JUG-43
	TIR-10	JUG-43	TIR-46 x ICR-45	TIR-46 x TIR-10	TIR-46 x JL-24	TIR-46 x K-134	134 x JUG-43 K-134	TIR-46 x ICR-45
	JUG-43	TIR-46	TIR-46 x JUG-37	TIR-46 x K-134	ICR-45 x JAL-6	TIR-46xJAL-6	x JAL-6	ICR-45 x JAL-6
Per cent reduction of Fv/Fm	JL-24	JL-24	JAL-6 x JL-24	JAL-6 x JL-24	JUG-37 x K-134	JAL-6 x JL-24	JUG-43 x JL-24	K-134 x JL-24
	JAL-6	JAL-6	K-134 x JL-24	JUG-37 x K-134	TIR-46 x JAL-6	JUG-37 x K-134	TIR-46 x JUG-37	JAL-6 x JL-24
	TIR-10	JUG-37	JUG-37 x K-134	K-134 x JL-24	TIR-46 x JL-24	K-134 x JL-24	JUG-37 x JUG-43	JAL-6 x JUG-43
Root length	JAL-6	JL-24	JUG-37 x JAL-6	JUG-37 x JAL-6	JUG-37 x TIR-10	JUG-37 x TIR-10	JUG-37 x JAL-6	TIR-10 x JAL-6
	JL-24	JUG-37	TIR-10 x JUG-43	TIR-10 x JUG-43	JUG-37 x JAL-6	JUG-43 x JL-24	JAL-6 x JL-24	K-134 x JAL-6
	K-134	JAL-6	TIR-46 x ICR-45	TIR-46 x ICR-45	TIR-46 x JUG-37	TIR-46 x ICR-45	JUG-37 x TIR-10	TIR-10 x JL-24
Harvest Index	K-134	TIR-46	TIR-46 x ICR-45	JAL-6 x JUG-43	All negative significant	JAL-6 x JUG-43	All negative	JUG-37 x ICR-45
	TIR-46	K-134	TIR-46 x K-134	TIR-46 x ICR-45	TIR-10 x JUG-43	TIR-10 x JUG-43	non-significant	JUG-37 x JL-24
	JUG-37	ICR-45	TIR-46 x JUG-37	TIR-10 x JUG-43	ICR-45 x JUG-43	TIR-46 x ICR-45	JUG-37 x JAL-6	K-134 x JAL-6
Shell thickness	JL-24	JL-24	TIR-46 x JL-24	TIR-46 x JL-24	ICR-45 x JUG-43	TIR-46 x JL-24	JUG-37 x JL-24	K-134 x JL-24
	TIR-10	K-134	K-134 x JL-24	TIR-46 x JUG-37	TIR-46 x JL-24	TIR-46xJUG-43	TIR-10 x JUG-43	TIR-46 x JL-24
	ICR-45	TIR-10	TIR-10 x K-134	K-134 x JL-24	TIR-46xJUG-43	TIR-46 x JUG-37	JUG-37 x TIR-10	TIR-10 x K-134
Oil per cent	K-134	K-134	TIR-46 x K-134	TIR-10 x JUG-43	TIR-10 x JUG-43	TIR-10 x JUG-43	All negative	JUG-43 x JL-24
	TIR-46	TIR-46	TIR-10 x JUG-43	TIR-10 x JUG-43	ICR-45 x JUG-43	JUG-37 x JAL-6	All negative	TIR-46 x TIR-10
	JL-24	JL-24	JUG-37 x K-134	TIR-46 x TIR-10	JUG-37 x JUG-43	ICR-45 x JUG-43	All negative	ICR-45 x TIR-10
Shelling per cent	JAL-6	TIR-46	TIR-46 x JAL-6	TIR-10 x JL-24	All negative	All negative	All negative	K-134 x JUG-43
	JUG-43	JAL-6	JUG-37 x JAL-6	ICR-45 x K-134	ICR-45 x K-134	JUG-37 x JL-24	ICR-45 x JL-24	ICR-45 x JL-24
	TIR-46	JUG-43	ICR-45 x K-134	JUG-37 x K-134	JUG-37 x JL-24	JUG-37 x JL-24	JUG-37 x JL-24	JUG-37 x JL-24
Sound mature kernel per cent	JAL-6	TIR-46	JUG-37 x JL-24	JUG-37 x JL-24	K-134 x JUG-43	TIR-10 x JAL-6	All negative	TIR-10 x JL-24
	K-134	JUG-37	TIR-46 x JUG-37	K-134 x JUG-43	TIR-46xJAL-6	TIR-10 x JAL-6	All negative	ICR-45 x JL-24
	JL-24	JUG-43	TIR-46 x ICR-45	TIR-10 x JAL-6	TIR-10 x JAL-6	TIR-10 x JUG-43	TIR-46 x TIR-10	JUG-46 x TIR-10
Number of well filled and mature pods per plant	TIR-46	TIR-46	TIR-46 x K-134	TIR-46 x JAL-6	TIR-46xJAL-6	TIR-46xJAL-6	TIR-46 xJ AL-6	JUG-43 x JL-24
	JAL-6	JUG-37	JUG-37 x K-134	JUG-37 x K-134	TIR-46 x K-134	TIR-46 x K-134	TIR-46 x K-134	JAL-6 x JL-24
	JUG-37	JAL-6	TIR-46 x JUG-43	TIR-46 x K-134	K-134 x JL-24	JUG-37 x K-134	JUG-37 x K-134	K-134 x JL-24
Kernel yield per plant	K-134	K-134	TIR-46 x JAL-6	JUG-37 x ICR-45	TIR-46xJAL-6	TIR-46xJAL-6	TIR-46xJAL-6	JUG-37 x JUG-43
	TIR-46	JUG-37	TIR-46 x JUG-37	TIR-46 x JAL-6	TIR-46 x JUG-37	TIR-46 x ICR-45	TIR-46 x JUG-37	ICR-45 x TIR-10
	JUG-43	K-134	TIR-46 x K-134	TIR-46 x xJUG-43	TIR-46xJUG-43	TIR-46 x JUG-37	TIR-46 x JUG-37	TIR-46 x TIR-10
Pod yield per plant	TIR-46	TIR-46	TIR-46 x K-134	JUG-37 x ICR-45	TIR-46 x TUG-37	TIR-46xJUG-43	TIR-46 x K-134	ICR-45 x JUG-43
	JUG-37	JUG-37	TIR-46 x JUG-43	TIR-46 x JUG-43	TIR-46 x K-134	TIR-46xJUG-43	TIR-46 x JUG-37	ICR-45 x K-134
	K-134	K-134	TIR-46 x JUG-37	TIR-46 x K-134	TIR-46 x K-134	TIR-46xJUG-43	TIR-46xJUG-43	ICR-45 x K-134

For SCMR in most of the F_1 s positive heterosis was observed over better parent, mid parent and standard parent in *rabi* (Table 14). The negative heterosis over mid parent, better parent and standard parent coupled with negative inbreeding depression in most of the F_1 s during *kharif* indicated the presence of non-additive gene action in the expression of SCMR. The F_1 , JUG-37 x JL-24 exhibited the highest significant and positive heterosis over better parent (20.71%), mid parent (12.11%) and standard parent (6.73%) during *rabi*. During *kharif*, JUG-43 x JL-24 recorded maximum significant positive heterosis over mid parent (10.00%) coupled with positive inbreeding depression indicating the non-additive gene effects in governing the character. These results are in agreement with those reported by Vasanthi *et al.* (2004) and Seethala Devi (2004).

Specific leaf nitrogen registered non-significant negative heterobeltiosis, relative heterosis and standard heterosis in almost all the F_1 s during *rabi*. Similarly, during *kharif* also majority of the crosses exhibited significant negative heterosis coupled with positive inbreeding depression (Table 15).

The F_1 s, TIR-46 x JAL-6 registered the highest significant positive heterobeltiosis (22.31%) and relative heterosis (23.89%) and ICR-45 x JUG-43 recorded the highest standard heterosis (46.88) for SLN during *kharif*. Both these F_1 s, besides high heterosis also registered significant positive inbreeding

depression indicating the presence of non-additive gene action in the expression of this character.

For specific leaf area as many as twenty eight and twenty six F_1 s expressed significant positive heterosis over better parent and mid parent, respectively during *rabi*. In the same season twenty one F_1 s also exhibited significant positive heterosis over standard parent (Table 16). Twenty seven and twenty two F_1 s during *kharif* recorded positive heterobeltiosis and relative heterosis, respectively. In the same season twenty six F_1 s also exhibited positive heterosis over standard parent. Significant negative heterosis coupled with both positive and negative inbreeding depression was observed in two F_1 s, viz., TIR-46 x JAL-6 and TIR-46 x JL-24 during *kharif* indicating the importance of both additive and non-additive gene action in the expression of the character. Peanut genotypes with low SLA had more photosynthetic machinery and the potential for greater assimilation per unit leaf area and large genotypic differences in the rate of light saturated photosynthesis per unit area was reported by Wright and Bell (1992). Heterosis for SLA in groundnut was reported earlier by Pallas and Samish (1974), Bhagsari and Brown (1976) and Pallas (1982).

For per cent reduction of F_v/F_m eight F_1 s expressed significant heterosis over their respective better parents and eleven F_1 s exceeded over their corresponding mid parental values in desirable direction during *rabi*. The

F_1 , ICR-45 x JL-24 recorded the highest significant negative heterosis over better parent and mid parent during *rabi*. During *kharif* the F_1 , JUG-37 x K-134 expressed the highest significant negative heterobeltiosis and relative heterosis with very low inbreeding depression (1.02%). The F_1 , JAL-6 x JL-24 recorded the highest significant negative heterosis (-63.54%) over standard parent coupled with low inbreeding depression (-11.68%) during *kharif*. These crosses can yield transgressive segregants in succeeding generation due to presence of high proportion of fixable alleles in them.

Out of twenty eight F_1 s, seven and eight F_1 s exhibited significant positive heterobeltiosis and relative heterosis for root length, respectively during *rabi*. Significant positive standard heterosis was also observed in nine F_1 s. In general, magnitude of positive heterosis was higher than negative heterosis in *rabi*. The F_1 , TIR-46 x JL-24 recorded the highest significant positive heterosis over better parent, mid parent and standard parent during *rabi*. During *kharif* majority of the crosses recorded negative heterosis coupled with negative inbreeding depression for root length indicating the preponderance of non-additive gene action in the inheritance of this trait. The F_1 , ICR-45 x JUG-43 recorded the highest significant positive heterosis over mid parent (23.77%) with the lowest (-32.31%) inbreeding depression indicating the chances of getting desirable genotypes through selection from the further segregating generations of this cross. Increase in root weight under

moisture stress indicates greater density of root and / or greater depths of root penetration both of these are important morphological adaptations to moisture deficit and result in greater extraction of soil water. Hoogenboom *et al.*, (1987) and Montell and Goldin (1964) recorded deeper penetration of roots under moisture stress and concluded that depth of root penetration can provide a useful selection criterion for breeding drought tolerant varieties in groundnut.

Significant positive heterobeltiosis for harvest index was observed in eight F_1 s, relative heterosis in fourteen F_1 s, and standard heterosis in eighteen F_1 s during *rabi*. The F_1 , K-134 x JL-24 recorded the highest significant positive heterobeltiosis (38.24%), relative heterosis (51.00%) and standard heterosis (40.00%) during *rabi* (Table 19). However, during *kharif* most of the F_1 s exhibited significant negative heterosis over mid parent and better parent and non-significant negative heterosis over standard parent coupled with negative inbreeding depression, indicating the presence of non-additive gene action in the inheritance of this character. The findings corroborate with the results of Swe and Branch (1986), Suresh Kumar (1993) and Nisar Ahmed (1995).

Majority of F_1 s recorded significant positive heterosis over mid parent, better parent and standard parent for shell thickness in both seasons. Further,

Most all crosses exhibited significant positive inbreeding depression during *kharif*. In the present study six F₁s had significantly thin shell than their better parent, while seven F₁s had thin shell than mid parent during *rabi*. None of the F₁ recorded significant standard heterosis in desirable direction either in *rabi* or *kharif*. The F₁, TIR-46 x K-134 recorded significant negative heterosis over mid parent and better parent during *rabi*. In *kharif*, TIR-46 x JL-24 exhibited significant negative heterobeltiosis and relative heterosis with low inbreeding depression indicating the importance of additive gene action in expression of this character. Similar results were reported by Vasanthi and Raja Reddy (2002) and Seethala Devi (2004).

Out of twenty eight F₁s, five and eight F₁s exhibited significant positive heterosis over better parent and mid parent, respectively for oil per cent during *rabi*. None of the F₁ recorded significant standard heterosis in desirable direction either in *rabi* or *kharif*. The F₁s, TIR-46 x JL-24 and ICR-45 x JAL-6 recorded the highest significant positive heterobeltiosis and relative heterosis, respectively during *rabi*. However, during *kharif* only one F₁, TIR-10 x JUG-43 expressed significant positive heterosis over better parent and mid parent coupled with low inbreeding depression indicating the importance of additive gene action in the expression of this character. The results of Mahesh Kumar (1981), Makne and Bhale (1991) and Jayalakshmi *et al.* (2000) further confirm these findings.

Shelling per cent registered significant positive heterobeltiosis and relative heterosis in desirable direction only in three F_1 s during *rabi*. Among these, F_1 , K-134 x JAL-6 recorded significant positive heterosis both over mid parent and better parent. However, none of the cross exhibited significant heterosis in desirable direction during *kharif*. Heterosis for shelling per cent over mid parent was reported by Garet (1976), Nadaf *et al.* (1988) and Varman and Raveendran (1997).

Significant negative heterosis over mid parent and better parent coupled with significant negative inbreeding depression was observed for most of the F_1 s in both seasons indicating the importance of non-additive gene action in the expression of SMK per cent. The F_1 , JAL-6 x JUG-43 during *rabi* recorded maximum significant positive heterobeltiosis and relative heterosis. During *kharif* F_1 s, K-134 X JUG-43 and JUG-37 x JL-24 expressed maximum significant positive heterobeltiosis and relative heterosis, respectively. K-134 x JUG-43 also recorded low inbreeding depression. Suneetha *et al.* (2004) and Dasaradha Rami Reddy and Suneetha (2004) also reported non-additive gene action for SMK per cent in groundnut.

For number of well filled and mature pods per plant four crosses registered significant positive heterobeltiosis and relative heterosis during *rabi*. The F_1 , ICR-45 x JL-24 exhibited the highest significant positive heterosis over better parent (54.07%) and mid parent (68.05%) in *rabi*.

However during *kharif* only one F_1 , TIR-46 x JAL-6 recorded significant positive heterosis over better parent (43.68%) and mid parent (44.88%) coupled with moderate positive inbreeding depression indicating the importance of additive gene action in the expression of this character. These results are in agreement with those reported by Deshmukh *et al.* (1985), Nadaf *et al.* (1988), Senthil and Vindhiyavarman (1998) and Kavani *et al.* (2004).

Kernel yield per plant registered in three and twelve F_1 s out of twenty eight F_1 s, significant positive heterobeltiosis and relative heterosis, respectively during *rabi*. Among twenty eight F_1 s studied cross K-134 x JL-24 recorded the highest significant positive heterobeltiosis (73.10%) and relative heterosis (52.08%) during *rabi*. However, in *kharif* none of the F_1 exhibited significant heterobeltiosis or relative heterosis in desirable direction. (Table 25) Majority of the F_1 s recorded positive inbreeding depression. Arunachalam *et al.* (1982), Islaib (1982), Reddi *et al.* (1989), Bansal *et al.* (1993) and Jayalakshmi *et al.* (2000) also reported positive heterosis for kernel yield in groundnut.

Pod yield per plant registered significant positive heterosis over better parent and mid parent in five and seven F_1 s, respectively during *rabi*. Among twenty eight F_1 s studied, cross K-134 x JUG-43 recorded the highest significant positive heterobeltiosis (62.63%) and relative heterosis (66.45%) during *rabi* (Fig.9). During *kharif*, none of the F_1 s registered significant

Fig. 9 : Per cent heterosis over Better Parent, Mid Parent and Standard Parent in F₁ generation for pod yield per plant (*Rabi*, 2002)

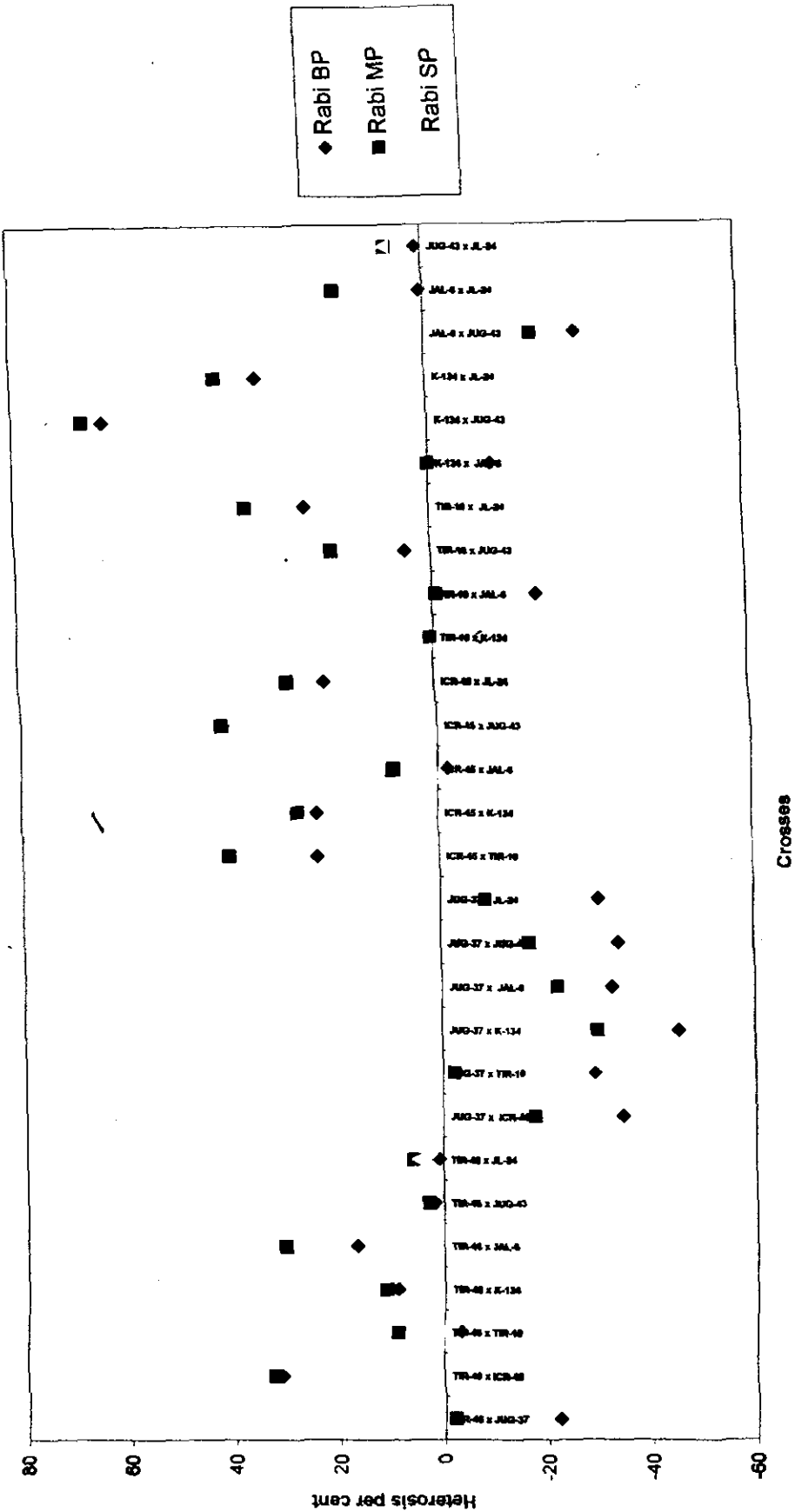
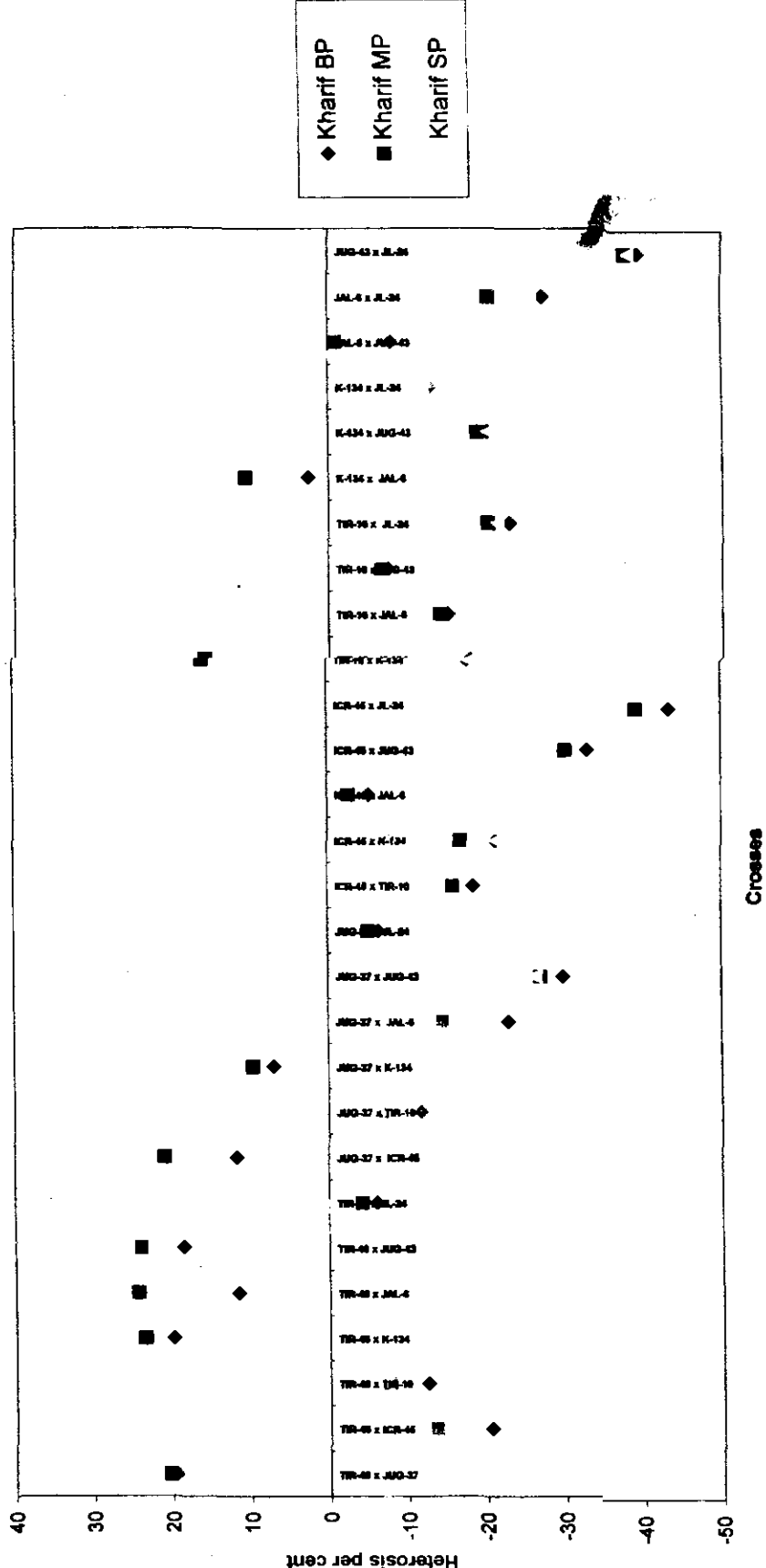


Fig. 10 : Per cent heterosis over Better Parent, Mid Parent and Standard Parent in F₁ generation for pod yield per plant (*Kharif*, 2003)



positive heterosis, but seven F_1 s recorded significant positive inbreeding depression (Table 26). Heterosis for pod yield in groundnut was also reported by Arunachalam *et al.* (1982), Deshmukh (1985), Reddi *et al.* (1989), Bansal *et al.* (1993), Varman and Raveendran (1997), Rudraswamy *et al.* (1999) and Parmar *et al.* (2004).

From the forgoing discussion it can be concluded that crosses K-134 x JUG -43 and K-134 x JL – 24 with high better parent heterosis and relative heterosis for pod yield per plant also expressed significant positive mid parent and better parent heterosis for yield contributing traits like number of mature pods per plant and harvest index etc., Thus the better parent heterosis and relative heterosis for pod yield can mainly be attributed to the manifestation of heterosis in component and associated characters. However, only few crosses recorded significant standard heterosis viz., cross, K-134 x JL-24 for harvest index, TIR-46 x JL-24 for root length and ICR-45 x JUG-43 for specific leaf nitrogen. For WUE traits, JUG – 37 x JL -24 for SCMR, TIR – 46 x JAL – 6 for SLN and TIR – 46 x JL – 24 for root length had recorded the highest positive heterosis. In all the above cross combinations that showed high heterosis involved one good general combiner and one poor combiner thereby indicating the roll of inter-allelic interactions. Therefore, for exploitation of such heterosis in future breeding programmes either recurrent selection or diallel selective mating system is to be examined in these crosses. Further, the

crosses which recorded high heterosis for pod yield also recorded high inbreeding depression in F_2 generation indicating importance of non-additive gene action. In case of crosses that showed heterosis for WUE, did not exhibit inbreeding depression in F_2 generation. Therefore, heterosis in these crosses might be due to complementary favourable genes largely with additive effects.

5.4 Variability, heritability and genetic advance

The success of groundnut breeding programme largely depends on the magnitude of genetic variability and to the extent of heritability of the desirable characters available for exploitation (Burton, 1952; which have a close relationship with response to selection (Panse, 1957). Although a number of researchers have reported variability for yield and its component traits in groundnut, it has not reflected in the improvement of yields (Bhagat *et al.*, 1986 and Kale and Dhoble, 1988). Despite the occurrence of perceptible variability in groundnut for different characters influencing a wide range of other attributes (Prasad, 1988), very little effort had gone into the studies regarding the pattern of genetic variability in segregating generations for important physiological attributes conferring drought resistance in groundnut. An attempt, therefore, has been made to study the genetic variability in F_2 progenies of 28 crosses.

The study of genotypic coefficient of variation revealed that except specific leaf nitrogen all the characters showed narrow genetic variability and thereby offering a limited opportunity to improve further these characters (Table 27). Similar results were obtained by Quadri and Khunti (1982), Mishra and Yadava (1992), Nisar Ahmed (1995), Naik *et al.* (2000) and Parameshwarappa *et al.* (2004).

Heritability estimates indicate the heritable portion of the variation and the estimation of genetic advance would show the extent of genetic gain that could be expected through selection in the character to be improved upon (Burton, 1952 and Johnson *et al.*, 1955). Heritability in broad sense include additive and epistatic gene effects, and therefore it will be reliable only if accompanied by high genetic advance Ramanujam and Thirumalachari, (1967).

In the present investigation, high heritability estimates were observed for per cent reduction of Fv/Fm, specific leaf area, specific leaf nitrogen, sound mature kernel per cent, harvest index and shell thickness. Reddy and Gupta (1992) and Seethala devi (2004) reported high heritability for harvest index. High heritability for shell thickness was reported earlier by Sharma and Varshney (1995). Moderate to high heritability for SPAD chlorophyll meter reading was observed by Seethala Devi (2004). Parmar *et al.* (2000) and Naik *et al.* (2000) reported low genotypic coefficient of variation and heritability

Table 40 : Comparative statement based on estimates of different genetic parameters for 13 characters in F₂ generation of groundnut (*Kharif- 2003*)

Characters with high GCV, moderate $h^2(b)$ and high GAM	Characters with low GCV, high $h^2(b)$ and high GAM	Characters with low GCV moderate $h^2(b)$ and moderate GAM	Characters with low GCV, low $h^2(b)$ and low GAM	Characters with low, GCV, moderate $h^2(b)$ and low GAM
Specific leaf nitrogen	Per cent reduction of Fv/Fm, Specific leaf area, Harvest index, Sound mature kernel per cent and Shell thickness	Kernel yield per plant	Root length, Number of well filled and mature pods per plant and Pod yield per plant	SPAD chlorophyll meter reading, Oil per cent and Shelling per cent

for sound mature kernel per cent. Seethala Devi (2004) reported high genotypic coefficient of variation and moderate heritability for sound mature kernel per cent

Low heritability values were obtained for pod yield per plant and number of well-filled and mature pod per plant. Wang *et al.* (1987) also noticed low heritability values for these characters. Low heritability for pod yield per plant was reported by Reddi *et al.* (1986a) and Swamy Rao *et al.* (1988).

The genetic gain that can be expected by selection for a character is given by the estimates of genetic advance. Among the characters, studied, specific leaf nitrogen, specific leaf area, per cent reduction of Fv/Fm, sound mature kernel per cent and harvest index showed high genetic advance as per cent of mean. Reddy and Gupta (1992) reported similar results. However SPAD chlorophyll meter reading, yield per plant, root length, oil per cent, number of well filled and mature pods per plant and shelling per cent exhibited low genetic advance as per cent of mean. Nagabhushanam *et al.* (1982), Vasanthi and Raja Reddy (2002) and Seethala Devi (2004) reported low genetic advance as per cent of mean for pod yield per plant. Manoharan *et al.* (1990b) indicated that genetic advance as per cent of mean values were low for number of well - filled and mature pods per plant. Rostini *et al.* (2000) studied variability and heritability of leaf chlorophyll content measured

through SPAD chlorophyll meter and reported wide variability but moderate heritability in a set of 40 peanut genotypes.

From the foregone discussion, it is evident that per cent reduction of Fv/Fm, specific leaf area, harvest index, sound mature kernel per cent and shell thickness had high heritability coupled with high genetic advance as per cent of mean are controlled by additive gene effects and are least influenced by environment (Table 40) Therefore selection for these characters would be very effective. Moderate heritability and genetic advance as per cent of mean was observed for kernel yield per plant indicating importance of both additive and non-additive gene action in the inheritance of this trait. Low heritability and low gain was observed for characters root length, number of well - filled and mature pods per plant and pod yield per plant, whereas moderate heritability coupled with low genetic advance as per cent of mean was observed for SPAD chlorophyll meter reading, oil per cent and shelling per cent indicating the preponderance of non-additive gene action in inheritance of these characters. Hence, selection for these characters is not effective in early segregating generations and has to be carried in later generations.

5.5 Character associations

Selection is generally based on number of characteristics rather than a single character. Hence, understanding of the inter-relationships of characters

Table 41 : Changes in character association from parents to F₁s (Rabi 2002)

Association between the character	Association in parents	Association in F ₁ s
SPAD chlorophyll meter reading with		
Specific leaf area	Negative significant	Positive non-significant
Per cent reduction of Fv/Fm	Negative non-significant	Positive significant
Sound mature kernel per cent	Negative non-significant	Positive significant
Kernel yield per plant	Positive non-significant	Negative significant
Specific leaf nitrogen with		
Harvest index	Positive significant	
kernel yield per plant	Negative non-significant	Positive significant
Per cent reduction of Fv/Fm with		
Harvest index	Positive significant	Negative significant
Kernel yield per plant	Positive non-significant	Negative significant
Pod yield per plant	Positive non-significant	Positive significant
Root length with		
Number of well filled and mature pods per plant	Positive significant	Negative non-significant
Shell thickness	Negative non-significant	Positive significant
Kernel yield per plant	Positive non-significant	Negative significant
Harvest index with		
Shell thickness	Positive significant	Negative non-significant
Shell thickness with		
Oil per cent	Positive significant	Negative non-significant
Pod yield per plant	Positive significant	Negative non-significant
kernel yield per plant	Positive significant	Negative non-significant

Table 42 : Changes in character association from parents to F₁ to F₂ generations (Kharif- 2003)

Association between the character	Association in parents	Association in F ₁ s	Association in F ₂ s
SPAD chlorophyll meter reading with			
Per cent reduction of Fv/Fm	Positive significant	Positive significant	Negative significant
Kernel yield per plant	Negative non -significant	Negative significant	Positive non -significant
Oil per cent	Negative significant	Negative non -significant	Positive non- significant
Pod yield per plant	Negative non-significant	Positive significant	Positive non - significant
Specific leaf nitrogen with			
Per cent reduction of Fv/Fm	Positive significant	Negative non-significant	Positive non- significant
number of well filled and mature pods per plant	Negative non-significant	Negative non-significant	Positive significant
Kernel yield per plant	Positive non -significant	Negative significant	Positive non- significant
Specific leaf area with			
Oil per cent	Positive significant	Positive non -significant	Negative significant
Shelling per cent	Positive significant	Negative non -significant	Negative non -significant
Sound mature kernel per cent	Positive non -significant	Negative significant	Positive non-significant
Kernel yield per plant	Negative non- significant	Negative significant	Positive non- significant
Per cent reduction of Fv/Fm with			
Root length	Negative non-significant	Negative significant	Positive significant
Kernel yield per plant	Positive non- significant	Negative non- significant	Negative significant
Number of well filled and mature pods per plant	Negative non- significant	Positive non-significant	Negative significant
Sound mature kernel per cent	Positive significant	Positive non- significant	Negative non- significant

Contd...

Association between the character	Association in parents	Association in F ₁ s	Association in F ₂ s
Root length with			
Harvest index	Positive non-significant	Positive non-significant	Negative significant
Oil per cent	Negative non-significant	Positive non-significant	Negative significant
Sound mature kernel per cent	Negative significant	Positive non-significant	Negative significant
Shell thickness	Negative significant	Positive non-significant	Positive significant
Kernel yield per plant	Negative non-significant	Positive significant	Negative significant
Pod yield per plant	Negative non-significant	Positive significant	Negative significant
Shelling per cent	Positive significant	Positive non-significant	Negative significant
Shell thickness with			
Oil per cent	Negative non-significant	Positive non-significant	Negative significant
Shelling per cent	Negative significant	Positive non-significant	Negative significant
Sound mature kernel per cent	Positive significant	Positive significant	Negative significant
Number of well filled and mature pods/ plant	Positive non-significant	Positive significant	Negative non-significant
Oil per cent with			
Number of well filled and mature pods per plant	Negative non-significant	Positive significant	Negative non-significant
Pod yield per plant	Positive non-significant	Positive significant	Negative non-significant
Harvest index with			
Shell thickness	Positive non-significant	Negative significant	Negative non-significant
Oil per cent	Negative non-significant	Positive non-significant	Positive significant
Shelling per cent	Negative non-significant	Positive significant	Positive significant
Sound mature kernel per cent	Negative non-significant	Positive non-significant	Negative significant

with yield and among themselves will be of great value in any crop improvement programme. Correlation studies are of special significance in groundnut breeding programmes because of its geocarpic nature of pod bearing. In order to make effective selection in breeding programmes the selection criteria have to be fixed on the association that exists between aerial vegetative parts and underground parts. Genotypic correlations were higher than phenotypic correlations for most of the characters in parents F_1 's and F_2 's. This indicate that the strong inherent association between the characters governed largely by genetic causes and reduced by environmental forces. However during *kharif* in parents zero correlations were observed for some characters due to sampling error.

The association studies has brought a large number of associations to surface in F_1 and F_2 generations. The change in correlation between the pairs of characters from parents to F_1 s to F_2 might have resulted due to modifications in the linkage as a result of new recombinations in the segregating populations. The nature and magnitude of associations changed depend on the environment i.e. season.

SPAD chlorophyll meter reading and specific leaf nitrogen exhibited significant negative association with pod yield in F_1 s, while its association changed into non-significant positive in F_2 s during *kharif* (Table 42) During *rabi* also the association of SPAD chlorophyll meter reading and specific leaf

nitrogen with pod yield was positive in parents and negative in F_1 s. Such changes in direction of association may be due to breakage of linkages and disruption of association due to recombination. Wright *et al.* (1994) have shown that in peanut, SCMR and SLN is an indicator of leaf chlorophyll content and hence CO_2 assimilation capacity. Increase in SCMR and SLN is associated with higher CO_2 assimilation and thereby increased pod yield even under water limited conditions.

Significant and non-significant negative association of SLA with pod yield was observed in parents and F_1 s respectively during *kharif*. Anuradha (1995) correlated the differences in photosynthetic rates with genotypic differences in SLA in many species. Peanut genotypes with low SLA had more photosynthetic machinery and the potential for greater assimilation per unit leaf area. The differences in photosynthetic rates were closely associated with leaf thickness in other legumes (Gupta *et al.*, 1989). Leaves with high SLW (inverse of SLA) were cooler under a given radiation load due to higher stomatal conductance resulting in more evaporative cooling. High stomatal conductance was also shown to be negatively correlated with SLA in cotton (Bhardwaj *et al.*, 1986). SLA was low in cooler climate (high temperature low), greater deposition of starch and other non-structural carbohydrates in the chloroplasts (Araus *et al.*, 1989). Based on many experiments, over a wide range of environments and cultivars it was concluded that SLA was closely

and negatively correlated with WUE and positively correlated with carbon isotope discrimination. This highlights the possibility of using SLA as a more rapid and inexpensive technique for selection of WUE (Wright *et al.*, 1988; Wright *et al.*, 1993 and Nageswara Rao and Wright, 1994.)

The association between per unit reduction of F_v/F_m and pod yield per plant was significant and negative in F_1 and F_2 generations during *rabi* and *khariif* respectively (Tables 29 and 32). Chauhan and Senboku (1997) while studying heat tolerance in groundnut by chlorophyll fluorescence technique, observed a strong positive correlation between chlorophyll concentration and chlorophyll fluorescence and F_v/F_m ratio decreased with increasing temperature stress hence lesser the per cent of reduction of F_v/F_m more will the ability of plant to tolerate to high temperature stress and thereby increased pod yield.

Root length had significant positive association with pod yield in F_1 and significant negative association in F_2 during *khariif*. Makhanlal *et al.* (2003) mentioned that yield which has so far been improved through the use of selection of yield contributing characters should now include root length as one of the selection criteria for improving yield. Selection for root length will result in improvement in yield through the increase in the number of nodules/plant, which is associated with nitrogen fixation. Significant linear

correlations between rooting traits and groundnut pod yield were reported by Gupta *et al.* (1994).

Pod yield had positive association with shell thickness in F_1 s and F_2 s during *rabi*. Ignacio *et al.* (1981) pointed out that shell characteristics of peanuts as well as relationship between them are important in handling and processing resistance to pest and general appearance. In peanut breeding, shell characteristics can make the genetic expression of characteristics of the seed, particularly when plants are segregating both for seed size and for duration of the seed filling period.

Hammons (1973) reported that thick shell and large pods had positive relation. He also observed linkage between size of the pod and thickness of pericarp. Further correlation between pod size and shell thickness appear to be positive.

Therefore, he concluded that only limited success in selecting for larger pods with higher shelling per cent could be expected. Shelling per cent had significant positive association with pod yield per plant in F_1 s during *kharif*. However the association between pod yield and SMK per cent was significant and positive in F_1 s while the association was negative and non-significant in F_2 s during *kharif*. The change in magnitude and direction of association may be due to breakage of linkages and disruption of association due to recombination. Rostini *et al.* (2000) and Seethala Devi (2004) reported

positive correlation between SCMR and pod yield in groundnut. Nagabhushanam *et al.* (1982), Arunchalam *et al.* (1984), Bhagat *et al.* (1986), Durgamani *et al.* (1987) and Pushkaran and Nair (1993) also reported significant positive association between pod yield and shelling per cent.

Pod yield per plant had significant positive association with harvest index, number of well filled and mature pods per plant and kernel yield per plant both in parents and F_1 s during *rabi*. Similar results were observed in F_1 s and F_2 s during *kharif*. These characters can be considered as criteria for selection for higher yield, as these were mutually and directly associated with pod yield. Similar results were obtained by Aruna (1986), Durgarani *et al.* (1987), Prasanthi *et al.* (1990) and Nisar Ahmed (1995).

The relationship between oil per cent and pod yield was either significant or non-significant but always positive in parents and crosses (F_1 s) in both seasons. Naazar Ali *et al.* (2000) and Sah *et al.* (2000) reported that oil per cent was positively correlated with pod yield.

SPAD chlorophyll meter reading was found to be positively associated with SLN in parents and crosses, while negatively with SLA only in parents. Nageswara Rao *et al.* (2001) reported positive relation between SCMR and SLN and negative relation between SCMR and SLA in groundnut. Samdur *et al.* (2000) demonstrated a strong positive association between SCMR and chlorophyll content in groundnut and concluded that SCMR could be used for

rapid and *in situ* screening genotypes for drought tolerance. SCMR also exhibited a strong negative relationship with per cent reduction of Fv/Fm in parents (*kharif*) and harvest index in F₁s (*rabi*).

Specific leaf nitrogen had significant positive association with shell thickness in F₁s and F₂s in both seasons, with per cent reduction of Fv/Fm in parents (*kharif*) and F₁s (*rabi*) and harvest index in parents (*rabi*). Harvest index exhibited significant positive association with number of well filled and mature pods per plant and kernel yield in F₁s during *rabi* and *kharif* seasons, respectively. Mishra (1995), Prasanthi *et al.* (1990), Jayalakshmi *et al.* (2000) also reported positive association between harvest index and number of mature pods per plant in groundnut. Similarly positive association of harvest index with kernel yield were reported by Abraham (1990), Reddy and Gupta (1992) and Nisar Ahmed (1995). Further, the association between harvest index and shell thickness was positive in parents (*rabi*) and negative in F₁s (*kharif*).

Arjunan *et al.* (1997) suggested that the leaf area and harvest index were positively correlated with pod yield in groundnut, hence these can be used as selection indices for development of drought resistant or tolerant groundnut varieties.

Per cent reduction of Fv/Fm exhibited significant negative association with root length in F₁s and with number of well filled and mature pods per plant, kernel yield per plant and harvest index in F₂s during *kharif*.

The association between shell thickness and SMK per cent was significant and positive in F_1 s (Table 36) while significant negative in F_2 s during *kharif*. Shell thickness also exhibited significant positive association with oil per cent and kernel yield per plant in parents during *kharif* however, its association with SLA is negative and significant in F_1 s in the same season.

Number of well filled and mature pods per plant had significant positive association with kernel yield in F_1 s and F_2 s in both the seasons. Similar results were reported by Venkataramana (2001) and Makhan Lal *et al.* (2003).

The association between shelling per cent and SMK per cent is positive and significant in F_1 and F_2 generations during *rabi* and *kharif*, respectively. This is in concurrence with the findings of Vasanthi *et al.* (1998).

The association between oil per cent and kernel yield is significant positive in parents (*rabi*). It also exhibited significant positive association with shelling per cent in F_2 s (*kharif*) and significant negative association with root length in F_1 s (*rabi*) and F_2 s (*kharif*). Layrisse *et al.* (1980) and Sanjeeva Kumar and Aravind Kumar (2000) reported the significant positive association of oil per cent with kernel yield per plant in groundnut.

From the foregoing discussion, it is evident that pod yield per plant was closely associated with number of well filled and mature pods per plant, kernel yield per plant, harvest index and root length. The significant association of physiological and yield attributes among themselves like significant positive

association of SPAD chlorophyll meter reading with specific leaf nitrogen and harvest index and its significant negative association with specific leaf area and per cent reduction of F_v/F_m ; significant positive association of specific leaf nitrogen with harvest index and sound mature kernel per cent; significant positive association of root length with number of well filled and mature pods per plant, kernel yield per plant and shelling per cent indicate that selection for these traits might be rewarding in improvement of tolerance to drought besides pod yield in groundnut.

5.6 Path Coefficients

Pod yield is a complex dependent character and is contributed by several components. Correlation studies simply measures the association of yield and yield attributes and does not give the actual dependence of yield on the correlated characters. Path coefficient analysis is an effective method to determine the direct and indirect causes of associations and also permits to examine the specific forces acting to produce to a given correlation. Majority of the reports of path analysis are based on variability existing between homozygous cultivars. It is necessary to emphasize that inferences derived from these will be meaningful only when this study is based on individual plant observations in a segregating generation.

Hence, an attempt was made to study the direct and indirect effects of characters on pod yield through path coefficient analysis in parents, F_1 and F_2 generations of twenty eight cross combinations in groundnut (Tables 33 to 37).

The results of path analysis revealed that kernel yield per plant had maximum positive direct effect on pod yield per plant in parents, F_1 s and F_2 s in both the seasons indicating kernel yield is the important yield contributing character. Reddi *et al.* (1986b), Prasanthi *et al.* (1990) and Mathews *et al.* (2000) reported maximum positive direct effect of kernel yield on pod yield in groundnut. A perusal of path coefficients in F_1 and F_2 generations in both the seasons revealed the moderate direct positive effect of number of well filled and mature pods per plant on pod yield in groundnut. The high direct effect of pods per plant was appeared to be the main factor for its strong positive correlation with pod yield. Hence, a direct selection for this trait would be effective. These findings are in agreement with the results of Deshmukh *et al.* (1986), Duragarani *et al.* (1987), Ofori (1996) and Venkataravana *et al.* (2000).

Per cent reduction of F_v/F_m had moderate positive direct effect on pod yield in parents in both seasons, while oil per cent exhibited reasonably moderate positive direct effect on pod yield in parents during *kharif* only.

Besides their positive and high direct effects, the character number of well filled and mature pods per plant both in parents and crosses in *rabi* and

kharif, harvest index in F_1 s in both seasons, shelling per cent in parents and F_2 s during *kharif*, shell thickness in parents during *rabi*, and oil per cent in parents (*rabi*) and F_1 s (*kharif*) exerted their high positive indirect effects through kernel yield per plant.

In F_1 s and F_2 s, the lesser direct effect of number of well filled and mature pods per plant and kernel yield per plant to that of their correlation coefficients in crosses (both seasons) were chiefly due to their indirect contribution via kernel yield per plant and number of well filled and mature pods per plant, respectively.

Harvest index, inspite of its negative direct effect in F_1 s in both seasons exhibited significant positive correlation with pod yield per plant due to high positive indirect effects through kernel yield per plant (Tables 34 and 36).

From the above discussion on path coefficient analysis it can be concluded that, kernel yield per plant and number of well filled and mature pods per plant had maximum positive direct effect on pod yield per plant in parents, F_1 s and F_2 s in both the seasons indicating that these traits are the important yield contributing character.

From the present investigation the following conclusions could be drawn.

1. In general, good general combiners had high *per se* performance.

2. Based on *per se* performance and general combining ability the following parents were identified as good general combiners for various traits.

RABI :

- * For SPAD chlorophyll meter reading, specific leaf area and specific leaf nitrogen : JUG – 37 and JUG – 43
- * For per cent reduction of F_v / F_m and shell thickness : JUG – 43 and K -134
- * For root length : JUG – 43 and JAL – 6
- * For harvest index and sound mature kernel per cent : TIR – 46 and ICR – 45
- * For oil per cent : JUG -37 and K – 134
- * For shelling per cent : TIR – 46
- * For kernel yield per plant and pod yield per plant : JUG – 37

☐ **KHARIF :**

- * For SPAD chlorophyll meter reading, specific leaf area and specific leaf nitrogen : JUG – 37 and JUG – 43
- * For per cent reduction of F_v / F_m : JAL – 6 and JL - 24
- * For shell thickness : JL – 24 and TIR -10
- * For root length : JL –24
- * For harvest index : TIR – 46 and TIR - 10

For sound mature kernel percent	:	TIR – 46 and JUG – 37
For oil per cent	:	K – 134
For number of mature pod per plant, kernel yield per plant and pod yield per plant	:	TIR - 46

JUG – 43 was found to be a good general combiner for most of the JE traits i.e., SCMR, specific leaf nitrogen, specific leaf area, heat tolerance, root length and shell thickness. The next best genotype was JUG – 37 with good general combining ability for most of the WUE traits as well as pod yield per plant, kernel yield per plant and oil content in both the seasons. Thus, while breeding for high yielding genotypes with high WUE, these should be included as donor parents. For harvest index, shelling out turn and sound mature kernel per cent TIR – 46 is the best general combiner in both the seasons. For heat tolerance, root length and shell thickness, JL – 24 was found to be a good general combiner during *kharif* season only.

Based on *per se* performance, *sca* effects and heterosis the following crosses were identified as best crosses for various traits

RABI :

- * For SPAD chlorophyll meter reading : JUG – 37 x JL – 24 and ICR -45 x JAL - 6
- * For per cent reduction of Fv / Fm : ICR -45 x JL –24 and JAL – 6 x JL - 24

- * For shell thickness : TIR – 46 x JUG -37 and
TIR -46 x K-134
- * For root length : TIR -46 x JL –24 and
JUG -37 x ICR -45
- * For harvest index : K-134 x JL -24 and
ICR -45 x TIR - 10
- * For sound mature kernel
per cent : JAL -6 x JUG -43
- * For oil per cent : JAL -6 x JL -24
- * For shelling per cent : K-134 x JAL – 6 and
JUG -37 x JAL-6
- * For number of mature pods
per plant : ICR -45 x JL -24 and
ICR -45 x TIR - 10
- * For kernel yield per plant and
pod yield per plant : K- 134 x JUG- 43 and
K -134 x JL – 24

KHARIF :

- * For specific leaf nitrogen : TIR – 46 x JAL – 6 and
JUG – 37 x JUG -43
- * For per cent reduction of Fv/Fm : JUG -37 x K-134 and
TIR – 46 x K -134
- * For shell thickness : TIR – 46 x JL – 24 and
TIR – 46 x JUG – 37
- * For number of mature pods
per plant : TIR -46 x JAL -6

In all the above crosses one of the parents is a good general combiner with high *per se* performance and other parent is poor combiner. Further all

these crosses exhibited moderate to high heterosis in desirable directions with low or negative inbreeding depression (except for shell thickness). Therefore, heterosis in these crosses may probably may be due to complimentary favourable genes largely with additive effects (additive x additive gene action). Through population improvement by intermating the improved genotypes in successive generations. These procedures allow a lot of recombinations at different steps. Thus there is a chance of breaking undesirable linkages which helps in bringing together favourable combination of genes into a single genotype.

High heritability along with high GAM observed for specific leaf area , specific leaf nitrogen, per cent reduction of Fv/Fm, harvest index, sound mature kernel per cent and shell thickness indicating that these characters are largely governed by additive gene action. Thus improvement in these traits could be made through early generation selections. The characters SCMR, oil percent, shelling per cent exhibited moderate heritability and low GAM. These traits may be influenced by non additive gene action. Hence, selection for these traits has to be postponed to later generations.

Correlations and path coefficient analysis in different generations and environments revealed the following associations between pod yield, yield attributes and WUE traits.

- Harvest index, number of mature pods per plant and kernel yield per plant (F_1 s and F_2 s) had significant positive association with pod yield and high positive direct effect. Hence these could be used for direct selection for high pod yield.
- Significant positive association of SCMR with specific leaf nitrogen and root length (F_1 s) and significant negative association between SCMR and specific leaf nitrogen (F_2 s) indicated that easily measurable trait SCMR could be effectively used as an alternative to specific leaf area in breeding programmes. Significant positive association was observed between specific leaf nitrogen and shell thickness (F_1 s). Though specific leaf area exhibited significant positive association with harvest index (Parents and F_1 s) the non significant negative association of specific leaf area with harvest index (F_1 s) suggested that simultaneous improvement in both low specific leaf area and high harvest index and ultimately high pod yield may be possible, which would help in the development of genotypes with high yield potential as well as high drought tolerance. However, many associations change depending on the nature of genetic material and environment. Therefore, emphasis while selection should be based on the nature and type of association in each generation.

Chapter - VI

Summary

CHAPTER - VI

SUMMARY

Drought is the major abiotic stress limiting groundnut productivity in rainfed areas. Due to lack of efficient holistic screening techniques to screen for drought tolerance, little efforts were made to study the genetics of drought tolerance in groundnut. With recent identification of easily measurable traits that confer water-use efficiency, the research on breeding of drought resistant groundnut gained momentum. In the present investigation efforts were made to understand the nature of inheritance of traits that confer water use efficiency which are highly desirable varietal characteristics for water limited areas.

The present investigation entitled "Genetic analysis of physiological, yield and yield attributes in F_1 and F_2 generation crosses of groundnut (*Arachis hypogaea* L.) " was aimed to understand nature of gene action, extent of heterosis, genetic variability and association among physiological and yield components including yield. For this purpose eight parental lines viz., TIR-46, JUG-37, ICR-45, TIR-10, K-134, JAL-6, JUG-43 and JL-24 were crossed in diallel fashion (without reciprocals) to produce 28 crosses at Regional Agricultural Research Station, Tirupati. Parents and F_1 s were raised in *rabi* 2002 whereas, parents, F_1 s and corresponding F_2 s, were together in *kharif* 2003. The data were collected for thirteen characters including

physiological and yield traits. Data were subjected for analysis of combining ability, heterosis, variability, character association and path coefficient.

Analysis of variance in parents and F_1 s (in both seasons) and parents and F_2 s in *kharif* revealed significant differences among the genotypes for all the characters studied.

A perusal of mean performance of parents revealed that JUG-37 had better performance for pod yield, kernel yield and oil per cent; JUG-43 for SPAD chlorophyll meter reading, per cent reduction of Fv/Fm, root length and shell thickness and TIR-46 for specific leaf nitrogen, harvest index and shelling per cent in *rabi* and while in *kharif*, TIR-46 had better performance for pod yield per plant and number of well filled and mature pods per plant; K-134 for specific leaf nitrogen, oil per cent, harvest index and kernel yield per plant and JAL-6 for shelling per cent, sound mature kernel per cent and root length.

Among the 28 F_1 s studied, the first ranking three F_1 s, which recorded superiority for pod yield per plant as well as for other important physiological and yield attribute during *rabi* were K-134 x JUG-43, JUG-43 x JL-24 and TIR-46 x K-134. However, during *kharif* TIR-46 x JAL-6 was distinct for its highest mean values for number of well filled and mature pods per plant, kernel yield per plant and shelling per cent. During the same season, the F_1 s,

TIR-46 x ICR-45 for specific leaf area and harvest index and TIR-46 x K-134 for pod yield per plant recorded the highest mean performance.

— Among the F_2 s, JUG-37 x JAL-6 was distinct for its highest mean values for specific leaf nitrogen and harvest index during *kharif*. The F_2 s, involving TIR-46 as one of parents showing highest *per se* performance are, TIR-46 x K-134 for shell thickness and shelling per cent, TIR-46 x JAL-6 for SPAD chlorophyll meter reading and per cent reduction of F_v/F_m , TIR-46 x TIR-10 for kernel yield per plant and TIR-46 x JUG-37 for sound mature kernel per cent. The F_2 s, viz., JUG-37 x ICR-45 for both number of well filled and mature pods per plant and pod yield per plant and JUG-37 x K-134 for oil per cent showed the highest *per se* performance during *kharif*.

The analysis of variance for combining ability revealed that both *gca* and *sca* variance were significant for all the characters studied in both the seasons, indicating the importance of both additive and non-additive genetic variances for these characters. A comparison of direction and magnitude of general combining ability effects among parental lines during *rabi* revealed the excellent general combining ability effects of the parent JUG-37 not only for pod yield per plant but also for kernel yield per plant, specific leaf nitrogen (in *kharif* also) and oil per cent. During *rabi*, another parent, JUG-43 was also found as the best general combiner for SPAD chlorophyll meter reading (in

kharif also), specific leaf area, per cent reduction of Fv/Fm, root length and shell thickness, while TIR-46 was the best general combiner for harvest index, shelling per cent and sound mature kernel per cent in the both seasons and for number of well filled and mature pods per plant and pod yield per plant during *kharif* only. JL-24 was the best general combiner for per cent reduction of Fv/Fm, root length and shell thickness during *kharif*.

Specific combining ability effects indicated that *sca* effects of any cross combination need not always depend on the level of *gca* effects of its parent. Out of the 28 F₁s studied in the present study, K-134 x JUG-43 showed the highest positive significant specific combining ability effects for kernel yield per plant, number of well filled and mature pods per plant, per cent reduction of Fv/Fm and pod yield per plant in *rabi*, while the F₁, K-134 x JL-24 recorded the highest positive significant specific combining ability effects for specific leaf nitrogen and harvest index. However, during *kharif* the F₁, JUG-37 x ICR-45 exhibited the highest positive significant specific combining ability effects for pod yield per plant and kernel yield per plant. The F₁, JUG-37 x JL-24 showed the highest significant positive specific combining ability effects for shell thickness and sound mature kernel per cent in the same season. The F₁, JUG-43 x JL-24 showed the highest significant negative specific combining ability effects for specific leaf area in both seasons and for SPAD chlorophyll meter reading in *kharif* only.

Analysis of gene action suggested, additive gene action for oil per cent and pod yield per plant, both additive and non-additive gene action for per cent reduction of Fv/Fm, shell thickness and SPAD chlorophyll meter reading and non-additive gene action for characters viz., specific leaf nitrogen, specific leaf area, harvest index, shelling per cent, number of well filled and mature pods per plant, root length, sound mature kernel per cent and kernel yield per plant was observed. Based on the study, it is suggested that intermating of the F₂ segregants followed by recurrent selection and pedigree breeding can harness the different kinds of gene effects for genetic improvement of different characters.

The magnitude of per cent heterosis expressed by the F₁s for thirteen characters varied among them. The magnitude of heterosis was very high in desirable direction for characters specific leaf area, specific leaf nitrogen, per cent reduction of Fv/Fm, number of well filled and mature pods per plant in cross TIR-46 x JAL-6 during *kharif*. The same F₁ also recorded high positive inbreeding depression for above three characters except specific leaf area where it is low but positive. During *rabi*, F₁s, K-134 x JUG-43 and K-134 x JL-24 exhibited the highest positive significant heterosis over mid parent and better parent for harvest index, number of well filled and mature pods per plant, kernel yield per plant and pod yield per plant.

Regarding genetic variability, except specific leaf nitrogen all other characters studied registered low GCV. High heritability coupled with high genetic advance as percentage of mean was observed for specific leaf area, per cent reduction of F_v/F_m , harvest index, sound mature kernel per cent and shell thickness indicating the involvement of additive genes in their expression and possibility of improving these characters through selection.

Genotypic and phenotypic correlation coefficients computed in parents, F_1 s and F_2 s indicated that harvest index, number of well filled and mature pods per plant and kernel yield per plant were positively and strongly associated with pod yield per plant. Hence, the simultaneous selection for these traits might bring about an improvement in pod yield per plant in groundnut. Significant positive association between kernel yield per plant and number of well filled and mature pods per plant; kernel yield per plant and harvest index; shell thickness and specific leaf nitrogen in crosses during both season and significant negative association between SPAD chlorophyll meter reading and specific leaf area in among F_1 s and F_2 populations during *kharif*, except among F_1 s during *rabi* was observed

Path analysis of physiological and yield contributing traits indicated that kernel yield per plant in parents, F_1 s and F_2 s in both seasons, per cent reduction of F_v/F_m in parents (*rabi* and *kharif*); oil per cent in parents (*kharif*), shelling per cent, sound mature kernel per cent per cent in parents

(*kharif*) and number of well filled and mature pods per plant in F_1 s and F_2 s (*kharif and rabi*) , largely contributed to pod yield both directly and indirectly through other characters. Selection with greater emphasis on these characters would be effective in isolation of better genotypes for drought and yield in groundnut.

The present study reveals that no single variety possess all favourable genes based on gca effects of parents. Studies on sca effects indicated that no cross combination was good for all the characters studied. The study also brought out the possibility of different characters being positively associated with pod yield per plant which could be relied upon for selection, but these association changed with environment and also with the generation (nature of material). Emphasis in breeding may have to be shifted accordingly.

The path coefficient analysis further identified characters having large positive and direct contributions. This information could be possibly used in formulating a sound selection scheme in breeding for improvement. It appears that there is a strong case for heterosis breeding in groundnut as in the case of other self fertilized crops like rice. The environment i.e. the season in which the crop is raised has profound effect on estimates of general and specific combining ability and heterosis. These have to be kept in mind in future breeding programmes to formulate a successful breeding strategy for attaining higher yields in groundnut in drought prone areas. The best combinations

involving at least one good general combiner or both are likely to throw transgressive segregants in the advanced generations which are of specific significance in practical plant breeding for improvement of yield and yield attributes.

The study also brought out the importance of both additive and non-additive gene actions through combining ability which was hitherto overlooked. Since both additive and non-additive components were involved reciprocal recurrent selection is to be followed to exploit both the components. However, groundnut being a highly self pollinated crop, this selection procedure is not practicable. Therefore the possible choice is the interspecific hybridization between the spanish and virginia types followed by intermating among F_2 progenies to exploit both the additive and non-additive genetic components. Further, low heritability estimates for pod yield obtained in the present study highlights the futility of attempting genetic manipulation by pedigree selection as the improvement would be marginal.



Plate 1 : Plate showing best cross for pod yield, kernel yield and number of mature pods in *rabi* 2002.



Plate 2 : Plate showing best cross for pod yield per plant in *kharif* 2003.



Plate 3 : Plate showing best cross for SCMR (*kharif*) and specific leaf area (*rabi*)



Plate 4 : Plate showing best cross for per cent reduction of F_v / F_m in both *kharif* and *rabi*



Plate 5 : Plate showing best cross for kernel yield and number of mature pods in *kharif*



Plate 6 : Plate showing best cross for specific leaf nitrogen and harvest index in *rabi*

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