

**Studies on genetic parameters for the traits related to  
WUE and yield in early generation recombinant inbred  
lines of NRCG12568 × NRCG 12326 in  
Groundnut (*Arachis hypogaea* L.)**

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**DEPARTMENT OF GENETICS AND PLANT BREEDING  
UNIVERSITY OF AGRICULTURAL SCIENCES  
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*Affectionately Dedicated to*



*Placed on the Golden feet  
of my Beloved Parents,  
My Guru  
Dr. D. L. Savithramma  
and  
Dedicated to starving  
millions in the land of  
surplus*

**DEPARTMENT OF GENETICS AND PLANT BREEDING  
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**C E R T I F I C A T E**

This is to certify that the thesis entitled “**Studies on genetic parameters for the traits related to WUE and yield in early generation recombinant inbred lines of NRCG 12568 × NRCG 12326 in Groundnut (*Arachis hypogaea* L.)**” submitted by **Mr. MALLIKARJUN, K., PALB 1060** in partial fulfilment of the requirement for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE) in GENETICS AND PLANT BREEDING** to the University of Agricultural Sciences, Bengaluru is a record of research work done by him during the period of his study in this University, under my guidance and supervision and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

Place: Bengaluru  
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**“Studies on genetic parameters for the traits related to WUE and yield in early generation recombinant inbred lines of NRCG12568 × NRCG 12326 in Groundnut (*Arachis hypogaea* L.)”**

**MALLIKARJUN, K.**

**ABSTRACT**

Present investigation was undertaken to study the genetic parameters in Recombinant Inbred Lines and other two crosses of F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation during *kharif* 2012, *summer* 2013, *kharif* 2013 and *summer* 2014 respectively for growth, traits related to WUE, yield and yield contributing characters. Higher GCV and PCV coupled with narrow difference between PCV and GCV were found for pod yield per plant, kernel yield per plant, pods per plant, Specific Leaf Area, SCMR, plant height and days to first flowering in all the three crosses indicating individual plant selection can be followed for improvement of these characters. High heritability coupled with high genetic advancement as a *per cent* of mean was observed for pod yield per plant, kernel yield per plant, pods per plant, SCMR and SLA indicating the involvement of additive gene action for expression of these traits in crosses studied. Pods per plant, kernels per plant, kernel yield per plant, SCMR exhibited high positive effect on development of pod yield per plant in all the generations studied suggesting pod yield per plant could be increased upon improving of these pod yield contributing characters. Presence of significant positive correlation between F<sub>5</sub> to F<sub>6</sub> generation for pods per plant, pod yield per plant, kernel yield per plant, kernels per plant, SCMR and SLA implies that these traits can be used as selection criteria from F<sub>5</sub> generation onwards. High broad sense coupled with high narrow sense heritability was observed for pods per plant, pod yield per plant, kernel yield per plant, SCMR and SLA in F<sub>6</sub> generation suggesting the alleles which are involved in expression of these traits are fixed. The segregants which were selected having higher SCMR, lower SLA and higher pod yield per plant.

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"ಕಡಲೆಕಾಯಿ ಇಳುವರಿ ಮತ್ತು ನೀರಿನ ಸದ್ಭವಗಳಿಗೆ ಸಂಬಂಧಿಸಿದ ಗುಣಗಳ ಅನುವಂಶಿಕ ನಿಯತಾರಿಕಗಳನ್ನು ಆರಂಭಿಕ ಪೀಳಿಗೆಯ ರಿಲ್ಸನ ಎನ್ ಆರ್ ಸಿ ಜಿ ೧೨೩೨೬ ರಲ್ಲಿ ಶೇಂಗಾದಲ್ಲಿ ಅಧ್ಯಯನ"

ಮಲ್ಲಕಾರ್ಜುನ್, ಕೆ.

ಸಾರಾಂಶ

ಪ್ರಸ್ತುತ ತನಿಖೆಯನ್ನು ೨೦೧೨ ರ ಮಳೆಗಾಲದಲ್ಲೂ, ೨೦೧೩ ರ ಬೇಸಿಗೆ ಕಾಲದಲ್ಲೂ ೨೦೧೩ ರ ಮಳೆಗಾಲದಲ್ಲೂ ಹಾಗೂ ೨೦೧೪ ರ ಬೇಸಿಗೆ ಕಾಲದಲ್ಲೂ ಕ್ರಮವಾಗಿ ಮೂರನೇ, ನಾಲ್ಕನೇ, ಐದನೇ ಮತ್ತು ಆರನೇ ಪೀಳಿಗೆಯ ರಿಲ್ಸ ಹಾಗೂ ಆಯ್ದು ಇತರ ಸಂಸ್ಕರಣಗಳಲ್ಲಿ ಇಳುವರಿ ಹಾಗೂ ನೀರಿನ ಸದಬಳಕೆಗೆ ಸಂಬಂಧಿಸಿದ ಗುಣಗಳ ಮೇಲೆ ಅಧ್ಯಯನವನ್ನು ನಡೆಸಲಾಯಿತು. ವರದಿಯಲ್ಲಿ ಮೂಡಿ ಬಂದ ಫಲಿತಾಂಶದ ಪ್ರಕಾರ ರಿಲ್ಸ ಹಾಗೂ ಆಯ್ದು ಇತರ ಸಂಸ್ಕರಣಗಳ ಎಲ್ಲಾ ತಲೆಮಾರುಗಳ ಎಲ್ಲಾ ಗುಣಗಳಲ್ಲಿ ಅಗಾಧವಾದ ಅನುವಂಶೀಯ ವಿಭಿನ್ನತೆಯನ್ನು ಹೊಂದಿರುವುದಾಗಿ ಸೂಚಿಸುತ್ತದೆ. ಅಧಿಕ ಪ್ರಮಾಣದ ವಂಶವಾಹಿ ರೂಪ ಗುಣಾಂಕಗಳು ಹಾಗೂ ದೃಶ್ಯವಾಹಿ ರೂಪ ಗುಣಾಂಕಗಳ ವಿಭಿನ್ನತೆಯನ್ನು ಎಲ್ಲಾ ಗುಣಗಳು ಹೊಂದಿರುವುದಾಗಿ ಈ ವರದಿಯು ಸೂಚಿಸುತ್ತದೆ. ಹೆಚ್ಚಿನ ಪ್ರಮಾಣದ ಅನುವಂಶೀಯತೆಯು ಜೊತೆಗೆ ಅಧಿಕ ಜನನ ಉತ್ಪತ್ತಿಯನ್ನು ಪ್ರತಿ ಸಸ್ಯದ ಕಾಯಿ ಇಳುವರಿ, ಪ್ರತಿ ಸಸ್ಯದ ಬೀಜ ಇಳುವರಿ ಹಾಗೂ ಪ್ರತಿ ಸಸ್ಯದ ಕಾಯಿಗಳು ಎಸ್ ಎಲ್ ಎ ಮತ್ತು ಎಸ್ ಸಿ ಎಮ್ ಆರ್ ಗುಣಗಳು ಹೊಂದಿರುವುದಾಗಿ ವರದಿಯು ಧೃಡೀಕರಿಸಿದೆ. ನೀರಿನ ಸದ್ಭವಗಳಿಗೆ ಸಂಬಂಧಿಸಿದ ಪ್ರಮುಖ ಗುಣಗಳಲ್ಲಿ ಹೊಂದಾದ ಎಸ್ ಸಿ ಎಮ್ ಆರ್ ಗುಣವು ಇತರ ಗುಣಗಳಾದ ಪ್ರತಿ ಸಸ್ಯದ ಕಾಯಿ ಇಳುವರಿ, ಪ್ರತಿ ಸಸ್ಯದ ಬೀಜ ಇಳುವರಿ, ಪ್ರತಿ ಸಸ್ಯದ ಕಾಯಿಗಳೊಂದಿಗೆ ಗುಣಾತ್ಮಕ ಸಂಬಂಧ ಹೊಂದಿರುವುದಾಗಿ ಈ ಅಧ್ಯಯನ ತಿಳಿಸುತ್ತದೆ. ರಿಲ್ಸ ಹಾಗೂ ಆಯ್ದು ಸಂಸ್ಕರಣಗಳ ಎಲ್ಲಾ ತಲೆಮಾರುಗಳಲ್ಲಿ ಪ್ರತಿ ಸಸ್ಯದ ಕಾಯಿಗಳು ಹಾಗೂ ಎಸ್ ಎಮ್ ಆರ್ ಗುಣಗಳು ಪ್ರತಿ ಸಸ್ಯದ ಕಾಯಿ ಇಳುವರಿಯ ಮೇಲೆ ಅಧಿಕ ಪ್ರಮಾಣದ ಗುಣಾತ್ಮಕ ಪ್ರಭಾವವನ್ನು ಬೀರುತ್ತವೆ ಎಂದು ವರದಿ ಧೃಡೀಕರಿಸಿದೆ. ಐದನೇ ಹಾಗೂ ಆರನೇ ಪೀಳಿಗೆಯ ರಿಲ್ಸ ಮತ್ತು ಆಯ್ದು ಸಂಸ್ಕರಣಗಳಲ್ಲಿ ಎಲ್ಲಾ ಗುಣಗಳು ಗುಣಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಹೊಂದಿರುವುದಾಗಿ ಈ ಅಧ್ಯಯನವು ಸೂಚಿಸುತ್ತದೆ.

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# *Introduction*



## I. INTRODUCTION

Groundnut (*Arachis hypogaea*. L) is one of the important oil seed crops of the world, which is native to Brazil in South America and presently cultivated throughout tropical, subtropical and warm temperate regions of the world. It belongs to Leguminosae or Fabaceae family. It is a self-pollinating allotetraploid crop with basic chromosome number  $X=10$  (Stebbins 1957; Stalrker and Dalmacio 1986) and genome size 2800 Mb (Guo *et al.*, 2009). Peanut or Groundnut is widely used as food crop around the world. It is mainly grown by resource-poor farmers in Africa and Asia for edible oil (48–50%).

The crop is grown in about 23.4 m ha worldwide with a total production of 34.9 mt and productivity of 1.5 t *per* hectare. India shares 22 *per cent* of the world groundnut production. In India, it is grown an about 6.41m ha with a production of 7.3 m t and a productivity of 1.46 t *per* hectare (Indiastat.com, 2012). Karnataka is one of the five important states that produce groundnut. In Karnataka it is grown in an area of about 1.0 m ha with the production of 8.5 lakh tonnes and productivity of 0.7 t per ha (Indiastat.com, 2012).

Over two thirds of groundnut area in India is grown under rainfed conditions where frequent dry spells is a major limiting factor for productivity. Occurrence of drought is highly dynamic over the years and locations in terms of timing, duration, intensity and stage of the crop. Limited water availability, especially during flowering and peg penetration stages appear to be one of the important constraints to harness complete genetic potential yield of improved cultivars.

The yield model, as proposed by Passioura (1986) clearly signifies the importance of total transpiration (T) and Water Use Efficiency (WUE) in determining the total biomass production and yield ( $\text{Yield} = T \times \text{WUE} \times \text{Harvest Index}$ ). Accordingly, increasing total transpiration as well as WUE at a given moderately high harvest index (HI), should result in enhanced economic yield of any crop. It has been estimated that 0.1 unit increase in WUE, at a given annual rainfall of 800 mm and about 45% of it is available for transpiration, would result in 0.32 t per ha increase in total biomass

(Bindhumadhava, 2003). At a reasonably high HI, increase in yield can be achieved through increase in WUE.

Concomitant reduction in total biomass while selecting for WUE is perhaps the major reason for the limited success in breeding crop plants for higher WUE (Uday Kumar *et al.*, 1998). Plants have naturally evolved to maximize WUE primarily through reduction in transpiration. Since, transpiration and carbon dioxide entry are controlled by stomatal factors, increased WUE results the reduction in biomass. Thus, a strong interdependence between transpiration (T) and WUE is often observed. Such types are not desirable from the agronomic point of view. With this background, it is important to identify genotypes where the interdependency between T and WUE is weak. Such genotypes are characterized by increased mesophyll capacity to fix carbon. Therefore, selecting for high WUE from such types would not result in reduced biomass and are hence desirable (Sheshashayee *et al.*, 2006). Substantial genetic variation for WUE has been demonstrated in groundnut (Wright *et al.*, 1994). But it is rather difficult to use WUE as a selection trait in routine groundnut breeding programme for drought tolerance because of difficulties associated with its measurement under field conditions (Nageshwara Rao *et al.*, 2001) and also high genotype  $\times$  environment interaction.

Significant negative association of transpiration with carbon isotope discrimination ( $\Delta^{13}\text{C}$ ) in a number of studies (Farquhar *et al.*, 1989; Wright *et al.*, 1994) indicated potential utility of  $\Delta^{13}\text{C}$  as a surrogate trait of WUE while breeding groundnut for drought tolerance. Specific leaf area (SLA: defined as ratio of leaf area to leaf dry weight) with  $\Delta^{13}\text{C}$  (Wright *et al.*, 1994; Nageshwara Rao and Wright, 1994) and negative significant relationship between SLA and WUE and strong positive correlation of WUE with Soil Plant Analytical Development (SPAD) will be recording in selection for drought tolerance. Chlorophyll meter reading (measures leaf nitrogen status), provides sufficient justification for the use of SLA and SCMR as potential surrogate traits for WUE (Nageshwara Rao *et al.*, 2001). SCMR is a low cost, rapid and non destructive criterion for selecting groundnut genotypes for improved productivity under drought prone environments (Nageshwara Rao *et al.*, 2001; Bindumadhava *et al.*, 2003; Sheshashayee *et al.*, 2006).

Recombinant inbred Lines (RIL) find wide usage in both conventional and DNA marker assisted breeding. RILs are the breeding output from which good stabilized segregants can be directly used as breeding lines with desirable traits. The early generation genetic variability is maintained in RILs serve as a stable mapping population.

Exploitation of genetic variability existing in the segregating population is the first principle in the crop improvement of any crop (groundnut being no exceptions to this). Analysis and exploitation of existing variability is a short term strategy for developing improved cultivars for meeting immediate requirement of the farmers and the end-users. Exploitation of variability created by hybridization through recombination breeding is the major approach adopted in groundnut improvement programmes. Often, a plant breeder/ researcher is confronted with the task of handling segregating populations derived from a large number of crosses. Early elimination of poor crosses helps in efficient utilization of land, time and human resources and allows handling of reasonably large segregating population derived from a few promising crosses. Therefore, it's an imperative to design an objective method of selecting parents that are likely to produce crosses which result in higher frequency of superior lines for commercial cultivation after extensive testing. As a result selection of parents is the key to success.

1. To understand the dynamics of variability for traits related to drought tolerance
2. To assess breeding potential of selected crosses
3. To explore detection and magnitude and association of traits related to WUE with kernel yield and its components in segregating generations

# *Review of Literature*



## II. REVIEW OF LITERATURE

The main goal of the plant breeding programme is to increase the yielding ability of the crop plants, after thorough understanding of the magnitude of genetic variability, character association and amount of heritability, *etc.*, the efforts made to understand the work done by earlier workers in this direction have been reviewed under the following headings:

2.1 Genetic variability, heritability and genetic advance in segregating populations

2.2 Interrelationship between kernel yield and its component traits

2.3 Genetic variability and interrelationship between traits related WUE and kernel yield

2.4 Direct and indirect contributions of various characters towards kernel yield

2.5 Intergeneration correlation and narrow sense heritability

### **2.1 Genetic variability, heritability and genetic advance in segregating populations**

The success of breeding programme depends upon the extent and magnitude of variability existing in the germplasm or segregating population. Variability may be defined as the amount of variation present among the members of a population or species for one or more characters at genotypic or phenotypic levels. A comprehensive summary of methods for estimating genetic variance is presented by Cockerham (1963). Phenotypic variability is observable, and it includes both genotypic and environmental variation and therefore it is also called as total variation. Genotypic variation refers to genetic or inherent variability which remains unaltered by environmental conditions. It is measured in terms of genotypic variance and consists of additive, dominance and epistatic components. Environmental variance is measured in terms of error mean variance. Generally, genotypic coefficient of variability (GCV) and phenotypic coefficient of variability (PCV) are used to assess the extent of variation between two different contrasting characters. Heritability is the transmissibility of characters from parents to offspring. Heritability in broad sense is the ratio of genotypic variance to total phenotypic variance in percentage. Effectiveness of selection of genotype depends on heritability. Genetic advance (GA) is the improvement over the base population that can be potentially achieved from selection. It is a function of heritability of the trait, the

amount of phenotypic variation and the selection differential (s) that the breeder uses. When high heritability is accompanied with high genetic advance, it indicates additive gene effects and selection may be effective. When low heritability accompanied with low genetic advance, it indicates predominance of environmental effects and selection would be ineffective. High heritability with low genetic advance indicates the importance of non-additive gene effects while low heritability with high genetic advance indicates the importance of additive gene effects.

A critical estimate of genetic variability is a prerequisite for initiating appropriate breeding procedures in crop improvement programmes. The variability observed in any population could be due to two factors, the genetic and environmental, which were explained in the early part of last century by Johansen (1909), who attributed the variation in a segregating population to both heritable and non-heritable factors and the variation within pure line is only due to environmental factors.

Nilsson Ehle (1909) and East (1916) later confirmed Johnson's work and showed that continuous variation also conforms to Mendelian Genetics.

Charles and Smith (1939), Powers (1942) and Powers *et al.*, (1950) partitioned genetic variance from total variance using the estimate of environmental variance in segregating population.

The heritable variation was further divided into additive and non-additive components and fraction included dominance and interallelic interaction (Fisher *et al.*, 1932; Panse, 1940; Lush, 1945; Mather, 1949 and Falconer, 1981).

Manoharan *et al.*, (1990 a) studied 21 F<sub>1</sub> hybrids of groundnut and recorded higher phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and genetic advance for the characters plant height, pod number and pod yield but observed high heritability only for plant height. In another study by Manoharan *et al.*, (1990b) in 23 genotypes of groundnut high heritability combined with genetic advance was observed for pod yield and kernel yield indicating the control of additive gene action for these characters.

A high magnitude of variability, heritability and genetic advance was observed for the primary branches per plant, 100 pod weight, test weight, sound mature kernel *per cent* and pod yield per plant in 32 diverse groundnut genotypes grown at three environments differing in dates of sowing (Reddi *et al.*, 1991).

Senapathi and Roy (1991) reported a wide range of variability for pod yield and days to maturity and also significant genotype x environment interactions in 51 bunch groundnut genotypes during four seasons. In another study involving 30 genotypes of groundnut belonging to different growth habits (bunch, spreading and semi spreading types) under four environments, Bansal *et al.*, (1992) showed high genetic variation, heritability and genetic advance for pod and kernel yield and pod number in all the three environments.

Reddy and Gupta (1992) studied 46 genotypes of groundnut in three different environments and observed high genetic coefficient of variation, heritability and genetic advance for days to 50 *per cent* flowering, plant height, number of secondary branches, mature pod number, kernel yield, pod yield and harvest index.

Maximum variability, high heritability coupled with high genetic advance were observed by Yadav (1992) in advanced generations in early maturity crosses of groundnuts for days to 50 *per cent* flowering, plant height, number of branches per plant, number of seeds per plant, seed yield per plant and 100 seed weight.

Deshmukh *et al.*, (1993) studied seven released varieties of groundnut for Vidharbha region of Maharashtra. He reported significant variations for pod yield, kernel yield and harvest index. In 125 accessions and breeding lines of groundnut, a higher genotypic component of variability was observed for number of pods, number of seeds, pod weight per plant, 100 seed weight and shelling percentage (Pathirana, 1993).

Pod yield, 100 pod weight and 100 seed weight recorded higher PCV and GCV, whereas height of main axis, 100 pod weight, 100 seed weight and harvest index recorded high heritability in 48 genotypes of groundnut (Reddy, 1994).

In 28 Spanish groundnut genotypes, Ganeshan and Sudhakar (1995) observed higher PCV and GCV for primary branches per plant, moderate PCV and GCV for mature pods, height of main axis and pod yield per plant. They also reported high heritability for days to 50 *per cent* flowering, primary branches, height of main axis and pod yield per plant. High genetic advance for primary branches and pod yield per plant was also recorded.

Sharma and Varshney (1995) studied 18 varieties of groundnut and observed wide range of variability, heritability and genetic advance for pod yield per plant, biological yield per plant and harvest index. Moderate heritability was reported by Sumathi and Ramanathan (1995b) for characters like plant height, number of primary branches, pod yield, number of mature pods, 100 pod weight, 100 kernel weight and shelling percentage in F<sub>3</sub> and F<sub>4</sub> generations of 33 lines in five crosses of groundnut.

In a study involving the F<sub>4</sub> generation for two crosses of groundnut reported higher variability for pod yield. However, variability was low for shelling percentage, mature kernel percentage and moderate for pod number and test weight (Gowda *et al.*, 1996).

Vindhiyavarman and Raveendran (1996) studied 63 three way crosses of F<sub>1</sub> population of groundnut and observed the higher GCV values for plant height, number of mature pods, kernel weight and number of branches per plant. High heritability and high genetic advance were observed for all the three traits indicating the action of additive gene effect in their expression.

Islam and Rasnl (1998) observed highest genotypic coefficient of variation (GCV) for number of developed pods per plant (27.11) and kernel yield per plant (25.2) and also heritability in broad sense were high for days to 50% flowering (96.25) and days to maturity (91.67). Highest genetic advance as *per cent* of mean also recorded for number of developed pods per plant and kernel yield per plant (49.66 and 43.36, respectively)

Jayalakshmi *et al.*, (1998) in a study involving F<sub>4</sub> progenies of eight crosses of groundnut and reported high PCV and GCV along with high heritability and genetic advance for traits like pod weight per plant, total dry matter and harvest index.

Singh and Singh (1998) reported moderate variability for days to 50 *per cent* flowering, days to maturity, plant height and number of pods per plant in 15 cultivars of groundnut. However, wide range of variation was observed for pod yield per plant, 100-seed weight and shelling percentage.

Rudraswamy *et al.*, (1999) reported low PCV for characters like height of main axis, number of mature pods, number of primary branches, number of secondary branches, number of immature pods, pod yield per plant, number of kernels per plant, 100-kernel weight, dry weight of plant and shelling percentage. However, moderate to high heritability and moderate genetic advance was reported for height of main axis, number of immature pods, dry weight of plant, shelling percentage, pod yield and kernel yield in six crosses of groundnut.

Suryanarayana Reddy *et al.*, (2001) reported high GCV and moderate heritability along with high genetic advance for plant height, haulm yield and biomass per plant and hundred kernel weight in groundnut germplasm.

Venkataravana (2001) studied 30 genotypes of groundnut observed high GCV for kernel yield oil yield and 100-kernel weight while sound mature kernel and oil content showed low to moderate GCV. However, high heritability and genetic advance was observed for 100-kernel weight, kernel yield and sound mature kernel percentage in groundnut.

Makhan Lal *et al.*, (2003) observed higher PCV and GCV for plant height, number of mature pods, 100-pod weight and yield per plant in 67 lines of groundnut. Whereas days to maturity showed lowest PCV and GCV. High heritability and genetic advance was noticed for days to maturity, plant height and 100 pod weight.

Suneetha *et al.*, (2004) studied 23 genotypes of groundnut which included 5 lines, 3 testers and 15 F<sub>1</sub>s derived out of line x tester mating system. High heritability coupled with moderate genetic advance for days to 50 *per cent* flowering, height of main axis, total dry matter per plant, 100-pod weight, 100-kernel weight and pod yield was reported indicating the importance of additive and non additive components of variance

Kavani *et al.*, (2004) in their study involving 15 genotypes of valencia groundnut, observed high GCV for pod yield per plant, kernel yield per plant and biomass yield per plant. Moderate GCV was recorded for harvest index and 100-kernel weight. These characters also registered high heritability coupled with high genetic advance.

Alan *et al.*, (2005) conducted a study for estimation of variability in F<sub>3</sub> and F<sub>4</sub> segregating generations. Results revealed the presence of high broad sense heritability for kernel yield and moderate heritability harvest index in both the generations.

Golakia *et al.*, (2005) observed higher magnitude of PCV and GCV for pod yield, kernel yield and sound mature kernel percentage, except for shelling percentage and oil content in both runner and bunch habit groups and for main stem height in Virginia runner types. High heritability coupled with high genetic advance was recorded for most of the characters studied, except for shelling percentage and oil content in 25 Virginia runner and 24 Spanish bunch groundnut genotypes.

John *et al.*, (2005) observed high estimates of phenotypic (PCV) and genotypic coefficient of variation (GCV), heritability (broad sense) and genetic advance as *per cent* of mean (GAM) for number of secondary branches, number of mature pods and pod yield per plant in F<sub>2</sub> generation. This indicates the role of additive gene action and the potential of phenotypic selection for yield improvement.

In a study involving the effect of chemical mutagens on M<sub>2</sub> generation of groundnut, Veeramani *et al.*, (2005) reported higher phenotypic coefficient of variation than the genotypic coefficient of variation for number of pod yield and kernel yield characters in all the treatments. Heritability and genetic advance as the mean percentage for different characters were more in the treated populations.

Upadhyaya (2005) reported high heritability for shelling percentage and hundred seed weight, moderate for days to first flowering and low for pod yield per plant. But Swamy Rao (1979) reported low heritability and low genetic advance for shelling percentage and moderate heritability and moderate genetic advance for hundred seed weight.

Studies conducted by Praveen Kumar (2006) revealed that there was positive association of pod and kernel yield with each other and other yield attributing traits like, number of pods per plant, number of mature pods per plant and sound mature kernel percentage.

John *et al.*, (2006) evaluated 100 groundnut germplasm accessions and noticed that GCV and PCV values were high for pod yield per plant. High heritability for all the characters ranging from 66.89% (SCMR) to 96.11% (plant height). High heritability along with high GAM for almost all the characters studied indicated the importance of additive gene action in the inheritance of these characters. Hence, phenotypic selection would be effective for improvement of these characters.

John *et al.*, (2007) observed significant differences among F<sub>2</sub> population of six single crosses. The traits such as plant height, secondary branches per plant, mature pods per plant, pod yield per plant, kernel yield per plant, haulms yield per plant and harvest index showed high estimates of GCV and PCV, heritability (broad sense) and GAM indicated the role of additive gene action in the inheritance of these traits.

Parameshwarappa and Girish Kumar (2007) observed major role of non-additive gene action in the inheritance of pod yield, shelling percentage, number of pods and number of mature and immature pods in groundnut and concluded that shelling percentage and 100-kernel weight were found to be governed by both additive as well as non-additive gene effects in different genetic backgrounds.

Hariprasanna *et al.*, (2008) reported predominance of additive gene action in the expression of shelling out turn and 100-seed weight, while non additive gene action played an important role in the inheritance of pod weight.

Korat *et al.*, (2009) observed higher PCV and GCV estimates for secondary branches per plant and number of aerial pegs per plant. High heritability along with high genetic advance as *per cent* of mean was observed for secondary branches per plant and number of aerial pegs per plant indicating that these traits are mainly governed by additive gene action and high responsive to selection for further improvement of these traits.

Shoba *et al.*, (2009) observed that the cross TMV2 × COG0437 had higher mean performance for all the characters followed by TMV2 × COG 438. Higher PCV and GCV values were also recorded by this cross. The cross TMV2 × COG0437 had high heritability and high to moderate GAM for most of characters followed by TMV2 × COGO438. Hence, based on mean and variability parameters, TMV2 × COG437 is adjudged as best cross combination for further selection programme to evolve a promising progeny.

Gopinath Jatti *et al.*, (2008) observed high estimates of PCV and GCV for mature pods per plant, pod yield per plant, kernel yield per plant, haulm yield per plant and oil yield per plant. High heritability coupled with high genetic advance was noticed for 100 kernel weight, haulm yield per plant, chlorophyll content, pod yield per plant and plant height. This indicates that these traits are mainly governed by additive gene action and high responsive to selection. Therefore, it would be rewarding to lay due emphasis on the selection of these characters for rapid improvement in pod yield.

Fifty diverse genotypes of bunch groundnut were evaluated by Vekariya *et al.*, during *Kharif* 2009. High heritability coupled with high genetic advance expressed as *per cent* of mean was observed for mature pods per plants, kernel yield per plant and pod yield per plant indicating that these traits were mainly governed by additive gene action and responsive for further improvement of these traits.

Nandini *et al.*, (2010) undertaken the investigation during *kharif* 2010. The results revealed that PCV was higher than GCV for all the characters studied indicating the influence of environment on the characters. A moderate to high degree of heritability and

genetic advance was observed for pod yield per plant, kernel yield per plant, pods per plant, sound mature kernel percentage, plant height, number of branches per plant and SLA indicated the involvement of additive gene action in controlling of these traits. Low heritability and moderate genetic advance as *per cent* of mean was observed for SPAD Chlorophyll meter reading (SCMR).

Fifty elite genotypes of bunch groundnut were evaluated by Meta *et al.*, during 2010. High magnitude of GCV and PCV observed for most of the traits indicated large extent of genetic variability for these traits in the material. High heritability was accompanied with high GAM for plant height and 100-pod weight, indicating involvement of additive gene action for these traits. Pod yield per plant expressed high genetic advance with low heritability, however, its high magnitude of GCV suggested the scope of pod yield improvement.

Twenty eight F<sub>2</sub> populations of groundnut were evaluated by Vishnuvardhan *et al.*, (2012). High GCV accompanied by high heritability and high GAM were obtained for number of immature pods per plant indicating predominant role of additive gene action and amenability for phenotypic selection in early generations. Moderate GCV, heritability and GAM were registered for most of the traits indicating that additive and non-additive gene actions have a role in their inheritance and phenotypic selection would be effective to some extent. For days to 50% flowering and days to maturity, GCV was low, heritability was high and GAM was low. Indicating larger role of non-additive gene action and selection would be effective in later segregating generations.

Thakur *et al.*, (2011) conducted a study for estimating genetic variability in groundnut. Results revealed that considerable high heritability and low GAM were found for days to maturity. Where as some other yield parameters *viz.*, 100 seed weight, pod length, seed length and width were found to recorded higher heritability coupled with higher genetic advance. Hence, these yield parameters were used for selection of genotypes during the breeding program.

Upadhyaya *et al.*, (2012) evaluated 184 minicore accessions. Significant genotypic and genotype  $\times$  environment interactions were observed for all the nutritional and agronomic traits in the entire mini core collection and within each *A. hypogaea* subspecies of *fastigiata* Waldron and *hypogaea*. Eighteen accessions with higher nutritional traits such as protein content, oil content, oleic acid, and oleic to linoleic acid ratio with superior agronomic traits were identified and their stability analysis resulted in identification of a high oleic acid content ( $>73\%$ ) accession (ICG 2381).

John *et al.*, (2013) observed high heritability coupled with high genetic advance as *percent* of mean for plant height, haulms yield per plant, pod yield per plant, kernel yield per plant and 100-pod weight indicating the importance of both additive and non additive gene action in the inheritance of these characters. Thus, results clearly suggested that the chances for improvement of these traits would be fairly high as magnitude of GCV for these characters.

Thakur *et al.*, (2013) carried out the study on variability in groundnut genotypes for tolerance to drought. The analysis of variance indicated highly significant differences for most of the plant characters used for their study. Remarkable levels of variability have existed among the groundnut varieties that are essentially used in groundnut improvement. The genotypes ICGV-99171, ICGV-98089, ICGV-97100, Baidehi, ICGV-00440 and B-4 were observed better for drought tolerance with high pod yield. It is suggested that these genotypes could be grown under regions of limited rainfall and may be used as parents in breeding programmes for developing drought tolerant groundnut cultivars.

## **2.2 Interrelationship between pod yield and its component traits**

Grain yield for any crop depends on many component characters that influence yield either jointly or singly and either directly or indirectly through other related characters. Selection for yield on the basis of *per se* performance alone may not be effective as that based on the component characters associated with it, which is biometrically determined by correlation coefficient and path analysis. The correlation between characters may exist due to various reasons such as pleiotrophy, genetic linkage

and association of loci or block of loci governing variability for different characters located on same chromosome. The extent of observed relationship between two characters is known as simple, total or phenotypic correlations.

Environmental correlation is the measure of environmental influence on the covariance between the two characters. An understanding of the nature and extent of association of the component characters with grain yield and amongst themselves is an essential prerequisite for formulating best breeding programme. The literature regarding correlation studies in groundnut have been reviewed and presented in the following paragraphs.

Positive correlation for 100 pod weight, and 100 kernel weight and primary branch number with pod yield was observed by Kuriakose and Joseph (1986). Tekale *et al.*, (1988) observed positive correlation for dry pod yield per plant with plant height, branches per plant, developed pods per plant and total pods per plant.

Miller and Norden (1980) reported that in a study of 32 cross derivatives tested in comparison with three standard varieties. Patra and Mohanty (1987) estimated correlation coefficient for yield components. The studies indicated that selection based on three components, shelling percentage, the number of mature pods and number of immature pods per plant proved to be more effective than selection based on yield alone.

Alam *et al.*, (1985) observed positive association of pod yield per plant with the number of pods per plant, days to maturity and plant height. However the shelling percentage was negatively associated with 100 kernel weight and oil content was negatively associated with all characters except days to maturity and 100 kernel weight.

Bhagat *et al.*, (1993) reported that oil content was positively correlated with majority of scored traits and it was highly significant with shelling percentage. They also reported that only mature pods maintained a strong positive direct effect with pod weight. The direct effect of shelling percentage was also substantial and positive.

Deshmukh *et al.*, (1986) noticed significant positive association for pod yield with number of mature pods per plant, 100 kernel weight and percentage of sound mature kernels, but negative association with days to 50 *per cent* flowering and dry matter at harvest at genotypic level.

Varman and Raveendran (1989) in their studies on 37 Spanish, two Valencia and 11 virginia bunch genotypes observed significant and positive correlations for length of main stem, primary and secondary branches and haulm yield with pod yield.

Abraham (1990) reported that kernel yield exhibited significant positive correlation with pods per plant, kernels per plant, 100 kernel weight and shelling percent in a study involving 42 bunch groundnut varieties. However, days to 50 *per cent* flowering showed significant negative correlation with sound mature kernel and shelling percent.

A significant and positive genotypic correlation was observed between kernel weight and pod weight, pod length and pod width in 23 genotypes of groundnut by Manoharan *et al.*, (1990a).

Reddi *et al.*, (1991) reported that pod yield per plant exhibited a strong and positive correlation with kernel yield, sound mature kernel and 100 kernel weight in 32 diverse groundnut genotypes grown at three environments arising due to three different dates of sowing.

A strong association of pod yield with kernel yield, number of mature pods, harvest index and shelling out turn was observed among 46 genotypes of groundnut grown at three simulated environments (Reddy and Gupta 1992).

Vaddoria and Patel (1992) studied 50 Virginia runner groundnuts and reported that pod yield showed a high significant and positive association with harvest index, shelling percentage, number of mature pods per plant, 100 seed weight and number of primary branches per plant. However, pod yield exhibited high significant and negative correlation with days to 50 *per cent* flowering and days to maturity.

Bhagat *et al.*, (1993) studied 653 virginia bunch groundnut varieties and observed that pod yield had strong positive correlation with number of mature pods per plant, pod weight per plant, 100 seed weight and shelling percentage.

A positive and significant correlation of seed yield per plant with number of primary branches, shelling percentage, 100 seed weight, number of pods per plant and number of seeds per plant was observed by Patirana (1993) in 125 accessions and breeding lines of groundnut. A significant positive correlation between seed weight per plant and number of pods per plant, number of seeds per pod and 100 seed weight was also observed.

Pushkaran and Gopinathan Nair (1993) studied 80 varieties of groundnut, pod yield was found to be highly correlated with fresh weight of pods, number of mature pods, number of immature pods, shelling percentage and *per cent* of pod set. However, pod yield was found to have a significant negative correlation with duration up to flowering and number of flowers. They also reported that pod yield was significantly and positively correlated with haulm yield, number of mature pods and number of immature pods.

In F<sub>2</sub> population pod yield exhibited positive and significant correlation with number of secondary branches, dry matter production, harvest index and number of pods per plant in Spanish bunch groundnut where as number of pods per plant was significantly and positively correlated with number of secondary branches, dry mater production and harvest index (Mishra, 1995).

Sharma and Varshney (1995) studied 18 varieties of groundnut and found that pod yield per plant had significant and positive correlation with pods per plant, shelling percentage, kernel weight and harvest index.

Sumathi and Ramanathan (1995a) observed that pod yield had significant positive genotypic correlation with number of flowers, number of mature pods, kernel yield, 100 pod weight and 100 kernel weight in 33 progenies of F<sub>3</sub> and F<sub>4</sub> generations.

Vindhiyavarnan and Raveendran (1996) studied 63 three way cross of F<sub>1</sub> population of bunch groundnut and showed that pod yield had significant positive genotypic correlation with number of mature pods and maturity index. They also reported positive association of kernel weight with shelling out turn and pod weight and significant negative association of number of mature pods with pod weight and kernel weight.

Moinuddin (1997) revealed a strong positive association of pod yield with number of mature pods per plant, 100 kernel weight and biomass per plant. However, pod yield was negatively correlated with haulm yield and shelling percentage.

Rose Mary and Sethupathi (1997) reported that inter correlation estimates of yield components revealed that number of mature pods, kernel yield and number of kernels were significantly and positively associated with one another and as well as with pod yield in 55 groundnut genotypes of F<sub>2</sub> generation.

Vasanthi *et al.*, (1998) observed that pod weight per plant showed significant positive correlation with sound matured kernel percentage (SMK%) and significant negative association with days to 50 *per cent* flowering, shelling percentage showed significant positive association with sound matured kernel percentage.

Singh and Singh (1999) in 44 groundnut genotypes reported that 100 kernel weight had high significant correlation with days to flowering, days to maturity, plant height, number of branches, number and weight of pods per plant.

Sah *et al.*, (2000) evaluated 24 genotypes of mutant cultures of groundnut and reported that pod yield per plant was positively and significantly correlated with number of pods per plant, 100 seed weight, seed yield per plant, oil yield, whereas, it was negatively associated with shelling percentage. Oil yield was positively associated with number of pods per plant, 100 seed weight, seed yield per plant, number of primary branches per plant and number of seeds per pod.

In 30 genotypes of groundnut, Venkataravana *et al.*, (2000) noticed that pod yield had significant positive correlation with plant height, number of branches per plant, number of mature pods per plant, shelling percentage, sound mature kernel percentage, 100 kernel weight, kernel yield per plant, harvest index and oil *per cent* at both genotypic and phenotypic levels. Further, pod yield showed negative association with days to 50 *per cent* flowering and maturity.

Nagda *et al.*, (2001) studied 80 F<sub>1</sub> s and two checks of groundnut (TAG-24 and SB-X1) and reported that dry pod yield per plant had significant positive genotypic correlation with number of mature pods per plants, kernel yield per plant in both parents and hybrids.

Mallikarjunaswamy (2001), reported that days to maturity is strongly associated with pod yield per plant, positive significant correlation for days to maturity and days to initiation of flowering, negative significant correlation for oil content with pod yield per plant.

Roy *et al.*, (2003) noticed that number of pods per plant, 100- kernel weight, 100 pod weight, shelling *per cent* and days to 75 *per cent* flowering was positively and significantly correlated with yield per plant in 95 genotypes of groundnut.

Makhan Lal *et al.*, (2003) studied 67 lines of groundnut and reported that plant height had significant positive correlation with leaf length, leaf width and number of mature pods, where as yield per plant was positively related with days to maturity and number of mature pods.

Lakshmidamma *et al.*, (2004) observed that pod yield possessed significant positive association with kernel yield, test weight, plant height, number of pegs, number of matured pods, test weight and oil yield at both genotypic and phenotypic levels.

Suneetha *et al.*, (2004) reported positive and significant association of pod yield per plant with number of mature pods, total dry matter per plant and harvest index in 8 parents and their 15 F<sub>1</sub>s of groundnut.

In a study involving 15 genotypes of Valencia groundnut, pod yield and kernel yield exhibited significant positive association with developed kernels per plant, 100 kernel weight and biomass yield (Kavani *et al.*, 2004). Suvarna *et al.*, (2004) in their study reported that pod yield exerted significant and negative correlation with specific leaf area and positive correlation with 100 kernel weight and sound mature kernel percentage

Golakia *et al.*, (2005) observed significant and positive correlation of pod yield per plant with developed pods per plant, biomass yield per plant and harvest index, indicating that simultaneous selection for these characters might bring an improvement in pod yield.

In a study involving F<sub>2</sub> population of six single crosses and parents showed plant pod yield had significant and positive correlation with number of secondary branches, number of mature pods, kernel yield, pod length, haulm weight and harvest index. Thus indicated pod yield could be increased by improving these characters (John *et al.*, 2005).

Kalmeshwar *et al.*, (2006) reported that pod yield per plant had positive association with number of pods per plant, shelling per cent and sound mature kernel per cent at three locations.

John *et al.*, (2007) observed significant positive association of pod yield with number of mature pods per plant (0.541), SCMR (0.588), kernel yield per plant (0.981), pod width (0.682) and harvest index (0.832). Improvement in pod yield could be brought by selection for characters viz., number of mature pods, kernel yield, pod width, SCMR and harvest index.

Mane *et al.*, (2008) observed Pod yield plant had positive and significant correlation with *per cent* sound maturity kernel, number of pegs plant, number of pods plant and shelling percentage. However, it showed negative and non-significant correlation with hundred kernel weight and days to 50 *per cent* flowering.

In a cross TKG 19A × J-11 and J-11 × TGLPS 3, revealed total number of pods, number of well filled pods, kernel weight, Sound Mature Kernel and days to flowering

had positive and significant association with pod yield and also observed Negative relationship of pod yield with damage of late leaf spot incidence. 100 kernel weight had positive association with shelling percentage and sound mature kernel percentage (Parmeshwarappa *et al.*, 2008).

Sudhir Kumar *et al.*, (2008) observed pod yield per plant has positive significant association with mature pod per plant and kernel yield per plant and also found pod yield per plant has high direct effect on kernel yield and oil content in a study involving 64 genotypes of groundnut.

Sadeghi and Niyaki were evaluated the 23 groundnut genotypes. The results revealed that 100 seed weight, total number of kernels per plant, total number of pods per plant and biomass had a high positive association with seed yield.

Channayya *et al.*, (2010) conducted a study on Induced genetic variability and correlation studies for yield and its component traits in Groundnut. Results revealed that Pod yield was positively and significantly associated with primary branches, pod weight per plant, 100-kernel weight, sound matured percentage and oil yield.

Korat *et al.*, (2010) found that the estimate of genotypic correlation coefficients in general higher than their corresponding phenotypic correlations indicating strong inherent association among the traits. Yield contributing characters like biological yield per plant, 100 kernel weight and harvest index had positive and significant association with pod yield per plant at phenotypic level. Days to maturity and pod yield per plant was found negative and significant correlation.

The analysis of the association between pod yield and quantitative characters in groundnut was carried out by Mukhtar *et al.*, (2011). Results revealed a positive and significant association with all the components assessed except shelling percentage this shows the importance of these components as yield contributing factors in groundnut.

An experiment was conducted using thirty four groundnut genotypes by Zaman| *et al.*, (2011) for estimation of correlation coefficient among different yield components.

The results indicated that seed yield per plant showed the highly significant and positive association with nut size, number of nuts per plant, kernel size and days to 50% flowering.

Thakur *et al.*, (2013) evaluated the twenty five groundnut genotypes. The pod yield ha<sup>-1</sup> showed highly significant and positive association with days to maturity, sound matured kernel (SMK)%, pod length, pod width and kernel length but the highly significant and negative association was shown with days to flowering, pod per plant, shoots length, shelling % and specific leaf area.

Sixty six genotypes of groundnut were used to study the correlation and path analysis for yield and yield contributing characters by Pavan Kumar *et al.*,(2014). Results revealed that kernel yield was significantly and positively associated with pod yield per plant, number of mature pods per plant, shelling percentage, harvest index, sound mature kernel percentage, specific leaf weight at 60 DAS, protein content and oil content.

## **2.3 Genetic variability and Interrelationship between traits related WUE and kernel yield**

### **2.3.1 Water use efficiency**

Identification of physiological traits contributing to superior performance of crop plants under drought conditions has been a long term goal of plant scientists. Water use efficiency is one such trait that can contribute to productivity when water resources are scarce. The yield model proposed by Passioura (1986), where Grain yield = Transpiration × Water Use Efficiency × Harvest Index, reveals that water use efficiency is an important parameter influencing the biomass production.

Water Use Efficiency has often been examined from various points of view in different context by hydrologists, agronomists, and physiologists. Physiologically, Water Use Efficiency (WUE) is defined at either single leaf level or at whole plant level and or at canopy level.

Existence of genetic variability both between and within species is necessary for successful exploitation of WUE through breeding programme. Variability in WUE is mainly determined by any one of the following three methods

A) At canopy level, under field conditions using crop growth and yield model. This technique is more employed in perennial tree species.

B) At whole plant (canopy) level in small pots or big containers (field mini-lysimeter) by adopting gravimetric technique

C) At a single leaf level by adopting the gas exchange approach.

Several studies were carried out for addressing the variation in WUE which are reviewed and listed below.

In ten genotypes of groundnut, NageshwaraRao *et al.*, (1993) observed a significant variability among genotypes for WUE that ranged between 1.38 to 2.50 g dry matter/kg of water. Hebbar *et al.*, (1994) studied 14 Spanish bunch groundnut genotypes under two different moisture regimes (at field capacity and 60 *per cent* capacity) reporting a significant variability in WUE between genotypes and moisture regimes.

Wright *et al.*, (1994) surveyed 4 groundnut genotypes under two drought regime and reported negative correlation of WUE with  $\Delta^{13}\text{C}$  and SLA.

Similar study was conducted by Roy Stephen (1995) who reported a range of WUE between 2.92 to 4.07 g dry matter/kg of water under 100% field capacity and between 3.19 to 5.46 g dry matter/kg of water under 50 % field capacity.

Craufurd *et al.*, (1999) noticed negative correlation of WUE with  $\Delta^{13}\text{C}$  and SLA, whereas, SLA was positively correlated with  $\Delta^{13}\text{C}$  ( $r=0.75$ ). Hence, SLA is a good indirect selection criterion for  $\Delta^{13}\text{C}$  and WUE while identifying genotypes of groundnut for adoption to the semi arid tropics.

Carbon isotope discrimination ( $\Delta^{13}\text{C}$ ) exhibited negative relationship with shoot biomass and root dry mass whereas it showed positive relationship with harvest index in seven parents and their non reciprocal diallel 21  $F_1$  progeny of groundnut (Jayalakshmi *et al.*, 2000).

Lambrides *et al.*, (2004) studied 161 germplasm lines and hybrids of sunflower and showed significant negative relationship with carbon isotopic discrimination ( $\Delta^{13}\text{C}$ ).

Carbon isotope discrimination ( $\Delta^{13}\text{C}$ ) exhibited strong negative relationship with Water Use Efficiency in two separate experiments consisting of 34 and six selected genotypes of rice respectively, concluding that  $\Delta^{13}\text{C}$  can act as a potential surrogate for WUE in rice (Impa *et al.*, 2005).

In a study involving twelve crosses obtained by line  $\times$  tester mating design using seven genotypes which had high carbon isotopic discrimination, a strong positive and significant correlation of yield per plant with number of mature pods per plant, total number of kernels per plant and biomass yield was observed (Rekha, 2005).

Chuni Lal *et al.*, (2005) observed strong inverse relationship of SCMR with SLA ( $r=-0.626$ ,  $p<0.01$ ) and  $\Delta^{13}\text{C}$  ( $r=-0.552$ ) and positive association with pod yield ( $r=0.505$ ,  $p<0.01$ ) and hence suggested that groundnut genotypes with low SLA and  $\Delta^{13}\text{C}$  and high SCMR values are likely to possess high WUE in the study carried on 32 genotypes comprising of 20 advanced breeding lines developed for high WUE and four check genotypes.

The study conducted by Praveen Kumar (2006) on the inheritance of carbon isotopic discrimination in a cross NRCG11915  $\times$  NRCG12326 has shown normal distribution for the  $\Delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  values suggesting that the character is under the control of many genes indicating the polygenic inheritance of the trait.

Krishnamurthy *et al.*, (2007) observed negative correlation of Transpiration Efficiency (TE) with SLA,  $\Delta^{13}\text{C}$  and positive association with SCMR. Direct gravimetric evaluation for Transpiration efficiency appeared to be more reliable in the study of 318

RIL's of F<sub>8</sub> generation derived from cross between high TE (ICGV 86031) and low TE (TAG 24) parent but this approach is laborious.

Latha *et al.*, (2007) have reported negative correlation between WUE and  $\Delta^{13}\text{C}$  ( $r = -0.87$ ) and between WUE and SLA ( $r = -0.89$ ).

Jongrunklang *et al.*, (2008) studied effect of drought and observed reduced TDM, pod dry weight, HI, WUE and SLA, but increased SCMR and canopy temperature. The positive correlation of WUE with SCMR is observed.

While evaluating eighteen diverse groundnut genotypes for two physiological traits SCMR and SLA, Nigam and Rupakula Aruna (2008) noticed negative correlation between SCMR and SLA and the relationship was insensitive to crop stage and season and identified high WUE lines like ICGV 99029 and ICR 48.

Arunyanark *et al.*, (2009) reported positive correlation of chlorophyll content with SCMR across different water regime, plant age and leaf position.

Rowland *et al.*, (2009) found significant genetic variation among 19 peanut cultivars grown in 6 locations in United States for  $\Delta^{13}\text{C}$ , SLA and SCMR but also found significant role of environment in the genetic expression of these traits.

#### **2.4 Direct and indirect contributions of various characters towards kernel yield**

Sahet *al.*, (2000) studied 21 genotypes of M<sub>7</sub> generation of mutant cultures of groundnut and reported that the seed yield per plant had high direct effect on pod yield per plant. It also revealed that number of pods per plant and 100-seed weight had low direct effect on pod yield per plant and had contributed mainly through seed yield per plant.

Johar Singh and Mohinder Singh (2001) reported that number of primary branches had maximum positive direct effect on pod yield followed 100 kernel weight, sound mature kernel percentage, harvest index and number of fruiting nodes. Plant height had largest negative direct effect on pod yield.

Yogendra Prasad *et al.*, (2001) in a study on path analysis at genotypic and phenotypic levels indicated high positive direct effects of harvest index, number of primary branches, number of pods per plant, and shelling percentage at both levels. The direct effect of days to 50 *per cent* flowering was negative at genotypic levels and low at phenotypic level. The direct effect of percentage of sound mature kernel and 100 kernel weight at both genotypic and phenotypic levels was negative.

Lakshmiddevamma *et al.*, (2004) reported high direct effects of kernel yield and oil content on pod as well as oil yield, and suggested to lay due emphasis on the selection of these characters for rapid improvement in pod and oil yield. In seven progenies of F<sub>2</sub> segregating population, it was noticed that number of primary branches had highest positive direct effect on pod yield followed by number of mature pods per plant, while plant height exhibited negative direct effect.

Nagda *et al.*, (2004) noticed that the direct effect of harvest index was remarkably positive and highest which was closely followed by indirect effects of 100-kernel weight through harvest index was positive and strongly followed by indirect effects of shelling outturn through haulm yield. Hence harvest index and 100 kernel weight should be considered in selection programme for improving yield in groundnut.

In 15 genotypes of groundnut, Gomes and Lopes (2005) noticed that splitting of the genotypic correlations in to direct and indirect effects, showed that the grain yield was positively influenced by the number of pods per plant and weight of 100 seeds, and negatively by the number of seeds pod per plant. In a favorable sense, the number of pods per plant was the trait of greatest direct influence on the grain yield.

Kalmeshwar *et al.*, (2006) noticed that three traits *viz.*, number of pods per plant, shelling percentage and sound mature kernel percentage had the maximum direct effect on Pod yield per Plant.

Mane *et al.*, (2008) observed per cent sound maturity kernel, shelling percentage and number of pods plant recorded the high magnitude of direct effects, suggesting the

importance of these characters for improving the yield of plant and direct negative effects were observed for number of pegs plant and days to 50 *per cent* flowering.

Korat *et al.*, (2010) observed that the genotypic and phenotypic path analysis revealed the highest positive direct effects of biological yield per plant and harvest index towards pod yield. Hundred-kernel weight contributed indirectly via biological yield per plant and harvest index. Based on correlation and path analysis, biological yield per plant, 100 kernel weight and harvest index were identified as the most important yield contributing characters.

Aisha *et al.*, (2012) studied the performance of three varieties (Samnut 11, Samnut 21 and Samnut 23); Plant height exhibited the highest positive effect, followed by total dry matter and number of branches in the three years and when combined. Path coefficient analysis revealed that among the growth characters selected, plant height made the highest positive contribution to pod yield of groundnut, followed by total dry matter suggesting plant height was the most critical growth parameter for determining yield of groundnut under irrigation.

Sadeghi and Niyaki (2012) they were conducted the study to estimate the interrelationship between oil yield and its components on 23 peanut. Results revealed that seed yield, total no. of kernels per plant, plant height and 100 seed weight had a high positive with oil yield.

## **2.5 Intergeneration correlation and narrow sense heritability**

The objectives of plant breeders are to develop varieties of high yielding ability, good quality and adaptation to different climatic environment and management systems (Cooper, 1982). To achieve these objectives breeders should have adequate knowledge on genetic properties of segregating population and must be able to identify the most appropriate selection procedures for the improvement of crop (cooper, 1982). The common breeding methods currently used in self pollinated crops are pure line selection, mass selection, backcross, pedigree and bulk population breeding (Allard, 1960). Where crossing is involved and segregating populations are grown, the latter three methods are

applied. These classical breeding methods are most efficient in terms of genetic gain per generation and per unit of time and it may not be advisable to evaluate large numbers of segregating populations (Bisen *et al.*, 1985a). However, the information on breeding procedures in oilseed crops is more limited. Hence the study on detection and establishment of some genetic parameters like correlation among segregating generation and narrow sense heritability in terms of parent offspring regression is much more required to guide the breeder for prediction and selection of effective early generation segregating lines in Groundnut.

In chickpea Dahiya *et al.*, (1983b) found positive and significant correlations between  $F_2$  and  $F_3$ ,  $F_2$  and  $F_4$  and  $F_3$  and  $F_4$  generations. Dahiya *et al.*, (1984) also reported that the  $F_3$  yield trial selection method resulted in significant yield increases over both random and visual selections. These results have also shown that visual selection and random selection were equally ineffective in the identification of high yielding lines. On the other hand, McKenzie and Lambert (1961) concluded that  $F_3$  yield tests were of little value in predicting  $F_6$  yields in barley.

Virupakshappa (1984) estimated the inter-generation correlations in two crosses of cowpea in  $F_2$  to  $F_3$ ,  $F_3$  to  $F_4$  and  $F_5$  to  $F_6$  generations and found significant intergeneration correlations in any of the cases for yield. On the other hand, Ntare *et al.*, (1984) reported that the differences in yielding ability of  $F_3$  lines of two cowpea crosses persisted over generations indicating that selection was effective. This was further confirmed by the highly significant correlations between  $F_3$  yields and those of later generations which ranged from  $r = 0.51$  to  $0.85$ .

In wheat, Whan *et al.*, (1981) planted all the generations from  $F_2$  to  $F_5$  together in one season so that the results were not influenced by seasonal differences. The correlations ranged from  $r = 0.51$  for the  $F_2$  to  $F_3$  mean comparison to  $r = 0.68$  for the  $F_3$  to  $F_4$  mean to  $r = 0.78$  for the  $F_4$  to  $F_5$  mean. Their observations revealed that the absence of replications, where single lines were grown as single plots, reduced the accuracy in the determination of the yield and could have lowered the correlations.

Alan *et al.*, (2004) conducted a study on genetic enhancement of drought resistance in peanut using combined physiological and breeding methods. The F<sub>2</sub>-derived families of peanuts from 4 crosses were subjected to trait-based among family index selection in the F<sub>3</sub> and F<sub>4</sub>. Heritability estimates for these traits were estimated using 3 different bases *i.e.*, broad-sense heritability on an F<sub>3</sub> row basis, broad-sense heritability on an F<sub>4</sub> family mean basis using variance components and standard unit heritability estimates using correlation among generations. The heritability estimates varied significantly between crosses and traits depending on levels of genetic variation in parents. In some cases the variation seems to be caused by errors in sampling method. Kernel yield (KY) generally had the best correlations between F<sub>3</sub> and F<sub>4</sub> (maximum 0.65), HI and TE were intermediate and correlations for T were very poor (one cross in one environment 0.56 the remainder not significant). Consideration of these differences in heritability and the costs of sampling lead to the proposal that a simpler index based on KY and TE may be a useful compromise for selection of superior drought performance in peanut. Use of an index including TE would prevent selection for decreasing TE when selecting for KY, where there are casual negative associations between TE and the other two components.

Gangashetty conducted a study on intergeneration correlation among F<sub>3</sub> and F<sub>4</sub> segregating generations of a single and double cross hybrid in okra during 2009. Results of this study clearly showed the presence of high heritability and significant correlation for internodal length, number of seeds per fruit and 100 seed weight in both single and double cross progenies, indicating that these traits are mostly governed by additive gene action and suitability of these traits for selection on individual plant basis in the advanced generations of segregating progenies. Where as the other traits like Plant height, number of branches per plant, fruit weight, number of fruits per plant and fruit yield per plant recorded low values of correlation coefficient and heritability which indicated the non-correspondence of two generation values for these characters due to preponderance of non additive variation. Preponderance of additive gene action leads to effective selection which would help in developing inbreds and varieties, while preponderance of dominance variance suggests exploitation of heterosis and hybrids may be developed.

# *Material and Methods*



### **III. MATERIAL AND METHODS**

The details of all the genetic material utilized in conducting present experiments, the methodology followed for recording the various observations and techniques required to estimate various parameters is presented in the following chapter.

#### **3.1 Location of the Experimental Site**

The present research work was conducted at K-block, University of Agriculture Sciences, Gandhi Krishi Vignana Kendra, Bangalore during *kharif* 2012, *summer* 2013, *kharif* 2013 and *summer* 2014. The experimental site is located at an altitude of 899 m above mean sea level and 13 00°N latitude and 77 35°E longitude. The details of experimental of materials used and techniques adopted in the present study for recording of observations, statistical tools and analysis of data are briefly presented under the respective experiments separately.

#### **3.2 Experimental Material**

##### **3.2.1 Development of Recombinant Inbred Lines (RILs) in the cross of NRCG 12568 × NRCG 12326.**

With the objective of developing RILs for high pod yield with high water use efficiency the genotypes such as NRCG12568 and NRCG 12326 were selected. The salient features of these two genotypes were mentioned in Table 1. Results from this table suggested that these genotypes are enough diverse for pod yield per plant, kernel yield per plant, pods per plant, kernels per plant, SCMR and SLA. Hybridization was made between these two genotypes to develop F<sub>1</sub> hybrid, selfing upon these hybrids was made to get F<sub>2</sub> plants and all F<sub>2</sub> plants were forwarded to get F<sub>3</sub> progenies.

As a procedure of plant to row progeny method each harvested plant from F<sub>2</sub> were sown in single row to get F<sub>3</sub>RILs. 553 plants harvested from F<sub>2</sub> were sown in augmented design along with parents and checks (TMV 2 and KCG 2) during *kharif* 2012. All recommended agronomic practices and plant protection measures were followed during

**Table 1: Salient features of the parental materials used in the study**

Sl. No	Genotypes		Pod yield(g)	Kernel yield (g)	Shelling percentage	$\Delta^{13}\text{C}$	SCMR	SLA (cm <sup>2</sup> g)
1	NRCG12568 x NRCG12326	P <sub>1</sub>	40.40	23.17	71.35	16.90	44.24	109.70
		P <sub>2</sub>	18.20	11.26	61.86	21.50	30.45	186.04
2	NRCG12274 x ICG12370	P <sub>1</sub>	53.06	34.06	64.19	21.60	42.56	129.14
		P <sub>2</sub>	35.25	20.19	80.14	16.50	30.25	195.44
3	NRCG12273 x ICG12370	P <sub>1</sub>	61.23	44.34	72.41	21.50	46.48	107.76
		P <sub>2</sub>	35.25	20.19	80.14	16.50	30.25	195.44
4	TMV-2*	P <sub>1</sub>	39.25	27.56	69.74	18.50	45.08	136.28
5	KCG-2**	P <sub>2</sub>	50.92	40.25	78.04	18.90	42.44	137.17

\*National check, \*\* state check

the crop growth period to ensure better growth and yield. The observations were recorded on all the plants of F<sub>3</sub> generation.

Similarly 456 F<sub>4</sub>, 340 F<sub>5</sub> and 325 F<sub>6</sub> RILs were sown each line in a single row as a method of plant to progeny row in augmented design along with parents and checks during *summer* 2013, *kharif* 2013 and *summer* 2014, respectively. All recommended agronomic practices and plant protection measures were followed during the crop growth period to ensure better growth and yield. The observations were recorded on all plants in all the generations.

### **3.2.2 Development of superior segregants in the cross of NRCG 12473 × ICG 12370.**

With the objective of developing superior segregants for high yield coupled with high water use efficiency the genotypes NRCG12473 and NRCG 12370 were selected. The salient features of these genotypes were depicted in Table1. The genotypes which are selected were highly diverse for SLA, SCMR, pod yield and kernel yield per plant. Hence crossing was made between these two genotypes to produce F<sub>1</sub> hybrid. Selfing of these hybrids was done to get F<sub>2</sub> plants.

Each selected F<sub>2</sub> plant was sown in a single row according to plant to row progeny method to get F<sub>3</sub> segregating lines. 156 F<sub>3</sub> segregating lines were raised along with parents and checks in augmented design during *kharif* 2012 and checks were repeated twice in each block. All recommended agronomic practices and plant protection measures were followed during the crop growth period to ensure better growth and yield. The observations were recorded on all the plants of F<sub>3</sub> generation. Individual plant selection based on mean ± 1SD for pod yield per plant, kernel yield per plant, pods per plant, kernels per plant, SCMR and SLA were made in F<sub>3</sub> generation.

Similarly each of 140 F<sub>4</sub>, 128 F<sub>5</sub> and 112 F<sub>6</sub> segregating progenies were sown in a single row as a method of plant to progeny row in augmented design along with parents and checks during *summer* 2013, *kharif* 2013 and *summer* 2014, respectively. All recommended agronomic practices and plant protection measures were followed during

the crop growth period to ensure better growth and yield. The observations were recorded on all the plants in all the generations.

### **3.2.2 Development of superior segregants in the cross of NRCG 12274 × ICG 12370**

With the objective of developing superior segregants for high yield coupled with high water use efficiency the genotypes NRCG12274 and NRCG 12370 were selected. The salient features of these genotypes were depicted in table1. The genotypes which are selected they were highly diverse for SLA, SCMR, pod yield, kernel yield per plant, and kernel yield per plant. Hence crossing was made between these two genotype to produce F<sub>1</sub> hybrid. Selfing of these hybrids was done to get F<sub>2</sub> plants.

Each of selected F<sub>2</sub> plant was sown in a single row according to plant to row progeny method to get F<sub>3</sub> segregating lines. 108 F<sub>3</sub> segregating lines were raised along with parents and checks in augmented design during *kharif* 2012 and checks were repeated twice in each block. All recommended agronomic practices and plant protection measures were followed during the crop growth period to ensure better growth and yield. The observations were recorded on all the plants of F<sub>3</sub> generation. Individual plant selection based on mean  $\pm$ 1SD for pod yield per plant, kernel yield per plant, pods per plant, kernels per plant, SCMR and SLA were made in F<sub>3</sub> generation.

Similarly 84 F<sub>4</sub>, 72 F<sub>5</sub> and 52 F<sub>6</sub> segregating progenies were sown each line in a single row as a method of plant to progeny row in augmented design along with parents and checks during *summer* 2013, *kharif* 2013 and *summer* 2014 respectively. All recommended agronomic practices and plant protection measures were followed during the crop growth period to ensure better growth and yield. The observations were recorded on all the plants in all the generations.

### **3.4 Recording of observations**

Since F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> populations are highly segregating for the genes at all loci observations were recorded on all individual plants on the following growth, traits related to WUE like, SLA and SCMR, yield and yield attributing traits. Recording of observations is described below.

**i) Days to first flowering**

Number of days taken for the emergence of flowers from the date of sowing was recorded in each plant.

**ii) Plant height (cm)**

Height of plant from the ground level of the main axis to the apical leaflet was measured at the time of harvest and expressed in centimeter.

**iii) Primary branches per plant**

The total number of primary branches borne on the main axis in each plant was counted.

**iv) Pods per plant**

Total number of pods (including both mature and immature pods) produced in each plant were counted together.

**v) Pod yield per plant (g)**

The weight of total pods per plant obtained after optimum drying of the plants was recorded.

**vi) Kernels per plant**

Total number of kernels (including both mature and immature kernels) produced in each plant were counted together

**vii) Kernel yield per plant (g)**

The weight of the total kernels obtained from mature pods per plant was recorded.

**viii) Shelling Percentage**

A random sample of pods from each treatment was drawn and its weight was recorded. Then, the quantity of kernels recovered after shelling the same sample of pods was recorded. The shelling percentage was calculated with the help of following formula;

$$\text{Shelling Percentage} = \frac{\text{Kernel weight (g)}}{\text{Pod weight (g)}} \times 100$$

#### **ix) Specific leaf area (SLA cm<sup>2</sup>/g)**

Third fully expanded leaf of the main branch was collected and the leaf area was measured using leaf area meter. Then the leaves were kept in an oven at 70°C for 3 days. The dry weight of the leaf was accurately measured using a sensitive balance. SLA was computed using the formula.

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

#### **x) SPAD chlorophyll meter reading**

Amongst several leaf characters, leaf thickness and chlorophyll content determines the leaf transmittance characters. Leaf nitrogen content normally influences the leaf chlorophyll content. A device has been developed by Minolta company, New Jersey USA (SPAD-502) which measures the light attenuation at 430nm (the peak wavelength for chlorophyll a and chlorophyll b) and at 750 nm (near infra red) with no transmittance. The unit value measured by the chlorophyll meter is termed as SCMR (SPAD chlorophyll meter reading) which provides information on the relative amount of leaf chlorophyll. The SPAD meter (Soil Plant Analytical Development) is a simple hand held instrument, which operates with DC power of three Volts.

The third leaf from the apex was selected to record the SCMR. Selected leaf of groundnut was clamped avoiding the mid rib region into the sensor head of SPAD meter. A gentle stroke was given to record the SPAD reading and the average of such four strokes was considered. Since groundnut has tetra foliate leaf, SCMR was recorded in all the four leaflets and the average value was recorded. The SCMR was recorded under normal sunlight between 9.00 am to 4.00 pm.

### 3.5 Statistical analysis

The mean of all the above quantitative traits was recorded in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations and were subjected to statistical analysis. The data was analyzed using WINDOSTAT (for augmented design) and SPSS (for descriptive statistics). The details of the statistical methods adopted for analysis of the data are presented below.

The following descriptive statistics will be calculated as per Sundararaj *et al.*, (1972).

#### 3.5.1 Mean

Mean is the sum of all observations in a sample divided by the number of observations (n).

$$\text{Mean} = \Sigma x_i/n$$

Where,

$x_i$  =  $i^{\text{th}}$  observation of a population

n = Total number of observations

#### 3.5.2 Range

The minimum and maximum value on the basis of individual plant observations was used to indicate the limit of range for a given character.

#### 3.5.3 Variance

Variance is defined as the average of the squared deviation of individual observation from the mean or it is the square of the standard deviation. It is estimated by the following formula.

$$\text{Variance} = \frac{\Sigma X_i^2 - (\Sigma X)^2/n}{n-1}$$

Where

$x_i$  =  $i^{\text{th}}$  observation of a population

n = number of observations

### 3.5.4. Standard Deviation

$$\text{Standard deviation (SD)} = \sqrt{\text{Variance}} = \frac{\sum d^2}{N}$$

Where,

d = Deviation of individual value from mean

N = Number of observations

### 3.5.5 Standard Error

It is the measure of uncontrolled variation present in a sample Thus,

$$SE = SD/\sqrt{n}$$

Where,

SD = Standard deviation

n = Number of observations

### 3.5.6 Analysis of variance (ANOVA)

ANOVA was performed following augmented design (Federer, 1956; Federer, 1961).

#### Structure of ANOVA as per augmented design

Source of variation	df	MSS	'F' ratio
Blocks (b)	(b-1)	MSS(b)	MSS(b)/ EMSS
Entries (e) [F <sub>3</sub> progenies + checks]	(e-1)	MSS (e)	MSS(e)/EMSS
Checks (c)	(c-1)	MSS (c)	MSS(c)/EMSS
F <sub>3</sub> progenies (v)	(v-1)	MSS (v)	MSS(v)/EMSS
Checks vs. + F <sub>3</sub> progenies (v)	(c-1) (v-1)	MSS (vc)	MSS (vc)/EMSS
Error	(c-1) (b-1)	EMSS	

Where,

v = Number of progenies

c = Number of check varieties

b = Number of blocks

The significance was tested by referring to the table given by Fisher (1936).

### 3.5.7 Coefficient of variation

The components viz., phenotypic, genotypic and environmental variances were utilized for estimation of coefficient of variation at both phenotypic and genotypic levels for all the characters and computed as suggested by Burton and De Vane (1953).

#### 3.5.7.1 Phenotypic and genotypic variance

Phenotypic and genotypic components of variance in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> population for ten characters were computed as per the method suggested by Weber, Moorthy (1952) and Dabholkar (1992).

i. Phenotypic variance( $\sigma_p^2$ ) = Total observed variance( $\sigma_{pF_2}^2$ )

ii. Genotypic variance( $\sigma_g^2$ ) =  $\sigma_{pF_2}^2 - \sigma_e^2$

Where,  $\sigma_e^2$  = Environmental variance =  $(\sigma_{P_1}^2 + \sigma_{P_2}^2 + 2\sigma_{F_1}^2)/4$

Where,

$\sigma_{P_1}^2$  = Phenotypic variance of parent 1 of that particular cross.

$\sigma_{P_2}^2$  = Phenotypic variance of parent 2 of that particular cross.

$\sigma_{F_1}^2$  = Phenotypic variance of F<sub>1</sub> of that particular cross.

#### 3.5.7.2 Genotypic and phenotypic co-efficient of variation

Both phenotypic and genotypic co-efficient of variation for all the characters were estimated using the formulae of Burton and De Vane (1953).

i. Genotypic Co-efficient of Variation (GCV):

$$G V ( ) = \frac{\sqrt{\sigma^2 g}}{\bar{X}}$$

ii. Phenotypic Co-efficient of Variation (PCV):

$$V ( ) = \frac{\sqrt{\sigma^2 p}}{\bar{X}}$$

Where,

$\bar{X}$  = General mean

$\sigma_p$  = Phenotypic standard deviation

$\sigma_g$  = Genotypic standard deviation

PCV and GCV were classified (Robinson *et al.*, 1949) as given below.

- |                  |          |
|------------------|----------|
| a) 0-10%         | Low      |
| b) 10-20%        | Moderate |
| c) 20% and above | High     |

### 3.5.8 Heritability (broad sense)

Heritability was estimated using the formula (Lush, 1945).

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

Where,

$h^2$  = Heritability percentage

$V_g$  = Genotypic variance

$V_p$  = Phenotypic variance.

The heritability estimates were categorized according to Robinson *et al.*, (1949) and given below.

- |                  |          |
|------------------|----------|
| a) 0-30%         | Low      |
| b) 30-60%        | Moderate |
| c) 60% and above | High     |

#### 3.5.8.1 Narrow sense ( $h^2$ ) heritability (Robinson *et al.*, 1965)

$$h^2(ns) = \frac{\sigma_A^2}{\sigma_P^2} \times 100$$

Where,

$h^2$  = Heritability *per cent* (narrow sense)

$\sigma_A^2$  = Additive genetic variance

$\sigma_P^2$  = Phenotypic variance

### 3.5.9 Genetic advance

The extent of genetic advance that can be expected with five *per cent* selection intensity was calculated by using following formula (Robinson *et al.*, 1949).

$$GA = h^2 \times \sigma_p \times K$$

Where,

K = Selection differential which is 2.06 @ 5% selection intensity

$\sigma_p$  = Phenotypic standard deviation

$h^2$  = Heritability in broad sense

### 3.5.10 Genetic advance as *per cent* of mean (GAM)

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

Where,

GA = Genetic advance

$\bar{X}$  = Mean of character

Genetic advance being categorized based on reports of Johanson *et al.* (1955) as follows.

- |              |          |
|--------------|----------|
| a) 0-10%     | Low      |
| b) 10-20%    | Moderate |
| c) Above 20% | High     |

### 3.5.11 Estimation of correlation coefficient

In all the segregating populations, the simple correlation coefficients were calculated to determine the direction and magnitude of associations among different characters and tested against table 'r' values (Fisher and Yates, 1963) at (n-2) degree of freedom both at 0.05 and 0.01 probability levels for their significance. Simple correlations were calculated by using the formula as given Weber and Moorthy (1952).

$$r_{xy} = \frac{\text{Cov}(xy)}{\sigma_x \sigma_y}$$

Where,

$r_{xy}$  = Correlation coefficient between x and y

$Cov(xy)$  = Covariance of x and y

$\sigma_x$  = Standard deviation of x

$\sigma_y$  = Standard deviation of y

Phenotypic correlations was calculated using the formula

$$r_p(xy) = \frac{P_x.P_y}{\sqrt{V_{px}V_{py}}}$$

Where,

$p_x p_y$  = Phenotypic covariance of x and y

$V_{p_x}$  = Phenotypic variance of x

$V_{p_y}$  = Phenotypic variance of y

$r_p(xy)$  = Phenotypic correlation of x and y

Significance of correlation coefficients was tested at (n-2) degrees of freedom using 't' table from Fisher and Yates at 5% and 1% probability level.

### 3.5.13 Intergeneration correlation and regression analysis

Correlation co-efficient of each character between  $F_3$  and  $F_4$  generation,  $F_3$  to  $F_5$ ,  $F_3$  to  $F_6$ ,  $F_4$  to  $F_5$ ,  $F_4$  to  $F_6$  and  $F_5$  to  $F_6$  was found out by calculating the phenotypic correlation coefficient exactly as described under taking the same character in both the generations.

Intergeneration correlation co-efficient (r) was calculated for each character between two generations. In each case the progeny means (y) generation was recorded on the parental plants (x) generation.

Intergeneration correlation co-efficient (r) =  $b_{yx} \frac{\sigma_x}{\sigma_y}$

$$b_{yx} = \frac{Cov(X,Y)}{V_x}$$

where,

$b_{yx}$  = regression of y on x

$\sigma_x$  = Standard deviation of x

$\sigma_y$  = Standard deviation of y

#### **3.5.14 Narrow sense heritability estimates (based on regression coefficient)**

Narrow sense heritability estimates were made based on the regression of  $F_4$  on  $F_3$ ,  $F_5$  on  $F_4$  and  $F_6$  on  $F_5$  using the following formula (Cahaner and Hillet, 1980).

$$b(F_4, F_3) = \frac{\text{Covariance of } F_4 F_3}{\text{Variance of } F_4}$$

$$h^2 (ns) = b (F_4, F_5) \times 0.67$$

Regression coefficient between  $F_4$  and  $F_3$ ,  $F_5$  and  $F_4$ ,  $F_6$  and  $F_5$  generations was estimated as heritability value using multiplicative factor of  $3/4$ ,  $4/5$  and  $5/6$  respectively. Heritability estimates were computed for the entire population of selected progenies for all the characters.

# *Experimental Results*



## IV. EXPERIMENTAL RESULTS

The success of plant breeding depends on the extent of variability present in a crop. The presence of genetic variability for economic traits is a key factor for improving crop productivity. Variability can be created by hybridization and so created variability need to be assessed in segregating populations. Therefore the present investigation was carried out to assess the extent of variability present in four segregating generations *viz.*, F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> populations of three crosses of groundnut. The results of the present investigation for growth, traits related to Water Use Efficiency (WUE), yield and yield attributing traits of various genetic parameters in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> progenies of three crosses are presented under following headings.

- 4.1 Phenotypic evaluation of F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL populations of the cross NRCG12568 X NRCG12326 for growth, traits related to WUE, yield and its component characters
- 4.2 Phenotypic evaluation of four segregating generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) of the cross NRCG 12473 X ICG12370 for growth, traits related to WUE, yield and its component characters
- 4.3 Phenotypic evaluation of four segregating generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) of the cross NRCG 12274 X ICG12370 for growth, traits related to WUE, yield and its component characters
  1. Analysis of variance
  2. Genetic variability
  3. Association studies
  4. Inter-generation correlation coefficient studies
  5. Correlation and regression analysis of pod yield on its component traits, growth parameters and traits related to WUE
  6. Comparison of Broad sense and narrow sense heritability studies
  7. Test of normality for yield and its attributing traits in F<sub>6</sub> RILs of the cross NRCG 12568 X NRCG 12326.
  8. Assessment of productive segregates in F<sub>6</sub> generation of three crosses

#### **4.1 Phenotypic evaluation F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL populations of the cross NRCG12568 X NRCG12326 for growth, traits related to WUE, yield and its component characters**

553 F<sub>3</sub>, 456 F<sub>4</sub>, 340 F<sub>5</sub> and 325 F<sub>6</sub> Recombinant Inbred Lines developed through single seed descent method were used for phenotypic evaluation. Mean performance of the RILs, parents and checks of the present study is presented in appendix 1 and 2.

##### **4.1.1.1 Analysis of variance**

The mean sum of squares of 553 F<sub>3</sub>, 456 F<sub>4</sub>, 340 F<sub>5</sub> and 325 F<sub>6</sub> RILs of the cross NRCG 12568 × NRCG 12326 for growth, traits related to WUE, yield and its attributing traits were carried out and is presented in Table 2. RILs of all the four generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) registered highly significant differences for days to flowering, plant height, pods per plant, kernels per plant, pod yield and kernel yield. Where as, SLA and SCMR showed the presence of high variability among the RILs in F<sub>5</sub> and F<sub>6</sub> generations. Value of mean sum of square for RILs and checks also exhibited highly significant difference for all the characters except primary branches per plant, SLA, SCMR and shelling percentage. However, checks *verses* RILs also exhibited significant variability for all the traits except plant height and pod yield per plant in F<sub>5</sub> and F<sub>6</sub> generations.

##### **4.1.1.2 Genetic variability studies**

To know the extent of genetic variability present in RILs of all the four generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>), data on various genetic parameters *viz.*, mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability ( $h^2$ ) and genetic advance as per cent of mean (GAM) are presented characterwise in Table 3.

##### **4.1.2.1. Days to flowering**

Days to flowering showed mean values of 39.93, 39.45, 37.58 and 39.63 days in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations respectively. Minimum of 25.17 days was observed in F<sub>4</sub> generation followed by 25.75 days, 26.75 days and 28.80 days in F<sub>6</sub>, F<sub>3</sub> and F<sub>5</sub> generations respectively. Wider range was observed in all the four generations.

**Table 2: Analysis of variance for growth parameters, traits related to WUE, yield and its component traits in recombinant inbred lines (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) of the cross NRCG12568 × NRCG12326 in groundnut**

Source of variance		Df	Days to first Flowering	Plant height (cm)	Primary branches/plant	SLA (cm <sup>2</sup> /g)	SCMR	Pods/plant (g)	Pod yield/plant (g)	Kernels/plant	Kernel yield/plant (g)	Shelling Percentage
Block (eliminating Check + Va.)	F <sub>3</sub>	6	3.87	23.66**	0.14	413.08	22.97	6.99	10.25	91.87	3.47	30.42
	F <sub>4</sub>	5	1.65	11.97	1.35	238.46	339.99*	48.56**	52.63	224.32*	18.23	20.09
	F <sub>5</sub>	4	3.94	3.01	0.28	816.39	184.20**	47.95**	171.91	502.53	13.78	20.51
	F <sub>6</sub>	4	5.57	0.97	0.13	537.42	12.82	3.52	18.29	24.16	6.77	3.68
Progenies + Checks	F <sub>3</sub>	555	38.96**	38.98**	0.64	2323.93	22.37	134.33**	186.21**	424.27**	83.30**	166.04
	F <sub>4</sub>	458	36.90**	30.50**	1.35*	1588.48	206.31*	107.15**	213.00**	335.17**	72.70**	95.40
	F <sub>5</sub>	342	27.28**	22.79**	0.38	2575.23**	224.84**	88.44**	368.93*	964.40**	54.25**	83.50*
	F <sub>6</sub>	327	34.00*	34.23**	0.36	4304.54**	175.52**	84.65**	133.60**	472.60**	53.36**	58.98
Checks	F <sub>3</sub>	3	148.04**	328.90**	1.03	2586.26**	94.85**	101.02**	290.52**	1711.33**	38.69*	547.38*
	F <sub>4</sub>	3	130.56**	3.67	0.16	2998.52	268.98	94.13**	141.96*	875.13**	68.24*	306.73*
	F <sub>5</sub>	3	66.13**	72.93**	0.02	1566.13	16.11**	85.15**	70.47	116.12**	44.42*	387.10**
	F <sub>6</sub>	2	12.6	5.83	0.02	639.37	24.66	110.36**	263.52**	292.95*	71.54**	203.32
Progenies	F <sub>3</sub>	552	38.34**	36.02**	0.62	2217.15	19.73	134.70**	186.16**	417.19**	83.26**	159.75
	F <sub>4</sub>	456	36.29**	30.67**	1.35*	1563.19	206.12*	107.43**	213.60**	333.08**	72.71**	94.14
	F <sub>5</sub>	339	27.03**	22.53**	0.37	2518.06**	226.06**	88.66**	363.85*	945.88*	53.68**	81.35*
	F <sub>6</sub>	324	33.52*	34.50**	0.31	4241.72**	176.49**	84.32**	133.20**	475.44**	53.31**	56.847
Checks vs Progenies	F <sub>3</sub>	1	153.63**	10.08**	11.65**	1268.36*	129.18**	1.67	1.06	165.08**	190.24**	278.24**
	F <sub>4</sub>	1	118.89**	9.69	2.93*	9816.65*	163.07	10.67	93.22	168.94	77.58*	226.65
	F <sub>5</sub>	1	28.70**	4.09	4.17**	2283.65**	252.55**	25.33*	386.60**	698.39*	256.62**	164.05*
	F <sub>6</sub>	1	233.20**	1.34	16.52**	3198.21**	162.72**	41.76**	5.54	313.14**	32.96*	461.33*
Error	F <sub>3</sub>	12	4.57	4.84	0.57	1571.28	10.03	8.04	12.48	62.22	8.92	80.56
	F <sub>4</sub>	10	4.95	6.03	0.45	898.15	75.47	5.16	27.35	46.73	11.33	71.69
	F <sub>5</sub>	8	1.93	1.57	0.25	364.56	1.65	2.32	259.24	512.33	9.36	20.12
	F <sub>6</sub>	8	7.02	2.74	0.28	409.07	9.37	3.94	5.99	14.5	3.65	52.59

\*Significant @ P =0.05      \*\* Significant @ P = 0.01

Estimated values of both GCV and PCV have decreased from F<sub>3</sub> RILs to F<sub>6</sub> RILs with a value of GCV (14.36 and 12.77), PCV (15.32 and 14.41) in F<sub>3</sub> and F<sub>4</sub> respectively and difference between the GCV and PCV is low in RILs of all the four generations. High heritability (87.78, 86.02, 92.63 and 78.51) coupled with moderate GAM (27.70, 26.71, 25.98 and 23.31) was observed in all four RILs *i.e.*, in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs respectively.

#### **4.1.2.2 Plant height (cm)**

The highest mean value for plant height was found in F<sub>3</sub>RIL (27.02 cm) population compared to F<sub>4</sub> RIL (21.06 cm) followed by F<sub>6</sub> RIL (19.59 cm) and F<sub>5</sub> RIL (18.77cm). F<sub>6</sub> RIL exhibited wider range (11.08 cm to 36.08 cm) for the plant height compared to F<sub>3</sub> RIL (13.23 cm to 22.38 cm), F<sub>4</sub> RIL (10.83cm to 30.38cm) and F<sub>5</sub> RIL (10.80 cm to 29.80cm).

The estimates of GCV and PCV were moderate in all RILs of all the four generations. The value of both genotypic and phenotypic coefficients of variability increased from F<sub>3</sub> RIL (21.95 and 23.24), F<sub>4</sub> RIL (23.24 and 26.00), F<sub>5</sub> RIL (23.99 and 24.90) and F<sub>6</sub> RIL (28.29 and 29.53). F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL populations exhibited higher heritability (86.23, 79.88, 92.82 and 91.82) coupled with high GAM (38.98, 42.78, 47.60 and 55.85).

#### **4.1.2.3 Primary branches per plant**

The mean value for number of branches per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL populations is 5.90, 5.47, 5.62 and 4.71 with a range of 3.14 to 7.50, 2.78 to 7.65, 3.98 to 7.22 and 3.36 to 6.89 was found in respective RIL populations. The observed GCV (21.18 and 17.18) and PCV (26.12 and 21.12) were moderate in F<sub>3</sub> and F<sub>4</sub> RILs. Whereas F<sub>5</sub> and F<sub>6</sub> RILs exhibited lower GCV and PCV with the value of 6.04 and 10.69 in F<sub>5</sub> RILs and in F<sub>6</sub> it was 7.85 and 11.89 respectively. Lower heritability coupled with low GAM was found in F<sub>5</sub> RIL (31.09 and 7.02 respectively). Moderate heritability and high GAM was observed in F<sub>3</sub>RIL (58.18 and 32.78 respectively), higher heritability (66.18 and

**Table 3: Genetic variability parameters for growth, traits related to WUE, yield and its component traits in recombinant inbred line population for four generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) of the cross NRCG12568 × NRCG12326 in groundnut**

CHARAECTERS		MEAN	RANGE		GCV (%)	PCV (%)	h <sup>2</sup> <sub>bs</sub> (%)	GAM
			MIN	MAX				
Days to first flowering	F <sub>3</sub>	39.93	26.75	42.88	14.36	15.32	87.78	27.70
	F <sub>4</sub>	39.45	25.17	44.00	13.98	15.08	86.02	26.71
	F <sub>5</sub>	37.58	28.80	39.13	13.11	13.62	92.63	25.98
	F <sub>6</sub>	39.63	25.75	45.21	12.77	14.41	78.51	23.31
Plant height (cm)	F <sub>3</sub>	27.02	13.23	29.38	20.38	21.95	86.23	38.98
	F <sub>4</sub>	21.06	10.83	30.38	23.24	26.00	79.88	42.78
	F <sub>5</sub>	18.77	10.80	29.80	23.99	24.90	92.82	47.60
	F <sub>6</sub>	19.59	11.08	36.08	28.29	29.53	91.81	55.85
Primary branches/plant	F <sub>3</sub>	5.90	3.14	7.50	21.18	26.12	58.18	32.78
	F <sub>4</sub>	5.47	2.78	7.65	17.18	21.12	66.18	28.78
	F <sub>5</sub>	5.62	3.98	7.22	6.04	10.69	31.09	7.02
	F <sub>6</sub>	4.71	3.36	6.89	7.85	11.89	66.25	16.54
SLA (cm <sup>2</sup> /g)	F <sub>3</sub>	186.43	79.10	318.09	13.45	25.16	68.57	14.80
	F <sub>4</sub>	175.83	84.10	281.94	14.45	22.35	71.88	19.25
	F <sub>5</sub>	176.97	83.31	337.82	25.78	27.95	85.10	48.99
	F <sub>6</sub>	212.54	102.75	325.23	28.68	30.22	90.06	56.71
SCMR	F <sub>3</sub>	13.63	5.57	32.12	22.53	32.37	48.46	32.31
	F <sub>4</sub>	37.67	7.15	73.31	29.90	37.76	62.71	48.77
	F <sub>5</sub>	18.80	7.02	67.19	77.33	78.63	96.24	84.23
	F <sub>6</sub>	38.15	10.43	70.20	33.32	34.27	94.52	66.73
Pods /Plant	F <sub>3</sub>	26.23	8.79	87.50	42.33	43.69	93.88	84.48
	F <sub>4</sub>	24.10	5.85	70.94	41.35	42.42	95.06	83.05
	F <sub>5</sub>	24.30	6.30	70.94	37.60	38.12	97.28	76.38
	F <sub>6</sub>	25.00	8.25	58.93	35.26	36.15	95.18	70.87
Pod yield/plant (g)	F <sub>3</sub>	27.60	7.84	96.37	47.10	48.81	93.12	93.63
	F <sub>4</sub>	24.86	6.34	90.36	54.10	58.04	86.87	85.32
	F <sub>5</sub>	27.12	11.63	98.37	42.75	48.90	70.87	56.79
	F <sub>6</sub>	24.32	5.16	67.29	45.60	46.69	95.36	91.73
Kernels/plant	F <sub>3</sub>	47.92	16.38	141.37	38.78	42.13	84.73	73.53
	F <sub>4</sub>	40.91	9.44	112.79	40.76	44.05	85.61	77.69
	F <sub>5</sub>	48.29	13.22	108.66	31.04	35.19	77.82	56.41
	F <sub>6</sub>	39.10	9.04	96.25	54.05	54.87	96.85	92.33
Kernel yield/plant(g)	F <sub>3</sub>	19.13	4.23	63.62	44.46	47.12	89.03	86.42
	F <sub>4</sub>	17.78	4.72	62.65	43.44	47.39	84.03	82.02
	F <sub>5</sub>	18.29	7.56	62.65	35.79	39.50	82.07	66.78
	F <sub>6</sub>	13.95	2.13	41.89	49.67	51.32	92.95	98.65
Shelling percentage	F <sub>3</sub>	70.78	40.40	96.77	12.40	17.74	48.88	17.86
	F <sub>4</sub>	74.09	49.05	96.72	6.30	13.05	33.31	6.26
	F <sub>5</sub>	67.81	43.51	93.64	11.35	13.13	74.64	20.19
	F <sub>6</sub>	55.19	42.15	76.18	8.25	13.64	60.48	36.21

66.25) coupled with moderate GAM (28.78 and 16.54) was noticed in F<sub>4</sub> and F<sub>6</sub> RIL populations.

#### 4.1.2.4 Specific leaf Area (cm<sup>2</sup>/g)

SLA showed high variability with a minimum value of 79.10 cm<sup>2</sup>/g, maximum of 318 cm<sup>2</sup>/g with a mean of 186.43 cm<sup>2</sup>/g in F<sub>3</sub> RIL. The value of SLA varies from 84.0 cm<sup>2</sup>/g to 281.94 cm<sup>2</sup>/g with a mean of 175.83 cm<sup>2</sup>/g was recorded in F<sub>4</sub> RIL. Both F<sub>5</sub> and F<sub>6</sub> RILs exhibited higher mean (176.97 cm<sup>2</sup>/g and 212.54 cm<sup>2</sup>/g respectively) with wider range (83.31 cm<sup>2</sup>/g to 337.82 and 102.75 cm<sup>2</sup>/g to 325.23 cm<sup>2</sup>/g of respectively). GCV and PCV were found to be moderate in all the four generations with the value of 13.45 and 25.16 in F<sub>3</sub> RIL, 14.45 and 22.35 in F<sub>4</sub> RIL, 25.78 and 27.95 in F<sub>5</sub>, 28.68 and 30.22 in F<sub>6</sub> RIL. High heritability (88.57 and 71.18) coupled with moderate GAM (14.80 and 19.25) was noticed in F<sub>3</sub> and F<sub>4</sub> RILs respectively. Where as in F<sub>5</sub> and F<sub>6</sub> RILs presence of high heritability (85.10 and 90.06 *per cent* of respectively) and high GAM (48.99 and 56.71 of respectively) was observed.

#### 4.1.2.5 SPAD chlorophyll meter reading (SCMR)

SCMR varied from 5.57 to 32.11 with a mean value of 13.63 in F<sub>3</sub>, 7.15 to 73.11 with a mean value of 37.67 in F<sub>4</sub> RILs. F<sub>5</sub> RILs had lower mean (18.80) wider range (7.02 to 67.19). Where as higher mean (38.15) and narrow range (10.43 to 70.20) was observed in F<sub>6</sub> RILs. Moderate GCV (22.53 and 29.90) and higher PCV (32.37 and 62.71) was observed in F<sub>3</sub> and F<sub>4</sub> RILs respectively, where as in other two generations *i.e.*, F<sub>5</sub> and F<sub>6</sub> RILs recorded with higher GCV (78.33 and 33.32 of respective RILs) and PCV (78.63 and 34.27 of respective RILs). Moderate heritability (48.46%) coupled with high genetic advance as *percent* of mean (32.31%) was observed in F<sub>3</sub> RILs. The *per cent* of heritability and GAM was high in F<sub>4</sub> (62.71 and 48.77), F<sub>5</sub> (99.24 and 84.23) and F<sub>6</sub> RILs (94.52 and 66.73) for this character.

#### 4.1.2.6 Pods per plant

Wider range of variation was observed in all the four generations *i.e.*, 8.79 to 87.50 pods per plant in F<sub>3</sub>, 5.85 to 70.94 in F<sub>4</sub>, 6.30 to 7.94 in F<sub>5</sub> and 8.25 to 58.93 in F<sub>6</sub>

RIL populations. The mean value for number of pods per plant remain consisted in F<sub>3</sub> (26.23), F<sub>4</sub> (24.10), F<sub>5</sub> (24.30) and F<sub>6</sub> (25.00) RILs. The *per cent* of genotypic and phenotypic coefficient of variability in F<sub>3</sub> (42.33 and 43.69 %), F<sub>4</sub> (41.35 and 42.42 %), F<sub>5</sub> (37.60 and 38.12 %) and in F<sub>6</sub> RILs (35.26 and 36.15 %) was observed to be higher and variability for number of pods per plant over generations remain unchanged. Heritability and GAM in F<sub>3</sub> (93.88 and 84.48), F<sub>4</sub> (95.06 and 83.05), F<sub>5</sub> (97.28 and 76.38) and in F<sub>6</sub> (95.18 and 70.81) RIL populations was found be high and all most same in all the generations.

#### **4.1.2.7 Pod yield per plant (g)**

Pod yield per plant showed maximum yield of 98.37 g per plant(F<sub>3</sub> RIL) and it was slightly decreased to 96.37 g per plant (F<sub>4</sub> RIL) followed by 90.36 g per plant (F<sub>5</sub> RIL) and 67.29 g per plant ( F<sub>6</sub> RIL) was observed. Where as mean value of pod yield per plant in F<sub>3</sub> is 27.60 g, 24.86 g in F<sub>4</sub>, 27.12 g in F<sub>5</sub> and in F<sub>6</sub> RIL 24.32 g was found to be same. Both genotypic and phenotypic coefficient of variability was very high in all the four generations *i.e.*, 47.10 *per cent* (GCV) and 48.81 *per cent* (PCV) in F<sub>3</sub>, 54.10 *per cent* (GCV) and 58.04 *per cent* (PCV), in F<sub>4</sub>, 32.75 *per cent*(GCV) and 38.90 *per cent* (PCV) in F<sub>5</sub> and in F<sub>6</sub> RIL it was 45.60 *per cent* (GCV) and 46.69 *per cent* (PCV). High heritability (93.12, 86.87, 70.87 and 95.36%) coupled with high genetic advance as *per cent* of mean (93.63, 85.32, 56.79 and 91.73%) with respect to F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs was observed for this character. Heritability and GAM was shown fluctuation over the generations.

#### **4.1.2.8 Kernels per plant**

The range for number of kernels per plant was noticed highest in F<sub>3</sub> RIL (16.38 kernels per plant) followed by F<sub>4</sub> RIL (9.44 to 112.37 kernels per plant) and F<sub>5</sub> RIL (13.22 to 121.66 kernels per plant) and lowest range was observed in F<sub>6</sub> RIL (9.04 to 96.25 kernels per plant). The mean value of F<sub>3</sub> (47.92 kennels per plant), F<sub>4</sub> (40.91 kernels per plant) and F<sub>5</sub> RILs (48.29 kernels per plant) exhibited similar mean values, where as drastic reduction for the mean value was observed in F<sub>6</sub> RIL (39.10 kernels per plant) in comparison to F<sub>5</sub> RIL. All the four generation showed the presence of higher

GCV and PCV values. Compared to F<sub>3</sub> (38.78 and 42.13) and F<sub>5</sub> RILs (31.04 and 35.19) the highest GCV and PCV values were noticed in F<sub>4</sub> (40.76 and 44.05) and F<sub>6</sub> RILs (54.05 and 54.87). Higher heritability coupled with higher GAM was found in all the four generations. However heritability and GAM was increasing from F<sub>3</sub> (87.73 and 73.53), to F<sub>4</sub> (85.61 and 77.69) and F<sub>6</sub> RIL (96.85 and 92.33). Except in F<sub>5</sub> RIL (77.82 and 56.41) there is drastic reduction of heritability and GAM was observed. High heritability was recorded for this trait with a value of 95.13 *per cent*. GAM was found to be 33.12 *per cent*.

#### **4.1.2.9 Kernel yield per plant (g)**

Kernel yield per plant exhibited a constant mean and range value from F<sub>3</sub> (19.13 g per plant with a range of 4.23 to 63.62) to F<sub>4</sub> (17.78 g per plant with a range of 4.72 to 62.65) and F<sub>5</sub> RILs (18.29 g per plant with a range of 7.56 to 62.65). Where as mean value and range for kernel yield per plant has decreased in F<sub>6</sub> RIL population (13.95 g per plant with a range of 2.13 to 41.89). This character exhibited high GCV and PCV with values of 44.46 and 47.12 in F<sub>3</sub> RIL, 43.44 and 47.39 in F<sub>4</sub> RIL, 35.79 and 39.50 in F<sub>5</sub> RIL, 49.67 and 51.32 in F<sub>6</sub> RIL population respectively. Higher heritability coupled with higher GAM was prevailed in all the four generations *i.e.*, 89.03 and 86.42 in F<sub>3</sub> RIL, 84.03 and 82.02 in F<sub>4</sub> RIL, 82.07 and 66.72 in F<sub>5</sub> RIL and F<sub>6</sub> RIL expressed heritability (92.95) and GAM (98.65) for this character.

#### **4.1.2.10 Shelling percentage**

Wide range of variation was observed for this character in F<sub>3</sub> RIL (4.40 to 96.77%), F<sub>4</sub> RIL (49.05 to 96.72%), F<sub>5</sub> RIL (43.51 to 93.64%) and F<sub>6</sub> RIL (42.15 to 76.185). Highest mean value was recorded in F<sub>4</sub> RIL (74.09%) and it decreased in F<sub>5</sub> RIL (67.81%) and further decreased in F<sub>6</sub> RIL (55.19%). The GCV and PCV were moderate in F<sub>3</sub> RIL generation (12.40 and 17.74) and F<sub>5</sub> (11.35 and 13.13) RILs. Lower GCV and moderate PCV was observed in F<sub>4</sub> RIL (6.30 and 13.05) and F<sub>6</sub> RIL (8.25 and 13.64). Moderate heritability coupled with moderate GAM was found in F<sub>3</sub> RIL (48.88 and 17.86), moderate heritability and low GAM was noticed in F<sub>4</sub> (33.31 and 6.26) RIL,

high heritability and moderate GAM was observed in F<sub>5</sub> RIL. Where as F<sub>6</sub> RIL (60.48 and 36.21) exhibited higher heritability and higher GAM for this character.

#### **4.1.3 Association studies**

Selection for specific character is known to result in correlated response in certain other characters. Generally, plant breeders make selection for one or two attributes at a time. Then it becomes important to know the effect of independent characters on other dependent characters. Improvement on pod yield per plant and the most important target traits in groundnut can be achieved by indirect selection through other easily observable characters. But this needs good understanding of association of different traits with pod yield per plant and their possible associations among themselves. Hence, the present investigation was carried out on phenotypic correlations of pod yield per plant with growth parameters, traits related to WUE and its component characters.

The phenotypic correlation co-efficient among all the characters was estimated in 553F<sub>3</sub>, 456 F<sub>4</sub>, 340 F<sub>5</sub> and 325 F<sub>6</sub> RILs of the cross NRCG 12568 and NRCG 12326 and results are presented in Table 4.

##### **4.1.3.1 Correlation coefficient of pod yield per plant with other characters**

The phenotypic correlation coefficient values were calculated by regressing phenotypic values of one trait on with other trait. Pod yield per plant showed significantly positive association in all the four segregating populations *i.e.*, F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations with SCMR (0.27, 0.63, 0.64 and 0.88), pods per plant (0.84, 0.83, 0.81 and 0.87 ) and kernels per plant (0.89, 0.89, 0.79 and 0.73), where as shelling percentage (-0.18, -0.37, -0.12 and -0.23) and SLA (-0.24, -0.55, -0.39 and -0.81) exhibited significantly negative correlation with pod yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL populations respectively.

**Table 4: Phenotypic correlation coefficients among growth parameters, traits related to WUE, yield and its component traits in recombinant inbred lines for four generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) of the cross NRCG12568 × NRCG12326 in groundnut**

Characters	Generations	Pods /plant	Kernels /plant	Kernel yield / plant (g)	Shelling percentage	SLA (cm <sup>2</sup> /g)	SCMR	Pod yield /plant (g)
Pods /plant	F <sub>3</sub>	<b>1.00</b>	0.93**	0.90**	0.10*	-0.56**	0.59**	0.62**
	F <sub>4</sub>	<b>1.00</b>	0.90**	0.86**	0.05	-0.74**	0.84**	0.74**
	F <sub>5</sub>	<b>1.00</b>	0.18*	0.87**	0.11*	-0.78**	0.88**	0.68**
	F <sub>6</sub>	<b>1.00</b>	0.86**	0.76**	0.03	-0.27*	0.86**	0.95**
Kernels / plant	F <sub>3</sub>		<b>1.00</b>	0.93**	-0.05	-0.60**	0.63**	0.69**
	F <sub>4</sub>		<b>1.00</b>	0.95**	-0.04	-0.87**	0.94**	0.70**
	F <sub>5</sub>		<b>1.00</b>	0.07	0.19*	-0.02	0.17*	0.07
	F <sub>6</sub>		<b>1.00</b>	0.96**	-0.04	-0.33*	0.88**	0.97**
Kernel yield / plant (g)	F <sub>3</sub>			<b>1.00</b>	0.12*	-0.48*	0.51**	0.57**
	F <sub>4</sub>			<b>1.00</b>	0.04	-0.92**	0.99**	0.59**
	F <sub>5</sub>			<b>1.00</b>	0.09	-0.93**	0.89**	0.65**
	F <sub>6</sub>			<b>1.00</b>	0.11*	-0.35*	0.92**	0.98**
Shelling percentage	F <sub>3</sub>				<b>1.00</b>	0.29*	-0.27*	-0.17*
	F <sub>4</sub>				<b>1.00</b>	-0.02	0.05	-0.11*
	F <sub>5</sub>				<b>1.00</b>	-0.02	0.09	-0.43**
	F <sub>6</sub>				<b>1.00</b>	0.01	-0.01	-0.03
SLA (cm <sup>2</sup> /g)	F <sub>3</sub>					<b>1.00</b>	-0.93**	-0.66**
	F <sub>4</sub>					<b>1.00</b>	-0.92**	-0.53**
	F <sub>5</sub>					<b>1.00</b>	-0.94**	-0.63**
	F <sub>6</sub>					<b>1.00</b>	-0.36	-0.35*
SCMR	F <sub>3</sub>						<b>1.00</b>	0.68**
	F <sub>4</sub>						<b>1.00</b>	0.56**
	F <sub>5</sub>						<b>1.00</b>	0.65**
	F <sub>6</sub>						<b>1.00</b>	0.94**
Pod yield / plant (g)	F <sub>3</sub>							<b>1.00</b>
	F <sub>4</sub>							<b>1.00</b>
	F <sub>5</sub>							<b>1.00</b>
	F <sub>6</sub>							<b>1.00</b>

\*Significant @ P =0.05      \*\* Significant @ P = 0.01

#### **4.1.3.2 Association among growth, traits related to WUE and yield attributing characters**

SCMR is significantly positively correlated with pod yield per plant (0.68, 0.56, 0.65 and 0.94), kernels per plant (0.63, 0.94, 0.17 and 0.88) and kernel yield per plant (0.51, 0.99, 0.89 and 0.92) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs respectively and it exhibited the negative significant correlation with shelling percentage (-0.27 in F<sub>3</sub> RILs) and SLA (-0.93, -0.92, -0.94 and -0.36 in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL respectively).

Pods per plant exhibited significant positive correlation with kernel yield per plant (0.90, 0.86, 0.87 and 0.76), kernel per plant (0.93, 0.90, 0.18 and 0.86), and pod yield per plant (0.62, 0.74, 0.68 and 0.95) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs respectively at phenotypic levels. Significant negative correlation was observed for specific leaf area (-0.56, -0.74, -0.78 and -0.27 in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL respectively) at phenotypic level.

Kernel yield per plant showed significant positive correlation with pod yield per plant (0.57, 0.59, 0.65 and 0.98), pods per plant (0.62, 0.74, 0.65 and 0.98) and SCMR (0.51, 0.99, 0.89 and 0.92) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs respectively. Where as negative significant correlation was observed with SLA (-0.48, -0.92, -0.93 and -0.35 in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs).

SLA exhibited significant negative correlation with pod yield per plant (-0.66, -0.53, -0.63 and -0.35), pods per plant (-0.56, -0.74, -0.78 and -0.27), kernels per plant (-0.60, -0.87, -0.02 and -0.33) and SCMR (-0.93, -0.92, -0.94 and -0.36) at phenotypic level in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL respectively.

#### **4.1.4 Intergeneration correlation studies**

The analysis was made to determine the relationship among F<sub>3</sub> to F<sub>6</sub> generations for the traits such as days to flowering, plant height, primary branches per plant, SCMR, SLA, pods per plant, kernels per plant, pod yield per plant, kernel yield per plant and shelling percentage. Results pertaining to this have been presented in Table 5.

**Table 5: Intergeneration correlation coefficients for growth parameters, traits related to WUE, yield and its component traits from F<sub>3</sub> to F<sub>6</sub> generations of recombinant inbred lines of the cross NRCG12568 × NRCG12326 in groundnut**

Characters	Generations	F <sub>3</sub>	F <sub>4</sub>	F <sub>5</sub>	F <sub>6</sub>
Days to flowering	F <sub>3</sub>	<b>1.00</b>	0.31**	0.25*	0.32**
	F <sub>4</sub>		<b>1.00</b>	0.73**	0.16*
	F <sub>5</sub>			<b>1.00</b>	0.27*
	F <sub>6</sub>				<b>1.00</b>
Plant height (cm)	F <sub>3</sub>	<b>1.00</b>	0.38**	-0.02	0.09
	F <sub>4</sub>		<b>1.00</b>	0.41**	0.14*
	F <sub>5</sub>			<b>1.00</b>	0.26
	F <sub>6</sub>				<b>1.00</b>
Primary branches/plant	F <sub>3</sub>	<b>1.00</b>	0.33**	0.02	0.47**
	F <sub>4</sub>		<b>1.00</b>	0.13*	0.18*
	F <sub>5</sub>			<b>1.00</b>	0.22*
	F <sub>6</sub>				<b>1.00</b>
Pods / plant	F <sub>3</sub>	<b>1.00</b>	0.13*	0.06	0.17*
	F <sub>4</sub>		<b>1.00</b>	0.24*	0.21*
	F <sub>5</sub>			<b>1.00</b>	0.56**
	F <sub>6</sub>				<b>1.00</b>
Kernels/ plant	F <sub>3</sub>	<b>1.00</b>	0.12	0.01	0.12
	F <sub>4</sub>		<b>1.00</b>	0.22*	0.15*
	F <sub>5</sub>			<b>1.00</b>	0.34**
	F <sub>6</sub>				<b>1.00</b>
Kernel yield per plant (g)	F <sub>3</sub>	<b>1.00</b>	0.11	0.02	0.05
	F <sub>4</sub>		<b>1.00</b>	0.13	0.04
	F <sub>5</sub>			<b>1.00</b>	0.51**
	F <sub>6</sub>				<b>1.00</b>
Shelling per cent age	F <sub>3</sub>	<b>1.00</b>	0.27*	0.04	0.05
	F <sub>4</sub>		<b>1.00</b>	0.18*	0.01
	F <sub>5</sub>			<b>1.00</b>	0.12
	F <sub>6</sub>				<b>1.00</b>
SLA (cm <sup>2</sup> /g)	F <sub>3</sub>	<b>1.00</b>	0.09	0.02	0.05
	F <sub>4</sub>		<b>1.00</b>	0.23*	0.15*
	F <sub>5</sub>			<b>1.00</b>	0.30**
	F <sub>6</sub>				<b>1.00</b>
SCMR	F <sub>3</sub>	<b>1.00</b>	0.14	0.05	0.12
	F <sub>4</sub>		<b>1.00</b>	0.23*	0.02
	F <sub>5</sub>			<b>1.00</b>	0.35**
	F <sub>6</sub>				<b>1.00</b>
Pod yield/ plant (g)	F <sub>3</sub>	<b>1.00</b>	0.11	0.05	0.10
	F <sub>4</sub>		<b>1.00</b>	0.29*	0.07
	F <sub>5</sub>			<b>1.00</b>	0.47**
	F <sub>6</sub>				<b>1.00</b>

Significant and positive correlation of F<sub>3</sub> RIL on F<sub>4</sub> RIL for days to flowering (0.31), plant height (0.38), primary branches per plant (0.33), and shelling percentage (0.27) was observed. Only primary branches per plant exhibited significant positive association between F<sub>3</sub> RIL and F<sub>6</sub> RILs.

Days to flowering (0.73), plant height (0.41), pods per plant (0.24), SLA (0.23) SCMR (0.33) and pod yield per plant (0.29) are found to be having significant positive association between F<sub>4</sub> RIL and F<sub>5</sub> RILs.

The traits such as days to flowering (0.16), plant height (0.14), primary branches per plant (0.18), pods per plant (0.21), kernels per plant (0.15) and SLA (0.15) were correlated positively between F<sub>4</sub> RILs with F<sub>6</sub> RILs.

Except shelling percentage all the traits *i.e.*, days to flowering (0.27), plant height (0.26), primary branches per plant (0.22), pods per plant (0.56), kernels per plant (0.34), kernel yield per plant (0.51), SLA (0.30), SCMR (0.35) and pod yield per plant (0.47) are found to be having significantly positive correlation between F<sub>5</sub> RILs and F<sub>6</sub> RILs.

#### **4.1.5 Correlation and regression of pod yield on its components traits and traits related to WUE**

Regression of pod yield on its component traits and traits related to WUE was carried out at phenotypic level taking pod yield per plant as the dependent character. Results' pertaining to this has been presented in Table 6.

In F<sub>3</sub> RIL the traits such as kernel yield per plant was found to be having positive association (0.90) with maximum positive effect (1.40) on pod yield per plant followed by pods per plant (0.83 and 1.07), kernels per plant (0.95 and 0.67), SCMR (0.90 and 0.68) and days to flowering ( 0.20 and 0.11), where as some other traits *viz.*,SLA (-0.83 and -0.13) correlation and shelling percentage (-0.14 and -0.18) had significantly negative association with negative effect on pod yield per plant.

Pod yield per plant was positively (0.88) associated and higher positive effect (1.52) with kernel yield per plant, pods per plant (0.811 and 1.13), kernels per plant (0.93

**Table 6: Correlation and regression of pod yield on growth parameters, traits related to WUE and yield component traits in recombinant inbred line population for four generations of the cross NRCG12568 × NRCG12326 in groundnut**

Characters	F <sub>3</sub> generation		F <sub>4</sub> generation		F <sub>5</sub> generation		F <sub>6</sub> generation	
	r-value	b-value	r-value	b-value	r-value	b-value	r-value	b-value
<b>Days to first flower</b>	0.08	0.04	0.04	0.09	0.04	0.34	0.06	0.01
<b>Plant height (cm)</b>	-0.01	-0.01	-0.08	-0.20	-0.08	-0.02	-0.03	-0.06
<b>Primary branches/plant</b>	0.06	0.96	-0.22*	-3.68	-0.01	-0.37	-0.09	-1.89
<b>SLA (cm<sup>2</sup>/g)</b>	-0.24*	-0.04	-0.55**	-0.08	-0.39*	-0.04	-0.81**	-0.14
<b>SCMR</b>	0.27*	0.24	0.63**	0.43	0.64**	0.47	0.88**	0.76
<b>Pods / plant</b>	0.84**	0.95	0.83**	1.03	0.81**	0.90	0.87**	1.09
<b>Kernels/ plant</b>	0.89**	0.57	0.89**	0.62	0.79**	0.48	0.73**	0.39
<b>Kernel yield / plant (g)</b>	0.92**	1.30	0.94**	1.42	0.86**	1.12	0.97**	1.54
<b>Shelling percentage</b>	-0.18*	-0.22	-0.37*	-0.43	-0.12*	-0.15	-0.23*	-0.35

\* Significant @ P=0.05    \*\* Significant @ P= 0.01

and 0.69), SCMR (0.79 and 0.55) and days to flowering (0.12 and 0.20) correlation in F<sub>4</sub> RIL was observed. SLA (-0.29 and -0.02) and shelling percentage (-0.35 and -0.41) were found to be having negative association as well as negative effect on pod yield per plant in F<sub>4</sub> RIL.

The positive association and positive effect of kernel yield per plant (0.94 and 2.09) on determination of pod yield per plant in F<sub>5</sub> RIL was found to be very high compared to SCMR (0.87 and 0.56), Kernels per plant (0.90 and 0.78) and pods per plant (0.75 and 1.33). Negative association and negative effect of SLA (-0.81 and -0.12) on pod yield per plant was more than the shelling percentage (-0.30 and -0.54) in F<sub>5</sub> RIL.

F<sub>6</sub> RIL showed the presence of positive association (0.90) and positive effect (0.96) of pods per plant, kernels per plant (0.95 and 0.97), kernel yield per plant (0.88 and 1.27) and SCMR (0.81 and 0.72) on pod yield per plant. Negative association and negative effect of SLA (-0.89 and -0.02) and shelling percentage (-0.22 and -0.06) on pod yield per plant was also observed in F<sub>6</sub> RIL population.

#### **4.1.6 Broad sense and narrow sense heritability estimates for growth, traits related to WUE and yield component characters**

The evaluation of parent and progeny provided an opportunity to compute heritability values following parent offspring regression method involving F<sub>3</sub> plant data and F<sub>4</sub> progeny mean for narrow sense heritability of F<sub>4</sub> RIL, similarly narrow sense heritability was estimated in F<sub>5</sub> and F<sub>6</sub> RIL populations. The heritability estimates computed by regression method can be utilized for predicting the response to selection in early and advanced generations. Comparison was made between broad sense and narrow sense heritability to know the difference between them and results are presented in Table 7.

The results depicted that broad sense heritability recorded high for all the characters in F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs except primary branches per plant in F<sub>5</sub> RILs which showed the presence of moderate heritability.

**Table 7: Comparison between broad sense and narrow sense heritability for growth parameters, traits related to WUE, yield and its component traits in recombinant inbred line population for four generation in the cross of NRCG12568 × NRCG12326 in groundnut**

Characters	F <sub>3</sub> -F <sub>4</sub>		F <sub>4</sub> -F <sub>5</sub>		F <sub>5</sub> -F <sub>6</sub>	
	Broad sense heritability	Narrow sense heritability	Broad sense heritability	Narrow sense heritability	Broad sense heritability	Narrow sense heritability
<b>Days to first flower</b>	86.02	23.14	92.63	47.95	78.51	56.00
<b>Plant height</b>	79.88	20.19	92.82	35.46	91.81	58.00
<b>Primary branches/plant</b>	66.18	24.88	31.09	23.19	77.25	52.00
<b>Pods / plant</b>	95.06	9.10	97.28	18.16	95.18	45.00
<b>Kernels / plant (g)</b>	85.61	8.23	77.82	16.67	96.88	36.00
<b>Kernel yield/ plant(g)</b>	84.03	7.91	82.07	10.06	92.95	45.00
<b>Shelling percentage</b>	78.23	23.91	74.64	12.37	70.12	23.00
<b>SLA (cm<sup>2</sup>/g)</b>	41.88	7.78	85.12	15.05	90.06	32.00
<b>SCMR</b>	62.71	12.39	97.24	16.35	94.46	28.00
<b>Pod yield/plant (g)</b>	86.87	8.24	70.87	18.44	95.36	43.00

Narrow sense heritability was moderate for days to flowering (23.14%), plant height (20.19%), primary branches per plant (24.88%) and shelling percentage (23.91%) in F<sub>4</sub> RILs, where as pods per plant (9.10%), kernels per plant (8.23). Kernel yield per plant (7.91 %), pod yield per plant (8.24 %), SLA (7.78%) and SCMR (12.39%) was associated with low narrow sense heritability in F<sub>4</sub> RILs. Difference between the broad sense and narrow sense heritability was less for days to flowering, plant height, primary branches per plant and shelling percentage in F<sub>4</sub> RIL population.

Higher broad sense heritability coupled with higher narrow sense heritability was observed in F<sub>5</sub> RILs for days to flowering (92.63% and 47.95%) and plant height (92.82%and 35.46%), where as higher broad sense and moderate narrow sense heritability was noticed for pods per plant (92.28 % and 18.16% ), kernels per plant (77.82 % and 16.67% ), pod yield per plant (70.87 % and 18.44% ), kernel yield per plant (82.07% and 10.06%), SLA (85.12 and 15.05%) and SCMR (97.24% and 16.35 %) in F<sub>5</sub> RIL population.

Days to flowering (78.51 and 56.00% ), plant height (91.81 and 58.00%), primary branches per plant (77.25 and 52.00%), SLA (90.06 and 32.00%), pods per plant (95.18 and 45.00%), kernels per plant (96.88 and 36.00% ), pod yield per plant (95.36 and 43.00%) and kernel yield per plant (92.95 and 45.00% ) exhibited higher broad sense and narrow sense heritability and the difference between broad sense and narrow sense heritability for these characters was found to be less in F<sub>6</sub> RIL population.

#### **4.1.7 Assessment of productive segregants in F<sub>6</sub> RILs.**

Superior progenies were selected based on traits like SCMR, SLA, pods per plant kernels per plant, pod yield per plant, kernel yield per plant and shelling percentage separately and are presented in Table 8.

The selected progenies which are present in Table 8 are having higher pod yield coupled with higher SCMR and lower SLA values for example, C1-F<sub>6</sub>- 45 progeny recorded higher pod yield per plant (67.29 g) and kernel yield per plant (47.26 g) and C1

**Table 8: Superior performance of selected lines in F<sub>6</sub> recombinant inbred lines of NRCG12568 × NRCG12326 in groundnut**

Line No.	Days to first flowering	Plant height (cm)	Primary branches/ Plant	SLA (cm <sup>2</sup> /g)	SCMR	No of pods/ Plant	Pod yield/ Plant (g)	No of kernel/ Plant	Kernel yield/ Plant (g)	Shelling percentage
C1-F <sub>6</sub> - 25	42.27	13.64	5.09	118.63	59.41	36.58	44.80	63.96	25.48	57.95
C1-F <sub>6</sub> - 30	44.85	24.62	4.31	171.36	53.48	55.51	42.39	71.80	29.01	72.48
C1-F <sub>6</sub> - 42	39.79	11.93	5.36	104.61	68.61	57.17	67.29	100.42	41.89	61.77
C1-F <sub>6</sub> - 45	33.64	24.36	5.07	108.86	64.74	48.81	57.37	85.25	35.06	60.59
C1-F <sub>6</sub> - 94	41.88	14.35	4.88	167.49	41.32	36.60	51.18	69.17	27.83	49.30
C1-F <sub>6</sub> - 98	31.64	23.64	4.91	108.05	65.08	42.50	44.30	69.37	27.92	62.79
C1-F <sub>6</sub> - 135	32.87	14.13	4.80	130.50	60.11	37.80	48.47	68.40	27.48	55.69
C1-F <sub>6</sub> - 163	47.81	19.00	4.81	171.28	51.95	33.31	45.31	61.82	24.52	51.37
C1-F <sub>6</sub> - 175	46.80	25.20	5.00	112.76	59.48	37.86	53.56	72.10	29.14	53.73
C1-F <sub>6</sub> - 245	40.89	18.95	4.84	142.83	59.01	58.93	44.59	82.43	33.79	73.48
C1-F <sub>6</sub> - 260	34.67	18.07	4.47	127.75	57.00	41.29	51.35	73.81	29.92	57.02
C1-F <sub>6</sub> - 270	31.64	15.64	4.21	128.72	55.79	46.33	66.37	89.46	36.96	54.77
C1-F <sub>6</sub> - 271	28.78	20.06	4.22	111.76	60.64	40.91	57.65	77.99	31.79	54.43
C1-F <sub>6</sub> - 349	42.36	23.07	4.57	149.75	47.82	47.26	55.67	82.52	33.84	59.61
C1-F <sub>6</sub> - 405	51.06	17.06	4.69	150.25	43.81	40.61	47.17	69.99	28.20	57.96
C1-F <sub>6</sub> - 418	38.53	27.41	4.24	182.45	49.81	51.30	47.27	79.09	32.29	62.30
C1-F <sub>6</sub> - 437	41.91	22.55	4.64	105.26	70.20	36.33	43.10	62.89	25.00	58.41
C1-F <sub>6</sub> - 538	44.56	33.75	4.69	122.66	58.54	39.59	50.55	71.61	28.92	56.81
MEAN	39.64	19.57	4.70	212.00	38.31	25.06	24.46	39.30	14.03	55.15
SE±	0.32	0.32	0.12	0.98	0.75	0.56	0.65	0.86	0.41	0.48
NRCG12568	36.00	34.92	5.85	105.58	55.32	38.45	36.73	56.23	26.75	74.31
NRCG12326	25.91	22.00	4.64	245.18	25.28	22.38	18.09	33.00	12.25	58.66
TMV-2	35.94	25.00	7.24	136.32	15.80	40.11	47.65	63.27	30.23	63.39
KCG-2	48.69	35.06	6.50	165.32	15.14	61.48	43.63	91.18	33.25	67.42

-F<sub>6</sub>- 245 progeny was yielded 44.95 g of pod yield per plant, 33.79 g kernel yield per plant, 58 pods per plant, 82 kernels per plant and 73.69% of shelling percentage.

#### **4.1.8 Test of normality for growth, traits related to WUE, yield and its attributing traits in F<sub>6</sub> RIL population of the cross NRCG 12568 X NRCG 12326**

##### **4.1.8.1 Skewness and Kurtosis**

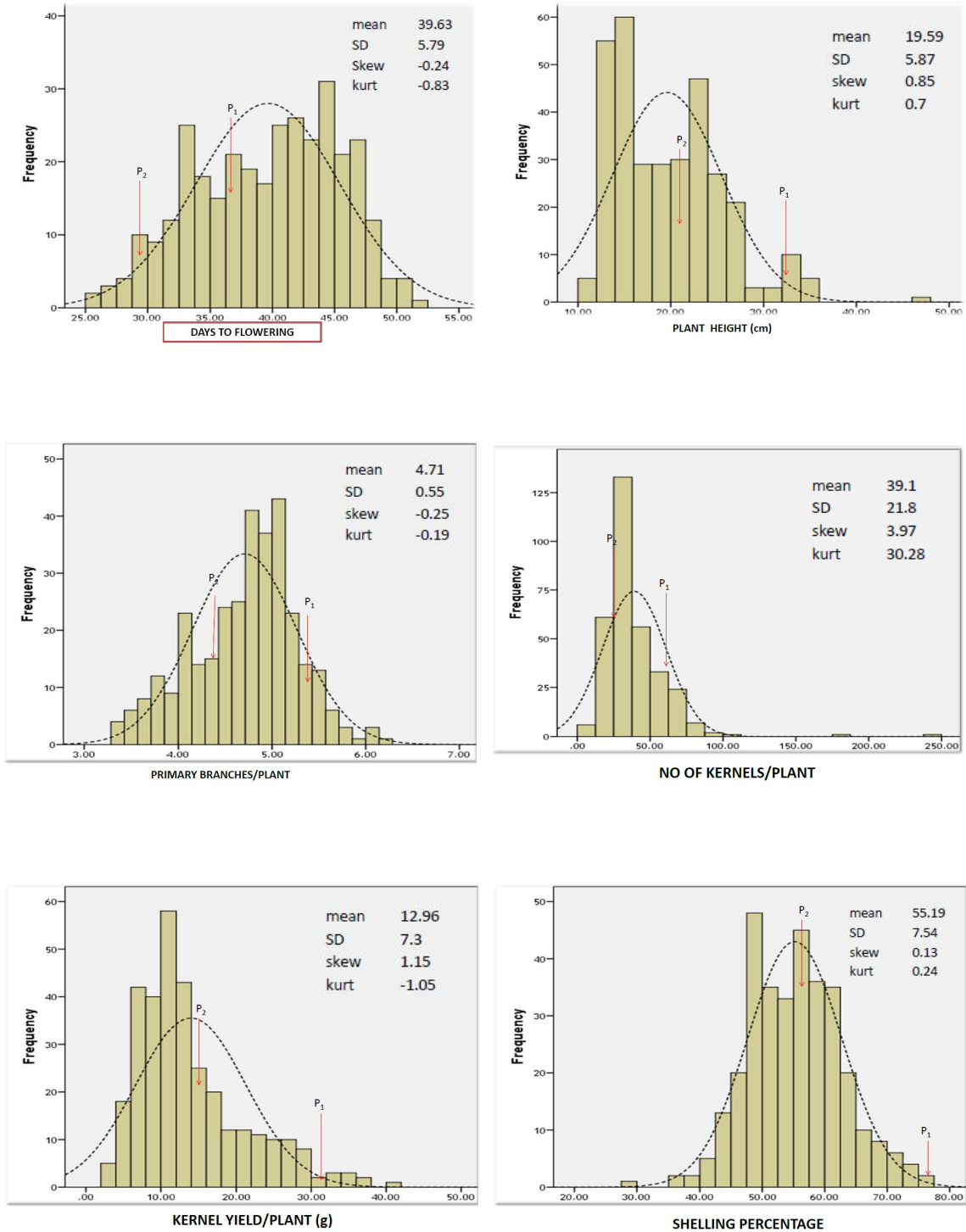
Plant height (0.85), pods per plant (1.19), kernels per plant(3.97), kernel yield per plant (1.35), shelling percentage (0.33), specific leaf area (0.24), SCMR (0.38), and pod yield per plant (0.13) were positively skewed, where as Days to flowering (-0.20) and primary branches per plant (-0.25) were negatively skewed.

The distribution curve also showed that days to flowering (-0.83), plant height (0.21), specific leaf area (-0.34), SCMR (-0.77), pod yield per plant (0.13), kernel yield per plant (-1.05), pods per plant (1.00), primary branches per plant (-0.39) and shelling percentage (0.24) were platykurtic with Kurtosis value less than '3' and the distribution of kernels per plant (30.28) were leptokurtic with Kurtosis value greater than '3'.

#### **4.2 Phenotypic evaluation of four segregating generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) of cross NRCG 12273 X ICG12370 for growth, yield and traits related to Water Use Efficiency (WUE)**

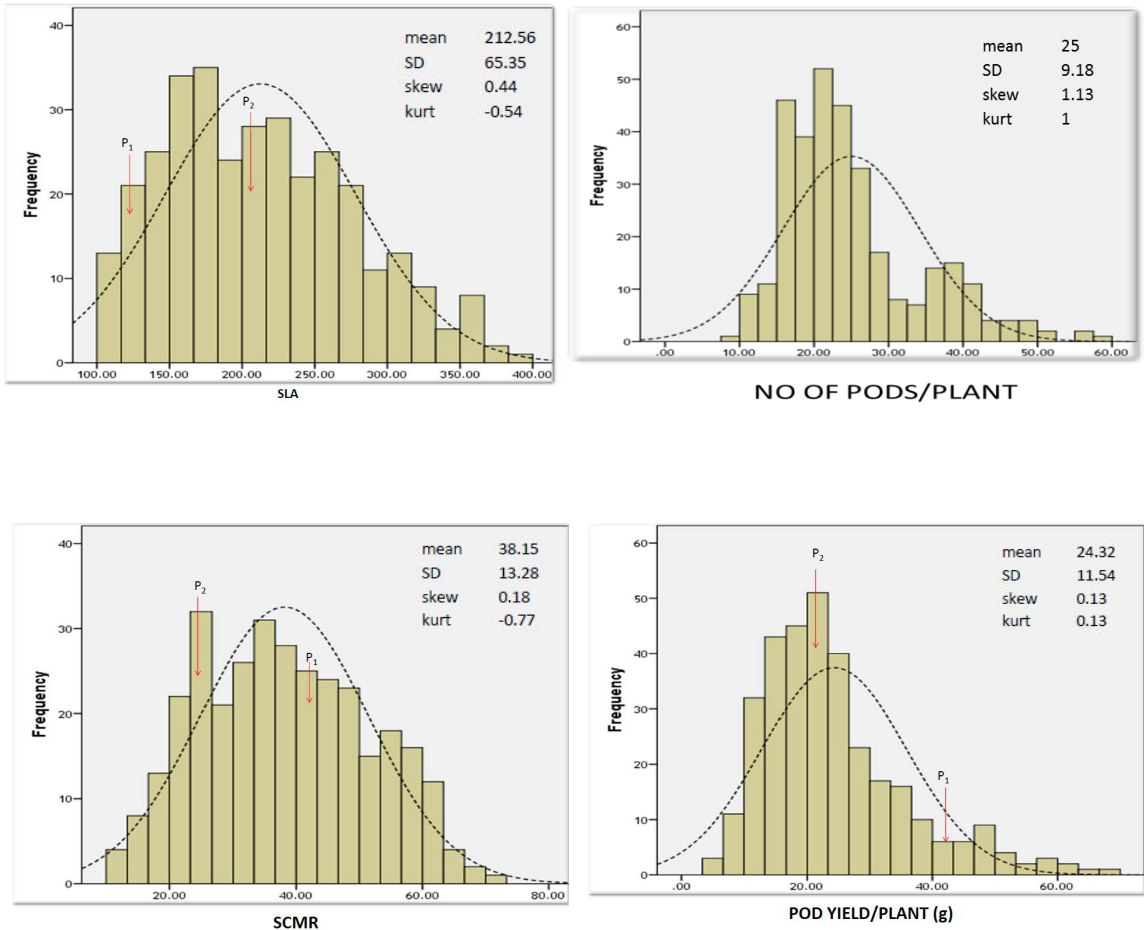
Breeders very often use segregating populations derived from hybrids which is obtained crossing two parents they are highly diverse for trait of interest. These segregating population used as source population to exercise selection for identifying homozygous lines with better performance to develop varieties. At the same time, the breeding lines from the advanced generations are also used as parental lines for developing commercially exploitable heterotic hybrids. But, most often the source of early generations *i.e.*, F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations offer wider opportunities for achieving high success, because of wider genetic base.

155 F<sub>3</sub>, 143 F<sub>4</sub>, 126 F<sub>5</sub> and 106 F<sub>6</sub> segregating progenies were developed through individual plant selection in each segregating generation based on mean  $\pm$  SE for component traits of pod yield and traits related to WUE and only selected plants were



**Fig. 1: Normality distribution for growth parameters, traits related to WUE, yield and yield attributing traits in  $F_6$  RILs of cross NRCG 12568  $\times$  NRCG 12326**

Contd...



**Fig. 1: Normality distribution for growth parameters, traits related to WUE, yield and yield attributing traits in F<sub>6</sub> RILs of cross NRCG 12568 × NRCG 12326**

used to forward to the next generation and selected plants were sown according to the procedure of plant to progeny row method and this process was followed in every generation.

#### **4.2.1 Analysis of variance**

The mean sum of squares of 155 F<sub>3</sub>, 143 F<sub>4</sub>, 126 F<sub>5</sub> and 106 F<sub>6</sub> segregating progenies of the cross NRCG 12273 × ICG 12370 for growth, traits related to WUE, yield and its component characters were carried out and is presented in Table 9. Segregating progenies of all the four generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) registered highly significant differences for all the characters studied except shelling percentage in F<sub>3</sub>, F<sub>4</sub> and F<sub>6</sub> generations. The values of mean sum of squares segregating progenies and checks recorded the presence of high variability for all the characters in all the four segregating generations except primary branches per plant and shelling percentage.

#### **4.2.2 Genetic variability studies**

To know the extent of genetic variability present in the population of all the four generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>), data on various genetic parameters *viz.*, mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability ( $h^2$ ) and genetic advance as per cent mean (GAM) were presented character-wise in Table 10.

##### **4.2.2.1 Days to first flowering**

A decrease in mean value for days to flowering was observed from F<sub>3</sub> to F<sub>6</sub> segregating generations. The highest mean value was recorded in F<sub>3</sub> generation (39.78 days) followed by F<sub>4</sub> (39.66 days) and lowest was observed in F<sub>5</sub> generation (36.24 days). Wider range was observed in all the segregating generations. Maximum range was noticed in F<sub>4</sub> generation (22.28 days to 49.31 days), followed by F<sub>5</sub> (22.27 days to 47.29 days), F<sub>3</sub> (23.72 days to 45.72 days) and F<sub>6</sub> (25.82 days to 43.39 days) generations. In all segregating generations presence of moderate GCV (15.46 in F<sub>3</sub>, 14.49 in F<sub>4</sub>, 14.55 in F<sub>5</sub> and 12.92 in F<sub>6</sub>) and PCV (15.98 in F<sub>3</sub>, 15.14 in F<sub>4</sub>, 16.24 in F<sub>5</sub> and 13.97 in F<sub>6</sub>) was observed. High heritability (91.66, 80.35 and 80.42) coupled with moderate GAM (28.58,

**Table 9: Analysis of variance for growth parameters, traits related to WUE, yield and its component characters in four segregating generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) of the cross NRCG12473 × ICG12370 in groundnut**

Source of variance		Df	Days to Flowering	Plant height (cm)	Primary branches/plant	SLA (cm <sup>2</sup> /g)	SCMR	Pods/plant (g)	Pod yield/plant (g)	Kernels/plant	Kernel yield/plant (g)	Shelling Percentage
Block (eliminating Check + Va.)	F <sub>3</sub>	3	15.80*	1.91	0.07	809.53	12.67	14.13	15.02	21.65	10.55	80.44*
	F <sub>4</sub>	3	14.71*	4.58	0.14	392.96	12.77	4.55	47.38	92.9884	38.79*	91.68
	F <sub>5</sub>	3	11.41	7.28**	0.04	776.77	51.71	2.95*	6.41	21.67	9.71	35.59
	F <sub>6</sub>	3	8.75	2.79	0.14	309.12	5.36	33.42	22.66*	79.57**	1.07	172.36*
Progenies + Checks	F <sub>3</sub>	154	42.43**	31.69**	0.67*	7403.56**	314.37**	99.73**	156.92*	319.44**	66.05*	115.47**
	F <sub>4</sub>	142	38.25**	31.28**	0.64	4669.95*	369.64**	89.52**	178.21**	315.62*	61.95**	157.54
	F <sub>5</sub>	126	36.22*	237.54**	0.59*	5013.64*	284.22**	37.06**	117.68*	162.04**	24.61	38.97
	F <sub>6</sub>	106	33.33**	36.89**	0.57	8114.87**	279.17**	162.37*	167.85**	466.49**	100.97**	75.10
Checks	F <sub>3</sub>	3	25.71*	12.82*	0.20	4216.06**	92.83**	75.45**	61.25	270.62*	81.61*	255.50**
	F <sub>4</sub>	3	53.42**	12.23*	1.03	1219.90**	383.21*	85.87**	106.02	336.07*	85.28**	182.60
	F <sub>5</sub>	3	17.94	16.37**	0.03	1822.63	27.03	68.31**	156.43*	567.11**	50.66*	33.10
	F <sub>6</sub>	3	140.08**	18.36*	0.05	8227.92**	352.09**	21.85	36.82**	116.68	11.51**	274.47*
Progenies	F <sub>3</sub>	151	42.66**	32.13**	0.28	7494.55**	319.39**	100.57**	159.10*	321.80**	66.09*	113.18**
	F <sub>4</sub>	139	38.18**	31.78**	0.62	4594.93*	370.11**	90.05**	176.68**	315.69*	60.08**	157.72
	F <sub>5</sub>	123	36.65*	24.01**	0.31	5031.23*	287.92**	36.83**	117.56*	156.38**	23.91	37.79
	F <sub>6</sub>	103	30.09**	36.91**	0.27	8245.26**	280.11**	166.32*	171.31**	478.00**	101.31**	47.92
Checks vs Progenies	F <sub>3</sub>	1	41.93**	3.17	60.78**	1339.01	20.39	22.25*	18.63	60.81	28.21*	181.26*
	F <sub>4</sub>	1	17.43	0.18	11.65**	4738.86	278.35*	22.68**	535.45**	264.44	27.97**	81.95
	F <sub>5</sub>	1	20.23	6.84**	36.84**	9231.83*	343.81*	1.94	54.93	48.72*	58.80*	195.88*
	F <sub>6</sub>	1	153.27**	72.20**	32.61**	91490.2**	37.19	37.21	73.31**	180.97**	45.12**	2475.72**
Error	F <sub>3</sub>	6	2.61	2.37	0.13	209.34	3.32	3.65	30.32	40.36	13.18	13.22
	F <sub>4</sub>	6	3.00	1.84	0.57	100.90	41.08	0.98	22.71	50.38	7.63	95.97
	F <sub>5</sub>	6	6.80	0.33	0.14	791.93	31.04	0.52	19.15	4.60	8.92	17.15
	F <sub>6</sub>	6	4.08	1.84	0.17	78.36	13.86	40.89	2.64	6.16	0.81	29.12

\*Significant @ P = 0.05

\*\* Significant @ P = 0.01

26.87 and 24.59) was observed in F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations. Where as F<sub>3</sub> generations exhibited high heritability (93.53) and high GAM (30.79) for this character. The difference between GCV and PCV was low in all the generations.

#### **4.2.2.2 Plant height (cm)**

The mean performance for plant height for all the segregating generations was 19.36 cm, 21.68cm, 20.90cm and 22.24cm in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation respectively. The highest mean was observed in F<sub>6</sub> generation (22.24cm) and lowest was observed in F<sub>3</sub> generation (19.36 cm). Wider range was observed in all the four generations. Maximum range was noticed in F<sub>3</sub> generation (10cm to 47.38cm) followed by F<sub>4</sub> generation (12.36cm to 39.87 cm), F<sub>5</sub> (14.10 cm to 39.00) and F<sub>6</sub> (14.60 cm to 37.67 cm) generations.

Moderate GCV (27.31, 25.90, 21.92 and 25.54) and moderate PCV (28.50, 26.73, 21.98 and 26.26) was observed in all the four generations. F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations exhibited high heritability (92.23, 93.85, 98.85 and 94.59) and high GAM (54.14, 51.67, 88.32 and 51.17).

#### **4.2.2.3 Primary branches per plant**

The mean value for number of branches in F<sub>3</sub> progenies were 5.61, in F<sub>4</sub> it was 3.27, where as in F<sub>5</sub> it was 5.39 and 4.99 in F<sub>6</sub> generation. More number of primary branches per plant was observed in F<sub>3</sub> (7.05), followed by F<sub>5</sub> (6.31) and F<sub>6</sub> (6.24) generation, where as less number of branches were observed in F<sub>4</sub> generation (3.27).

Low GCV (7.35 and 7.25) and moderate PCV (10.09 and 10.22) was observed in F<sub>5</sub> and F<sub>6</sub> segregating progenies, where as F<sub>3</sub> segregating progenies exhibited the low GCV (6.75) and PCV (9.32). However, presence of high GCV (35.18) and PCV (41.25) were observed in F<sub>4</sub> segregating generation. Moderate heritability (52.4 and 53.07) accompanied with moderate GAM (10.06 and 11.02) was recorded in F<sub>3</sub> and F<sub>5</sub> segregating generations, where as high heritability (66.18) and moderate GAM (28.78), high heritability (70.93) and low GAM (8.56) was observed in F<sub>4</sub> and F<sub>6</sub> generations respectively.

**Table 10: Genetic variability parameters for growth, traits related to WUE, yield and its component traits in four segregating generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> And F<sub>6</sub>) of the cross NRCG12473 × ICG12370 in groundnut**

CHARECTERS		MEAN	RANGE		GCV (%)	PCV (%)	h <sup>2</sup> <sub>bs</sub> (%)	GAM
			MIN	MAX				
Days to first flowering	F <sub>3</sub>	39.78	23.72	45.72	15.46	15.98	93.53	30.79
	F <sub>4</sub>	39.66	22.28	49.31	14.49	15.14	91.66	28.58
	F <sub>5</sub>	36.24	22.27	47.29	14.55	16.24	80.35	26.87
	F <sub>6</sub>	37.86	25.82	43.39	12.92	13.97	85.42	24.59
Plant height (cm)	F <sub>3</sub>	19.36	10.83	47.38	27.37	28.50	92.23	54.14
	F <sub>4</sub>	21.68	12.36	39.87	25.90	26.73	93.85	51.67
	F <sub>5</sub>	20.90	14.10	39.00	71.92	71.98	99.85	88.32
	F <sub>6</sub>	22.24	14.60	37.67	25.54	26.26	94.59	51.17
Primary branches/plant	F <sub>3</sub>	5.61	3.23	7.05	6.75	9.32	52.4	10.06
	F <sub>4</sub>	3.27	2.23	4.46	35.18	41.12	66.18	28.78
	F <sub>5</sub>	5.39	2.76	6.31	7.35	10.09	53.07	11.02
	F <sub>6</sub>	4.99	3.71	6.24	7.25	10.22	70.93	8.56
SLA (cm <sup>2</sup> /g)	F <sub>3</sub>	230.96	78.95	368.45	35.90	36.44	97.05	72.85
	F <sub>4</sub>	182.49	89.56	213.25	34.54	39.35	77.04	62.45
	F <sub>5</sub>	193.64	95.36	365.26	32.46	35.56	83.3	61.02
	F <sub>6</sub>	269.88	102.23	365.12	35.90	36.44	97.05	72.85
SCMR	F <sub>3</sub>	34.74	10.20	78.65	49.72	49.99	98.90	78.32
	F <sub>4</sub>	51.84	10.74	92.15	33.91	36.10	88.26	65.62
	F <sub>5</sub>	45.29	13.95	80.78	34.16	36.30	88.52	66.2
	F <sub>6</sub>	32.41	7.27	63.01	48.28	49.63	94.64	96.77
Pods /Plant	F <sub>3</sub>	25.29	10.13	60.67	37.81	38.56	96.16	76.38
	F <sub>4</sub>	28.01	12.82	68.06	32.65	32.84	98.84	66.87
	F <sub>5</sub>	24.99	14.27	43.71	23.27	23.45	98.48	47.57
	F <sub>6</sub>	24.17	8.27	66.89	44.43	51.71	73.83	78.65
Pod yield/plant (g)	F <sub>3</sub>	29.09	8.38	89.26	37.90	42.37	80.03	69.84
	F <sub>4</sub>	34.07	10.23	75.51	35.30	37.97	86.42	67.59
	F <sub>5</sub>	35.39	17.50	72.27	27.06	29.75	82.73	50.69
	F <sub>6</sub>	25.12	6.65	64.41	49.57	49.99	98.33	78.27
Kernels/plant	F <sub>3</sub>	45.55	15.95	121.26	35.78	38.40	86.81	68.67
	F <sub>4</sub>	51.34	20.52	119.48	30.75	33.71	83.18	57.76
	F <sub>5</sub>	48.87	26.26	88.84	24.33	24.73	96.85	49.32
	F <sub>6</sub>	40.27	9.09	98.65	51.73	52.09	98.60	52.32
Kernel yield/plant(g)	F <sub>3</sub>	19.61	7.18	54.57	36.05	40.52	79.13	66.05
	F <sub>4</sub>	22.00	9.17	53.76	31.91	34.29	86.58	61.16
	F <sub>5</sub>	17.79	9.16	34.62	21.01	26.89	61.03	33.8
	F <sub>6</sub>	18.58	4.23	51.09	51.74	51.97	95.13	106.13
Shelling percentage	F <sub>3</sub>	68.43	45.88	89.92	14.20	15.17	87.71	27.4
	F <sub>4</sub>	64.48	89.92	42.25	11.81	19.25	37.66	14.93
	F <sub>5</sub>	50.46	40.14	60.93	8.69	11.95	52.86	13.01
	F <sub>6</sub>	74.23	62.66	90.02	6.23	9.17	67.93	8.05

#### 4.2.2.4 Specific Leaf Area (cm<sup>2</sup>/g)

SLA showed high variability with a minimum value of 89.56 cm<sup>2</sup>/g. Maximum of 213.25 cm<sup>2</sup>/g and mean of 182.49 cm<sup>2</sup>/g in F<sub>4</sub> generation. The value of SLA varies from 95.36 cm<sup>2</sup>/g to 365.26 cm<sup>2</sup>/g with a mean of 193.64 cm<sup>2</sup>/g was recorded in F<sub>4</sub> generation. Both F<sub>3</sub> and F<sub>6</sub> segregating progenies exhibited the higher mean (230.96 cm<sup>2</sup>/g and 269 cm<sup>2</sup>/g respectively) with wider range (78.95 cm<sup>2</sup>/g to 368.45 and 102.23 cm<sup>2</sup>/g to 365.12 cm<sup>2</sup>/g of respectively). GCV and PCV were found to be high in all the four segregating generations with the value of 35.90 and 36.44 in F<sub>3</sub>, 34.54 and 39.33 in F<sub>4</sub>, 32.46 and 35.56 in F<sub>5</sub>, 35.90 and 36.44 cm<sup>2</sup>/g in F<sub>6</sub> segregating generation. High heritability (97.05, 77.04, 83.30 and 97.05) coupled with high GAM (72.85, 62.45, 61.02 and 72.85) was noticed in all four segregating generations *viz.*, F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations respectively.

#### 4.2.2.5 SPAD chlorophyll meter reading (SCMR)

SCMR varied from 10.20 to 78.65 with a mean value of 34.74 in F<sub>3</sub>, 13.95 to 80.78 with a mean value of 45.29 in F<sub>5</sub> segregating progenies. F<sub>6</sub> RILs had lower mean (32.41) and narrow range (10.13 to 63.01). Where as higher mean (45.29) and wider range (10.74 to 92.15) was observed in F<sub>4</sub> segregating progenies. Higher GCV (49.72, 33.91, 34.16 and 48.26) and higher PCV (49.99, 36.10, 36.30 and 49.63) were observed in all the four segregating (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) generations respectively. Higher heritability (98.90 %, 88.26 %, 88.52% and 94.64%) coupled with high genetic advance as *percent* of mean (78.32%, 65.62%, 66.20% and 96.77%) was observed in segregating progenies of all the four generations for this character.

#### 4.2.2.6 Pods per plant

Wider range of variation was observed in all the four generations *i.e.*, 10.13 to 60.67 pods per plant in F<sub>3</sub>, 12.82 to 68.06 in F<sub>4</sub>, 14.27 to 43.71 in F<sub>5</sub> and 8.27 to 66.89 in F<sub>6</sub> segregating populations. The mean value for number of pods per plant remain consisted in F<sub>3</sub> (25.29), F<sub>4</sub> (28.01), F<sub>5</sub> (24.999) and F<sub>6</sub> (24.17) segregating generations. The *per cent* of genotypic and phenotypic coefficient of variability in F<sub>3</sub> (49.72 and 49.99 %), F<sub>4</sub> (33.91 and 36.10 %), F<sub>5</sub> (34.16 and 36.30 %) and in F<sub>6</sub> (48.28 and 49.63 %) segregating progenies was observed to be higher. Variability for mean number of pods

per plant over generations was all most remain same. Heritability and GAM in F<sub>3</sub> (98.90 and 78.32), F<sub>4</sub> (88.26 and 65.26), F<sub>5</sub> (8.52 and 66.20) and in F<sub>6</sub> (94.64 and 96.64) segregating populations was found be high and all most same in all the generations.

#### **4.2.2.7 Pod yield per plant (g)**

Pod yield per plant showed maximum yield of 89.26 g per plant (F<sub>3</sub> segregants) and it slightly decreased to 75.51 g per plant in F<sub>4</sub> segregants followed by 72.27 g per plant (F<sub>5</sub> segregants) and 64.41 g per plant ( F<sub>6</sub> segregants) was observed. Where as mean value of pod yield per plant in F<sub>3</sub> is 29.09 g, 34.07 g in F<sub>4</sub>, 35.39 g in F<sub>5</sub> and in F<sub>6</sub> (25.12 g) segregants it was found to be having consistent value. Both genotypic and phenotypic coefficient of variability was very high in all the four generations *i.e.*, 37.90 *per cent* (GCV) and 42.37 *per cent* (PCV) in F<sub>3</sub>, 35.30 *per cent* (GCV) and 37.97 *per cent* (PCV), in F<sub>4</sub>, 49.57 *per cent* (GCV) and 49.99 *per cent* (PCV) in F<sub>6</sub> except F<sub>5</sub> segregants which had moderate GCV (27.06) and PCV (29.75). High heritability (80.03, 86.42, 82.73 and 98.33%) coupled with high genetic advance as *per cent* of mean (69.84, 67.59, 50.69 and 78.27%) with respect to F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating progenies was observed for this character.

#### **4.2.2.8 Kernels per plant**

The highest mean number of kernels per plant was observed in F<sub>4</sub> generation (51.34) followed by F<sub>5</sub> (48.87), F<sub>3</sub> (45.55) and lowest in F<sub>6</sub> generation (40.27). Maximum range was noticed in F<sub>3</sub> generation (15.95 to 121.26) and minimum range was observed in F<sub>5</sub> generation (26.26 to 88.84).

High GCV (35.78, 30.75 and 51.73) and high PCV (38.40, 33.71 and 52.09) was observed in F<sub>3</sub>, F<sub>4</sub> and F<sub>6</sub> segregating generation where as F<sub>4</sub> segregants showed moderate GCV (24.33) and PCV (24.73). High heritability (86.81, 83.18, 96.85 and 79.13 %) and high GAM (68.67, 57.76, 49.32 and 52.32 %) was observed in all the four segregating generations.

#### **4.2.2.9 Kernel yield per plant (g)**

Kernel yield per plant exhibited a constant mean and range value from F<sub>3</sub> (19.61 g per plant with a range of 7.18 to 54.57) to F<sub>4</sub> (22.00 g per plant with a range of 9.17 to 53.76) and F<sub>6</sub> segregants (18.58 g per plant with a range of 4.23 to 51.09). Where as mean and range for kernel yield per plant has decreased in F<sub>5</sub> segregants (17.79 g per plant with a range of 9.16 to 34.62). This character exhibited a high GCV and PCV with a mean value of 36.05 and 40.52 in F<sub>3</sub> segregants, 31.91 and 34.29 in F<sub>4</sub> segregants, 51.74 and 51.97 in F<sub>6</sub> segregants, where as moderate GCV (21.01) and PCV (26.89) was observed in F<sub>5</sub> segregants. Higher heritability coupled with higher GAM was prevailed in all the four generations *i.e.*, 79.13 and 66.05 in F<sub>3</sub> segregants, 86.58 and 61.16 in F<sub>4</sub> segregants, 61.03 and 33.80 in F<sub>5</sub> segregants and F<sub>6</sub> segregants expressed very high heritability (95.13) and GAM (88.13) for this trait.

#### **4.1.2.10 Shelling percentage**

Wide range of variation was observed for this character in F<sub>3</sub> segregants (45.88 to 89.92%), F<sub>4</sub> segregants (42.25 to 89.92%), F<sub>5</sub> (40.14 to 60.93%) and F<sub>6</sub> segregants (62.66 to 90.02). Highest mean value was recorded in F<sub>6</sub> segregants (74.23%) and it decreased in F<sub>3</sub> segregants (68.43%) and further decreased in F<sub>4</sub> segregants (64.48%). The GCV and PCV were moderate in F<sub>3</sub> segregants (14.20 and 15.17) and F<sub>4</sub> (11.81 and 19.25) segregants. Lower GCV and moderate PCV was observed in F<sub>5</sub> (8.69 and 11.95), where as lower GCV (6.23) and lower PCV (9.17) was observed in F<sub>6</sub> segregants. High heritability coupled with moderate GAM was found in F<sub>3</sub> segregants (87.71 and 27.40) and F<sub>5</sub> segregants (52.86 and (13.01). High heritability and low GAM was noticed in F<sub>6</sub> (67.93 and 8.05) generation, moderate heritability (37.66) and moderate GAM (14.93) was observed in F<sub>4</sub> segregants for this trait.

#### **4.2.3 Association studies**

The phenotypic correlation co-efficient among growth, traits related to WUE, yield and its component characters were recorded in 156 F<sub>3</sub>, 140 F<sub>4</sub>, 128 F<sub>5</sub> and 112 F<sub>6</sub> segregating progenies of the cross NRCG 12473 × ICG 12370 were estimated and results are presented in the Table 11.

#### **4.2.3.1 Correlation coefficient of pod yield per plant with growth, traits related to WUE and its component traits.**

The phenotypic correlation values between traits were calculated by regressing phenotypic values of one trait with those of other traits. Pod yield per plant showed significantly positive association in all the four generations *i.e.*, F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> with SCMR (0.90, 0.79, 0.87 and 0.81), pods per plant (0.83, 0.81, 0.75 and 0.90) and kernels per plant (0.95, 0.93, 0.90 and 0.95) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> respectively, whereas shelling percentage (-0.14, -0.35, -0.30 and -0.22) and SLA (-0.83, -0.29, -0.81 and -0.89) was exhibited significantly negative correlation with pod yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation respectively.

#### **4.2.3.2 Association among growth, traits related to WUE, yield attributing characters.**

SCMR is significantly positively correlated with pod yield per plant (0.90, 0.79, 0.87 and 0.81), kernels per plant (0.87, 0.69, 0.79 and 0.77), kernel yield per plant (0.84, 0.65, 0.83 and 0.92,) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation respectively.

Pods per plant exhibited significant positive correlation with kernels per plant (0.93, 0.90, 0.87 and 0.91), kernel yield per plant (0.92, 0.92, 0.88 and 0.85), SCMR (0.78, 0.56, 0.67 and 0.64) and pod yield per plant (0.83, 0.81, 0.75 and 0.90) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation respectively. Significant negative correlation was observed for SLA (-0.72, -0.25, -0.65 and -0.76 in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> respectively) at phenotypic level.

Kernel yield per plant showed significant positive correlation with SCMR (0.84, 0.65, 0.83 and 0.82) and pod yield per plant (0.90, 0.88, 0.94 and 0.88) and kernels per plant (0.96, 0.93, 0.91 and 0.89) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> respectively at phenotypic levels. However, it showed significant negative correlation with specific leaf area (-0.77, -0.26, -0.78 and -0.62) at phenotypic level in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation respectively.

SCMR exhibited significant positive correlation with pods per plant (0.78, 0.56, 0.67 and 0.64), kernels per plant (0.87, 0.64, 0.83 and 0.82), Kernels yield per plant (0.84, 0.65, 0.83 and 0.82) and pod yield per plant (0.90, 0.79, 0.87 and 0.81) in all the

**Table 11: Phenotypic correlation coefficients among growth parameters, traits related to WUE, yield and its component traits in four segregating generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) of the cross NRCG12473 × ICG12370 in groundnut**

Characters	Generations	Pods / plant	Kernels /plant	Kernel yield/ plant (g)	Shelling percentage	SLA (cm <sup>2</sup> /g)	SCMR	Pod yield / plant (g)
Pods / plant	F <sub>3</sub>	<b>1.00</b>	0.93**	0.92**	0.21*	-0.72**	0.78**	0.83**
	F <sub>4</sub>	<b>1.00</b>	0.90**	0.92**	0.06	-0.25*	0.56**	0.81**
	F <sub>5</sub>	<b>1.00</b>	0.87**	0.88**	0.11*	-0.65**	0.67**	0.75**
	F <sub>6</sub>	<b>1.00</b>	0.91**	0.85**	-0.10*	0.76**	0.64**	0.90**
Kernels/ plant	F <sub>3</sub>		<b>1.00</b>	0.96**	-0.06	-0.80**	0.87**	0.95**
	F <sub>4</sub>		<b>1.00</b>	0.93**	-0.17*	-0.27*	0.69**	0.93**
	F <sub>5</sub>		<b>1.00</b>	0.91**	-0.22*	-0.74**	0.79**	0.90**
	F <sub>6</sub>		<b>1.00</b>	0.89**	-0.14*	0.89**	0.77**	0.95**
Kernel yield/ plant (g)	F <sub>3</sub>			<b>1.00</b>	0.17*	-0.77**	0.84**	0.90**
	F <sub>4</sub>			<b>1.00</b>	0.05	-0.26*	0.65**	0.88**
	F <sub>5</sub>			<b>1.00</b>	-0.04	-0.78**	0.83**	0.94**
	F <sub>6</sub>			<b>1.00</b>	0.25*	-0.82**	0.92**	0.88**
Shelling percentage	F <sub>3</sub>				<b>1.00</b>	0.17*	-0.15*	-0.14*
	F <sub>4</sub>				<b>1.00</b>	0.10*	-0.36*	-0.35*
	F <sub>5</sub>				<b>1.00</b>	0.28*	-0.29*	-0.30**
	F <sub>6</sub>				<b>1.00</b>	0.04	-0.01	-0.22*
SLA (cm <sub>2</sub> /g)	F <sub>3</sub>					<b>1.00</b>	-0.95**	-0.83**
	F <sub>4</sub>					<b>1.00</b>	-0.33*	-0.29*
	F <sub>5</sub>					<b>1.00</b>	-0.92**	-0.81**
	F <sub>6</sub>					<b>1.00</b>	-0.91**	0.89**
SCMR	F <sub>3</sub>						<b>1.00</b>	0.90**
	F <sub>4</sub>						<b>1.00</b>	0.79**
	F <sub>5</sub>						<b>1.00</b>	0.87**
	F <sub>6</sub>						<b>1.00</b>	0.81**
Pod yield / plant (g)	F <sub>3</sub>							<b>1.00</b>
	F <sub>4</sub>							<b>1.00</b>
	F <sub>5</sub>							<b>1.00</b>
	F <sub>6</sub>							<b>1.00</b>

\*Significant @ P = 0.05      \*\* Significant @ P = 0.01

four segregating generation respectively. SCMR exhibited significant negative correlation with SLA (-0.95,-0.33, -0.92 and -0.91) and shelling percentage (-0.15, -0.36, -0.29 and -0.41) at phenotypic level in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation respectively.

SLA exhibited significant negative correlation with number of pods per plant (-0.72, -0.25, -0.65 and -0.76), number of kernels per plant (-0.80, -0.27, -0.74 and -0.89), kernel yield per plant (-0.77, -0.26, -0.78 and -0.89) and pod yield per plant (-0.83, -0.29, -0.81 and -0.89) at phenotypic level in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations.

#### **4.2.4 Intergeneration correlation studies**

The analysis was made to determine the relationship among F<sub>3</sub> to F<sub>6</sub> segregating generation for the traits such as days to flowering, plant height number of primary branches per plant, SCMR, SLA, pods per plant, kernels per plant, pod yield per plant, kernel yield per plant and shelling percentage. Result pertaining to this has been presented in Table 12.

Significant and positive correlation between F<sub>3</sub> and F<sub>4</sub> generation for days to flowering (0.46), plant height (0.31), pods per plant (0.40), kernels per plant (0.36), kernel yield per plant (0.25), SLA (0.24) and SCMR (0.30) was observed.

Traits like days to flowering (0.54), plant height (0.25) and primary branches per plant (0.69) exhibited significant positive correlation between F<sub>3</sub> and F<sub>5</sub> segregating generations.

Days to flowering (0.54), plant height (0.59), pods per plant (0.36), kernels per plant (0.32), kernel yield per plant (0.35), SLA (0.24), SCMR (0.29) and pod yield per plant (0.28) were found to be having significant positive correlation of F<sub>4</sub> generation with F<sub>5</sub> generation.

Except shelling percentage all the traits *i.e.*, days to flowering (0.27), plant height (0.26), primary branches per plant (0.22), pods per plant (0.56), kernels per plant (0.34), kernel yield per plant (0.51), SLA (0.30), SCMR (0.35) and pod yield per plant (0.47) were found to be having significantly positive association of F<sub>5</sub> with F<sub>6</sub> generation

**Table 12: Intergeneration correlation coefficients for growth parameters, related to WUE, yield and its component traits from F<sub>3</sub> to F<sub>6</sub> segregating generations of the cross NRCG12473 × ICG12370 in groundnut**

characters	Generations	F <sub>3</sub>	F <sub>4</sub>	F <sub>5</sub>	F <sub>6</sub>
<b>Days to flowering</b>	F <sub>3</sub>	<b>1.00</b>	0.46**	0.54**	0.36**
	F <sub>4</sub>		<b>1.00</b>	0.33**	0.48**
	F <sub>5</sub>			<b>1.00</b>	0.65**
	F <sub>6</sub>				<b>1.00</b>
<b>Plant height (cm)</b>	F <sub>3</sub>	<b>1.00</b>	0.31**	0.25*	0.33**
	F <sub>4</sub>		<b>1.00</b>	0.59**	0.45**
	F <sub>5</sub>			<b>1.00</b>	0.56**
	F <sub>6</sub>				<b>1.00</b>
<b>Primary branches/plant</b>	F <sub>3</sub>	<b>1.00</b>	0.12	0.69**	0.36**
	F <sub>4</sub>		<b>1.00</b>	0.20*	0.42**
	F <sub>5</sub>			<b>1.00</b>	0.41**
	F <sub>6</sub>				<b>1.00</b>
<b>Pods/ plant</b>	F <sub>3</sub>	<b>1.00</b>	0.40**	-0.03	0.09
	F <sub>4</sub>		<b>1.00</b>	0.36**	0.25*
	F <sub>5</sub>			<b>1.00</b>	0.35**
	F <sub>6</sub>				<b>1.00</b>
<b>Kernels /plant</b>	F <sub>3</sub>	<b>1.00</b>	0.36**	-0.10	0.04
	F <sub>4</sub>		<b>1.00</b>	0.32**	0.20*
	F <sub>5</sub>			<b>1.00</b>	0.47**
	F <sub>6</sub>				<b>1.00</b>
<b>Kernel yield / plant (g)</b>	F <sub>3</sub>	<b>1.00</b>	0.25*	-0.08	0.15*
	F <sub>4</sub>		<b>1.00</b>	0.35**	0.32**
	F <sub>5</sub>			<b>1.00</b>	0.52**
	F <sub>6</sub>				<b>1.00</b>
<b>Shelling percentage</b>	F <sub>3</sub>	<b>1.00</b>	0.16*	0.11	0.21*
	F <sub>4</sub>		<b>1.00</b>	0.19*	0.05*
	F <sub>5</sub>			<b>1.00</b>	0.32**
	F <sub>6</sub>				<b>1.00</b>
<b>SLA (cm<sup>2</sup>/g)</b>	F <sub>3</sub>	<b>1.00</b>	0.24*	-0.06	0.14
	F <sub>4</sub>		<b>1.00</b>	0.24*	0.22*
	F <sub>5</sub>			<b>1.00</b>	0.36**
	F <sub>6</sub>				<b>1.00</b>
<b>SCMR</b>	F <sub>3</sub>	<b>1.00</b>	0.30*	-0.09	0.11
	F <sub>4</sub>		<b>1.00</b>	0.29*	0.19*
	F <sub>5</sub>			<b>1.00</b>	0.22*
	F <sub>6</sub>				<b>1.00</b>
<b>Pod yield / plant (g)</b>	F <sub>3</sub>	<b>1.00</b>	0.15	-0.06	0.07
	F <sub>4</sub>		<b>1.00</b>	0.28*	0.25*
	F <sub>5</sub>			<b>1.00</b>	0.55**
	F <sub>6</sub>				<b>1.00</b>

#### **4.2.5 Correlation and regression of pod yield on growth parameters, traits related to WUE and its components traits**

Regression of pod yield on its component traits and traits related to WUE was carried out at phenotypic level taking pod yield per plant as the dependent character. Result pertaining to this has been presented in Table 13.

In F<sub>3</sub> generation the traits such as kernel yield per plant (0.90 and 1.40) was found to be highly significant positive association with maximum positive effect on pod yield per plant followed by pods per plant (0.83 and 1.07), kernels per plant (0.95 and 0.67), SCMR (0.90 and 0.68) and days to flowering (0.20 and 0.11). Where as some other traits viz., SLA (-0.83 and -0.13) and shelling percentage (-0.14 and -0.18) had significantly negative association and negative effect on pod yield per plant in F<sub>3</sub> population.

Pod yield per plant was positively associated on kernel yield per plant (0.88 and 1.52), pods per plant (0.811 and 1.13), kernels per plant (0.93 and 0.69), SCMR (0.79 and 0.55) and days to flowering (0.12 and 0.20) in F<sub>4</sub> generation was observed. The SLA (-0.29 and -0.02) and shelling percentage (-0.35 and -0.41) was found to be having negative association with negative effect on pod yield per plant in F<sub>4</sub> segregating generation.

The positive association with positive effect of kernel yield per plant (0.94 and 2.09) on determination of pod yield per in F<sub>5</sub> generation was found to be very high compared to SCMR (0.87 and 0.56), kernels per plant (0.90 and 0.78) and pods per plant (0.75 and 1.33). Negative association and negative effect of SLA (-0.81 and -0.12) on pod yield per plant was more than the shelling percentage (-0.30 and -0.54) in F<sub>5</sub> segregating population.

In F<sub>6</sub> generation the traits like, pods per plant (0.90 and 0.96), kernels per plant (0.95 and 0.97), kernel yield per plant (0.88 and 1.27) and SCMR (0.81 and 0.72) showed the presence of positive association and positive effect on pod yield per plant. The negative association and negative effect of SLA (-0.89 and -0.02) and shelling percentage (-0.22 and -0.06) on pod yield per plant was observed in F<sub>6</sub> generations.

**Table 13: Correlation and regression of pod yield on growth parameters, traits related to WUE and yield component traits in four segregating generations of the NRCG12473 × ICG12370 in groundnut**

Characters	F <sub>3</sub> generation		F <sub>4</sub> generation		F <sub>5</sub> generation		F <sub>6</sub> generation	
	r-value	b-value	r-value	b-value	r-value	b-value	r-value	b-value
<b>Days to first flower</b>	0.20*	0.11	0.12*	0.20	0.08	0.16	-0.23*	0.03
<b>Plant height (cm)</b>	0.08	0.19	-0.03	-0.04	0.02	0.02	-0.33*	-0.26
<b>Primary branches/plant</b>	-0.04	-0.11	0.09	2.32	-0.24*	-4.80	0.08	2.23
<b>SLA (cm<sup>2</sup>/g)</b>	-0.83**	-0.13	-0.29*	-0.02	-0.81**	-0.12	0.89**	-0.02
<b>SCMR</b>	0.90**	0.68	0.79**	0.55	0.87**	0.56	-0.81**	0.72
<b>Pods / plant</b>	0.83**	1.07	0.81**	1.13	0.75**	1.33	0.90**	0.96
<b>Kernels / plant</b>	0.95**	0.67	0.93**	0.69	0.90**	0.78	0.95**	0.57
<b>Kernel yield / plant (g)</b>	0.90**	1.40	0.88**	1.52	0.94**	2.09	0.88**	1.27
<b>Shelling percentage</b>	-0.14*	-0.18	-0.35*	-0.41	-0.30**	-0.54	-0.22*	-0.06

\* Significant @ P=0.05    \*\* Significant @ P= 0.01

#### **4.2.6 Comparisons of Broad sense and narrow sense heritability for growth parameters, traits related to WUE, yield and its component characters.**

The evaluation of parent and progeny provided an opportunity to compute heritability values following parent offspring regression method involving F<sub>3</sub> plant data and F<sub>4</sub> progeny mean for narrow sense heritability of F<sub>4</sub> generation, similarly narrow sense heritability for F<sub>5</sub> and F<sub>6</sub> generation were also estimated. The heritability estimates computed by regression method can be utilized for predicting the response to selection in early and advanced generations. The result obtained from the study is presented in Table 14.

The results depicted that broad sense heritability recorded high for all the characters in F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations except primary branches per plant in all segregating generations which showed the presence of moderate heritability for all the characters and low heritability was observed for shelling percentage in all segregating generations.

Narrow sense heritability was moderate for days to flowering (32.97%), plant height (23.28%), pods per plant (28.19%), kernels per plant (24.97%), kernel yield (17.08 %) and SCMR (21.92 %) in F<sub>4</sub> generation. Where as primary branches per plant (9.34%), shelling percentage (14.26%), SLA (13.29 %) and pod yield per plant (10.44 %) was associated with low narrow sense heritability in F<sub>4</sub> segregating generation. Difference between the broad sense and narrow sense heritability was less for days to flowering, primary branches per plant, SCMR and shelling percentage in F<sub>4</sub> segregating population.

Higher broad sense heritability coupled with higher narrow sense heritability was observed in F<sub>5</sub> generation for days to flowering (80.35% and 25.15%) and plant height (99.85% and 38.12%). Higher broad sense and moderate narrow sense heritability was noticed for pods per plant (98.48% and 20.05%), kernels per plant (96.85% and 17.46%), SLA (83.3% and 19.82%), SCMR (88.52% and 21.27%) and pod yield (82.73% and 18.12%) in F<sub>5</sub> segregating generation. However, moderate broad sense and moderate narrow sense heritability was observed for kernel yield per plant (61.03% and 18.09%) and primary branches per plant (53.07% and 16.90%). Whereas low broad sense

**Table 14: Comparison between broad sense and narrow sense heritability for growth parameters, traits related to WUE, yield and its component traits in segregating populations for four generations in the cross of NRCG12473 × ICG12370 in groundnut**

Characters	F <sub>3</sub> -F <sub>4</sub>		F <sub>4</sub> -F <sub>5</sub>		F <sub>5</sub> -F <sub>6</sub>	
	Broad sense heritability	Narrow sense heritability	Broad sense heritability	Narrow sense heritability	Broad sense heritability	Narrow sense heritability
<b>Days to first flower</b>	91.66	32.97	80.35	25.15	85.42	46.97
<b>Plant height (cm)</b>	93.85	23.28	99.85	38.12	94.59	44.26
<b>Primary branches/plant</b>	66.18	9.34	53.07	16.90	66.25	34.86
<b>Pods / plant</b>	98.84	28.19	98.48	20.05	73.83	61.42
<b>Kernels per plant</b>	83.18	24.97	96.85	17.46	98.60	70.55
<b>Kernel yield / plant (g)</b>	86.58	17.08	61.03	18.09	98.13	63.91
<b>Shelling percentage</b>	47.66	14.26	52.86	8.14	37.25	26.56
<b>SLA (cm<sup>2</sup>/g)</b>	77.04	13.29	83.3	19.82	95.25	36.23
<b>SCMR</b>	88.26	21.92	88.52	21.27	94.64	53.42
<b>Pod yield/plant (g)</b>	86.42	10.44	82.73	18.12	98.33	61.22

heritability and low narrow sense heritability was noticed for shelling percentage (52.86% and 8.14%) in F<sub>5</sub> generation.

Days to flowering (85.42% and 46.97%), plant height (94.59% and 44.26%), primary branches per plant (66.25% and 34.86%), pod per plant (73.83 and 61.42%), kernels per plant (98.60 % and 70.55), kernel yield per plant (98.13% and 63.91%), SLA (95.25% and 36.23%), SCMR (94.64% and 53.42%) and pod yield per plant (98.33 % and 61.22%) exhibited higher broad sense and narrow sense heritability. The difference between broad sense and narrow sense heritability for these characters was found to less in F<sub>6</sub> generation. For shelling percentage lower broad sense and narrow sense heritability was observed (37.25 and 26.56%) in F<sub>6</sub> segregating population.

#### **4.2.7 Assessment of productive segregants in F<sub>6</sub> segregating generation.**

Best performing progenies were selected based individual mean  $\pm$  SE for number of pods per plant, number of kernels per plant, pod yield, kernel yield and shelling percentage and which are presented in Table 15.

The line 80B1B recorded higher SCMR (49.14), lesser SLA (138.43) coupled with higher pod yield per plant (63 g per plant) among the top ten selected superior segregants in F<sub>6</sub> generation of the cross NRCG 12473  $\times$  ICG 12370.

### **4.3 Phenotypic evaluation of four segregating generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) of the cross NRCG 12274 X ICG12370 for growth, traits related to Water Use Efficiency (WUE), yield and its component traits**

Segregating populations derived from hybrids which is obtained by crossing two parents they are highly diverse for trait of interest. These segregating population used as source population to exercise selection for identifying homozygous lines with better performance to develop varieties. At the same time, the breeding lines from the advanced generations are also used as parental lines for developing commercially exploitable heterotic hybrids. But, most often the source of early generations *i.e.*, F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations offer wider opportunities for achieving high success, because of wider genetic base.

**Table 15: Performance of superior segregants for growth, traits related to WUE, yield and yield component traits in F<sub>6</sub> segregating generation of the cross NRCG12473 × ICG12370 in groundnut**

Line No.	Days to first flowering	Plant height (cm)	Primary branches/plant	SCMR	SLA (cm <sup>2</sup> /g)	Pods/plant	Kernels/plant	Pod yield/plant (g)	Kernel yield/plant (g)	Shelling percentage
1B2A1	32.36	21.27	5.09	45.25	165.25	55	99	54.30	46.28	85.23
1B2A2	33.08	24.00	4.23	40.21	175.25	42	68	39.99	31.94	79.86
1B2B1	32.20	17.07	4.33	55.26	125.32	65	115	60.61	45.23	74.62
6A1A1	31.65	21.65	4.41	47.12	145.23	55	96	50.21	40.12	79.90
10C2A2	39.53	29.80	4.73	40.12	165.25	48	66	44.75	32.25	72.06
13A1A1	40.71	16.33	4.86	58.20	125.23	62	95	67.72	55.24	81.58
14A1A1	32.12	25.35	5.06	39.25	185.25	47	84	37.75	26.44	70.03
14A1A2	31.21	16.89	5.11	45.25	155.26	52	78	48.98	40.95	83.61
16B1A1	31.00	17.77	5.08	58.20	165.25	63	96	55.21	35.44	64.19
19A2A1	30.92	15.92	5.17	47.25	185.25	45	67	45.53	32.10	70.50
21A1A1	32.50	36.28	4.67	50.18	135.23	55	83	55.13	45.79	83.06
28B1A1	38.33	15.25	5.17	57.25	142.25	55	83	55.49	45.79	82.51
30A1A1	40.60	16.67	5.13	53.25	133.20	66	105	58.21	45.74	78.57
38A1A1	40.42	27.17	5.25	44.78	165.55	62	110	62.17	44.32	71.29
54A2B1	36.31	34.77	5.00	41.21	144.25	49	94	53.04	34.62	65.27
86B1A1	42.85	27.62	4.31	40.25	175.25	55	103	65.73	44.06	67.02
122A2A1	25.82	16.53	5.18	48.25	145.20	42	84	60.03	52.32	87.16
139A1A2	36.79	17.79	4.43	58.26	175.25	71	120	68.69	50.80	82.26
145A1A1	36.11	26.00	5.17	55.41	136.20	62	96	53.57	43.25	52.27
155A2A1	42.63	17.13	5.50	39.25	178.25	45	67	45.53	32.10	70.50
156A2A1	37.79	14.93	5.36	42.15	145.20	55	83	55.13	45.79	83.06
156A2B1	31.64	27.36	5.07	35.25	199.25	55	83	55.49	45.79	82.51
NRCG12273	28.78	34.56	4.89	29.25	189.25	31	52	22.36	28.36	78.84
ICG12370	39.25	28.12	4.25	18.25	201.23	24	38	16.12	25.36	63.56
TMV-2	35.26	27.45	6.25	20.12	210.25	23	39	13.45	21.93	61.33
KCG-2	37.12	22.56	5.12	12.25	213.02	20	35	17.23	22.36	77.06

108 F<sub>3</sub>, 84 F<sub>4</sub>, 72 F<sub>5</sub> and 52 F<sub>6</sub> segregating progenies was developed through individual plant selection in each segregating generation based on mean  $\pm$  SE for component traits of pod yield and traits related to WUE and only selected plants were used to forward to the next generation and selected plant sown according to the procedure of plant to row progeny method and this process was followed in all generations.

#### **4.3.1 Analysis of variance**

The mean sum of squares of 108 F<sub>3</sub>, 84 F<sub>4</sub>, 72 F<sub>5</sub> and 52 F<sub>6</sub> selected superior progenies from the cross NRCG 12274  $\times$  ICV12370 for growth, traits related to WUE, yield and its component characters were carried out and is presented in the Table 16. The selected progenies of all the four segregating generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) registered highly significant differences for all the characters studied. Segregating progenies and checks also exhibited significant variability for all the characters in all the four generations except kernel yield per plant and primary branches per plant in F<sub>3</sub> segregating generation.

#### **4.3.2 Genetic Variability studies**

Mean, range, genotypic co-efficient of variation (GCV), phenotypic co-efficient of variation (PCV), heritability in broad sense ( $h^2$ ) and expected genetic advance as percent of mean of all characters are presented in Table 17.

##### **4.3.2.1 Days to first flowering**

Days to first flowering showed mean value of 39.08, 39.61, 39.07 and 35.13 days in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations respectively. Minimum of 20.55 days was observed in F<sub>3</sub> generation followed by 23.77 days, 25.71 and 30.25 days in F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation respectively. Wider range was observed for all the four segregating generations.

Estimated value of both GCV and PVC have decreased from F<sub>3</sub> to F<sub>6</sub> segregating generation with the value of GCV (19.01, 16.55, 17.27 and 14.44 ), PCV (19.10, 17.49, 17.86 and 15.93) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation respectively, the difference between

**Table 16: Analysis of variance for growth parameters, traits related to WUE, yield and its component characters in four segregating generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) of the cross NRCG12274 × ICG12370 in groundnut**

Source of variance		Df	Days to Flowering	Plant height (cm)	Primary branches/plant	SLA (cm <sup>2</sup> /g)	SCMR	Pods/plant (g)	Pod yield/plant (g)	Kernels/plant	Kernel yield/plant (g)	Shelling Percentage
Block (eliminating Check + Va.)	F <sub>3</sub>	4	71.62**	11.76	0.44	2046.67	30.06	26.38	34.12	36.77	4.071	50.46*
	F <sub>4</sub>	4	3.09	3.93*	0.04	406.88	23.23*	35.39*	19.74**	22.37**	1.17	42.49*
	F <sub>5</sub>	3	40.81*	20.25	0.03	1584.29	91.12*	24.08*	5.06	46.20	4.06	13.13
	F <sub>6</sub>	3	11.33	1.41	0.01	282.23	23.63**	4.08	20.07	33.01	2.66	2.53
Progenies + Checks	F <sub>3</sub>	110	58.55**	29.76*	0.32	5035.69*	288.17**	112.90**	200.71*	374.93**	76.1339	169.92
	F <sub>4</sub>	86	50.84*	25.23**	0.57**	4957.34*	242.15*	93.22**	134.99**	288.99**	62.95**	93.54**
	F <sub>5</sub>	78	48.00**	28.36*	0.67*	5275.84*	180.33**	79.80**	164.04**	242.40*	53.84*	107.01
	F <sub>6</sub>	54	34.00*	19.36**	0.30**	6333.72**	103.56**	196.64**	177.947**	479.91**	125.59**	163.13**
Checks	F <sub>3</sub>	3	37.51**	43.57**	0.77*	1161.24**	97.47*	115.20**	146.38	167.67**	111.83	126.31
	F <sub>4</sub>	3	37.22*	15.28**	0.01	6314.86*	226.89*	103.85**	104.81**	135.63**	71.91**	54.30*
	F <sub>5</sub>	3	48.00*	57.70	0.02	4105.19*	70.69*	124.62**	127.50**	382.04*	155.59**	367.39*
	F <sub>6</sub>	3	20.58	13.01**	0.76**	2210.08	35.41	94.24**	131.05*	260.09*	66.48	392.55**
Progenies	F <sub>3</sub>	107	59.44**	29.78*	0.31	4956.89*	293.88**	113.83**	203.64*	362.12**	76.08	172.18
	F <sub>4</sub>	83	51.60*	25.77**	0.28**	4867.23*	245.26*	93.71**	137.30**	294.31**	63.03**	95.29**
	F <sub>5</sub>	71	48.44**	17.64*	0.28	5338.97*	186.40**	79.378**	167.19**	240.34*	51.06*	100.28
	F <sub>6</sub>	51	35.86*	19.46**	0.28**	4978.61**	109.40**	138.42**	141.75**	368.80**	82.50**	86.11**
Checks vs Progenies	F <sub>3</sub>	1	8.25*	0.21	0.21	6520.99	75.78*	11.53*	4.64	69.12*	9.80	21.39
	F <sub>4</sub>	1	15.00	0.72	25.34**	9722.17*	14.81	31.01*	3.29	153.62**	37.94**	26.09
	F <sub>5</sub>	1	20.68	0.23	26.55**	3703.11	22.93	16.46*	41.92*	90.81	22.42	3.73
	F <sub>6</sub>	1	6.18	0.31**	26.74**	8809.51**	11.70	33.39**	21.51**	86.08**	25.30**	32.51**
Error	F <sub>3</sub>	4	0.52	2.29	0.11	641.97	6.28	1.11	26.81	13.71	24.04	30.99
	F <sub>4</sub>	4	5.01	0.41	0.01	663.00	23.43	3.84	1.03	5.42	1.78	4.48
	F <sub>5</sub>	4	2.84	18.35	0.11	546.66	7.49	1.91	5.38	21.66	7.50	22.60
	F <sub>6</sub>	6	5.58	0.98	0.02	355.63	2.29	4.08	14.64	27.50	2.36	1.56

\*Significant @ P = 0.05      \*\* Significant @ P = 0.01

GCV and PCV is low in all the four segregating populations. High heritability coupled with high GAM was observed in three segregating generation *i.e.*, 99.06, 89.56 and 93.51 percent of heritability coupled with 38.98, 32.26 and 34.40 per cent of GAM was observed in F<sub>3</sub>, F<sub>4</sub>, and F<sub>5</sub> populations respectively.

#### **4.3.2.2 Plant height (cm)**

The highest mean value for plant height was observed in F<sub>5</sub> generation (22.28 cm) compared to F<sub>6</sub> (22.28 cm) followed by F<sub>4</sub> (19.91 cm) and F<sub>3</sub> (18.89 cm) segregants. F<sub>3</sub> (12.00 cm to 36.23 cm) population exhibited wider range for the plant height compared to F<sub>6</sub> (12.60 cm to 29.80 cm), F<sub>5</sub> (14.28 cm to 32.25 cm) and F<sub>4</sub> (12.60 to 30.94 cm) population.

The estimates of GCV and PCV were moderate in all the four segregating generations and the value for both genotypic and phenotypic coefficient of variability has been maintained similar trend from F<sub>3</sub> (24.76 and 25.84), F<sub>4</sub> (25.63 and 25.83), and F<sub>6</sub> (23.43 and 25.78), where as in F<sub>5</sub> segregating generation reduction of GCV (17.19) and PCV (18.34) was observed. High heritability (91.84, 98.27, 94.17 and 82.59 %) was coupled with high GAM (48.87, 52.28, 35.56 and 43.86 %) was noticed in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations respectively.

#### **4.3.2.3 Primary branches per plant**

The mean value for number of branches per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations is, 5.09, 4.53 and 5.21 with a range of 4.06 to 6.49, 3.25 to 6.36, 3.41 to 5.48 and 4.11 to 6.20 respective segregating generations. Low GCV (8.28 and 9.97) and moderate PCV (10.42 and 10.18) was observed in F<sub>3</sub> and F<sub>4</sub> generations respectively. Where as F<sub>6</sub> population exhibited the lower GCV (7.53) and PCV (9.82). Higher heritability coupled with moderate GAM was found in F<sub>3</sub> (63.15 and 13.54), F<sub>4</sub> (95.91 and 20.11) and F<sub>5</sub> (91.84 and 20.68) segregants respectively, where as moderate heritability and moderate GAM was observed in F<sub>6</sub> (58.72 and 11.87) segregating population.

**Table 17: Genetic variability parameters for growth, traits related to WUE, yield and its component traits in four segregating generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> And F<sub>6</sub>) of the cross NRCG12274 × ICG12370 in groundnut**

CHARECTERS		MEAN	RANGE		GCV (%)	PCV (%)	h <sup>2</sup> <sub>bs</sub> (%)	GAM
			MIN	MAX				
Days to first flowering	F <sub>3</sub>	39.08	20.55	48.80	19.01	19.10	99.06	38.98
	F <sub>4</sub>	39.61	23.77	44.80	16.55	17.49	89.56	32.26
	F <sub>5</sub>	37.07	25.71	49.80	17.27	17.86	93.51	34.40
	F <sub>6</sub>	35.13	30.25	42.15	14.44	15.93	82.17	26.96
Plant height (cm)	F <sub>3</sub>	20.50	12.00	36.23	24.76	25.84	91.84	48.87
	F <sub>4</sub>	18.89	12.60	42.94	25.60	25.83	98.27	52.28
	F <sub>5</sub>	19.91	12.60	29.80	23.43	25.78	82.59	43.86
	F <sub>6</sub>	22.28	14.28	32.25	17.79	18.34	94.17	35.56
Primary branches/plant	F <sub>3</sub>	5.27	4.06	6.49	8.28	10.42	63.15	13.54
	F <sub>4</sub>	5.09	3.25	6.36	9.97	10.18	95.91	20.11
	F <sub>5</sub>	5.21	4.11	6.20	7.53	9.82	58.72	11.87
	F <sub>6</sub>	4.53	3.41	5.48	10.47	10.93	91.84	20.68
SLA (cm <sup>2</sup> /g)	F <sub>3</sub>	199.31	89.65	365.26	31.90	34.34	86.30	61.04
	F <sub>4</sub>	211.82	93.25	312.05	29.40	31.81	85.40	55.96
	F <sub>5</sub>	239.47	95.32	365.23	27.40	29.09	88.74	53.17
	F <sub>6</sub>	243.58	102.13	385.26	25.73	26.87	91.70	50.85
SCMR	F <sub>3</sub>	44.83	11.95	89.98	36.62	37.04	97.72	74.56
	F <sub>4</sub>	41.49	22.56	78.57	34.48	36.40	89.72	67.27
	F <sub>5</sub>	34.74	14.43	77.73	36.50	37.34	95.55	73.48
	F <sub>6</sub>	31.18	13.88	68.87	30.60	30.98	97.55	62.26
Pods /Plant	F <sub>3</sub>	26.83	11.92	62.00	38.30	38.50	98.96	78.48
	F <sub>4</sub>	27.86	15.39	71.00	32.68	33.43	95.57	65.8
	F <sub>5</sub>	28.17	15.39	55.00	29.61	30.02	97.33	60.18
	F <sub>6</sub>	40.95	13.22	67.22	26.09	26.55	96.55	52.82
Pod yield/plant (g)	F <sub>3</sub>	31.27	10.14	94.48	41.17	44.38	86.04	78.67
	F <sub>4</sub>	30.29	12.63	57.50	37.01	37.16	98.18	75.92
	F <sub>5</sub>	35.27	12.63	63.84	34.19	34.82	96.43	69.16
	F <sub>6</sub>	28.17	15.39	62.00	29.61	30.02	97.33	60.18
Kernels/plant	F <sub>3</sub>	48.59	18.23	98.29	37.01	37.20	98.95	75.83
	F <sub>4</sub>	51.03	27.73	95.72	31.99	32.31	98.01	65.23
	F <sub>5</sub>	52.86	28.16	89.00	26.52	27.94	90.07	51.84
	F <sub>6</sub>	62.50	22.66	116.97	27.25	28.51	91.34	53.65
Kernel yield/plant(g)	F <sub>3</sub>	21.00	8.45	45.02	33.26	40.64	66.97	56.06
	F <sub>4</sub>	21.39	11.25	43.48	35.14	35.69	96.94	71.27
	F <sub>5</sub>	21.09	10.43	42.50	29.67	32.39	83.93	55.99
	F <sub>6</sub>	29.64	10.23	53.56	27.84	28.32	96.65	56.39
Shelling percentage	F <sub>3</sub>	66.76	44.18	95.80	17.23	19.14	81.02	31.94
	F <sub>4</sub>	66.25	44.25	85.41	13.81	14.18	94.25	27.72
	F <sub>5</sub>	57.00	40.29	83.12	14.66	16.87	75.54	26.24
	F <sub>6</sub>	75.59	46.77	86.46	11.21	11.33	97.88	22.85

#### 4.3.2.4 Specific leaf Area (cm<sup>2</sup>/g)

SLA showed high variability with a minimum value of 89.65 cm<sup>2</sup>/g, maximum of 365.26 cm<sup>2</sup>/g and mean of 199.31 cm<sup>2</sup>/g in F<sub>3</sub>. The value of SLA varied from 93.25 cm<sup>2</sup>/g to 312.05 cm<sup>2</sup>/g with a mean value of 211.82 cm<sup>2</sup>/g was recorded in F<sub>4</sub> generation. Both F<sub>5</sub> and F<sub>6</sub> generations exhibited higher mean (243.58 cm<sup>2</sup>/g and 239.47 cm<sup>2</sup>/g respectively) with wider range (102.13 to 385.26 and 95.32 to 365.23 cm<sup>2</sup>/g of respectively). GCV (25.73 and 26.87) and PCV (27.40 and 29.09) were found to be moderate in F<sub>5</sub> and F<sub>6</sub> generations respectively. High heritability (86.30, 85.40, 88.74 and 91.70) coupled with high GAM (61.04, 55.96, 53.17 and 50.85) was noticed in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations respectively.

#### 4.3.2.5 SPAD chlorophyll meter reading (SCMR)

SCMR varied from 11.95 to 89.98 with a mean value of 44.83 in F<sub>3</sub>, 22.56 to 78.57 with a mean value of 41.49 in F<sub>4</sub> generations. F<sub>6</sub> population had lower mean (31.18) and wider range (13.88 to 68.87) and F<sub>5</sub> had higher mean (34.74) and higher range (14.43 to 77.73). Higher GCV (36.62, 34.48, 36.50 and 30.60) and higher PCV (37.04, 36.40, 37.34 and 30.98) were observed in all the four segregating generations respectively. High heritability (97.92, 89.72, 95.55 and 97.55) coupled with high genetic advance as *per cent* of mean (74.56, 67.27, 73.48 and 62.26) was observed in all the four segregating generations respectively.

#### 4.3.2.6 Pods per plant

Wider range of variation was observed in all the four segregating generations *i.e.*, 11.92 to 62.00 in F<sub>3</sub>, 15.39 to 62.00 in F<sub>4</sub>, 13.22 to 67.22 in F<sub>5</sub> and 15.39 to 62.00 in F<sub>6</sub> segregating populations. The mean value for number of pods per plant remain consisted in F<sub>3</sub> (26.83), F<sub>4</sub> (27.86), and F<sub>6</sub> (28.17) populations. The *per cent* of genotypic and phenotypic coefficient of variability in F<sub>3</sub> (38.30 and 38.50 %), F<sub>4</sub> (32.68 and 33.43 %), F<sub>5</sub> (26.09 and 26.55 %) and in F<sub>6</sub> (26.52 and 27.94 %) generations was observed to be high. Heritability and GAM in F<sub>3</sub> (98.96 and 78.48), F<sub>4</sub> (95.57 and 65.80), F<sub>5</sub> (96.55 and 52.82) and in F<sub>6</sub> (93.33 and 60.18) segregating populations was found be high and all most same in all the generations.

#### 4.3.2.7 Pod yield per plant (g)

Pod yield per plant exhibited maximum yield of 94.48 g per plant in F<sub>3</sub> and it was decreased to 57.50 g per plant in F<sub>4</sub> again it was increased to 67.97 g in F<sub>5</sub> and F<sub>6</sub> (63.84) generation. Where as mean value of pod yield per plant in F<sub>3</sub> is 31.27 g, 30.29 g in F<sub>4</sub>, 39.51 g in F<sub>5</sub> and 35.27g in F<sub>6</sub> generation was observed consistence over generations. Both genotypic and phenotypic coefficient of variability was very high in F<sub>3</sub>, F<sub>4</sub> and F<sub>6</sub> generations *i.e.*, 41.17% (GCV) and 44.38% (PCV) in F<sub>3</sub>, 37.01% (GCV) and 37.16% (PCV), in F<sub>4</sub>, and 34.19% (GCV) and 34.82% (PCV) in F<sub>6</sub> generation. High heritability (86.04, 98.18, 88.07 and 96.43%) coupled with high genetic advance as *per cent* of mean (78.67, 75.92, 50.85 and 69.16%) with respect to F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation was observed for this character. Heritability and GAM was exhibited fluctuation over the generations.

#### 4.3.2.8 Kernels per plant

The range for number of kernels per plant was noticed highest in F<sub>5</sub> generation (22.66 to 116 kernels per plant) followed by F<sub>3</sub> (18.23 to 98.29 kernels per plant) and F<sub>6</sub> (28.16 to 89.00 kernels per plant) generation. The mean value of F<sub>3</sub> (48.59 kernels per plant), F<sub>4</sub> (51.03 kernels per plant) and F<sub>5</sub> (62.50 kernels per plant) exhibited similar values, where as drastic reduction for the mean value was observed in F<sub>6</sub> (35.27 kernels per plant) generation in comparison to F<sub>5</sub> generation. Higher GCV and PCV was observed in F<sub>3</sub> (37.01 and 37.2) and F<sub>4</sub> (31.99 and 32.31) generations, where as moderate GCV and PCV was noticed in F<sub>5</sub> (27.25 and 28.51) and F<sub>6</sub> (26.52 and 27.94) generations. Higher heritability coupled with higher GAM was noticed in all the four generations. However heritability and GAM was decreasing from F<sub>3</sub> (98.95 and 75.83), to F<sub>4</sub> (98.01 and 65.23) then F<sub>5</sub> (91.34 and 53.65) and F<sub>6</sub> (90.07 and 51.84) generations.

#### 4.3.2.9 Kernel yield per plant (g)

Kernel yield per plant exhibited a constant mean and range value from F<sub>3</sub> (21.00 g per plant with a range of 8.45 to 45.02) to F<sub>4</sub> (21.31 g per plant with a range of 11.25 to 43.48) and F<sub>6</sub> (21.09 g per plant with a range of 10.43 to 42.50) where as mean value and range for kernel yield per plant increased in F<sub>6</sub> (29.64 g per plant with range of 10.23 to

53.56) generation. This character exhibited high GCV and PCV values of 33.26 and 40.64 in F<sub>3</sub> generation and 35.14 and 35.69 in F<sub>4</sub> generation, moderate GCV (27.84) and PCV (28.32) in F<sub>5</sub> generation and moderate GCV (29.67) and high PCV (32.39) in F<sub>6</sub> generation. Higher heritability (66.97, 96.94, 83.93 and 96.65) coupled with higher GAM (56.06, 71.27, 55.99 and 56.39) were prevailing in all the four generations for this character.

#### **4.3.2.10 Shelling percentage**

Wide range of variation was observed for this character in all the generations *i.e.*, F<sub>3</sub> (44.18 to 95.80%), F<sub>4</sub> (44.25 to 85.41%), F<sub>5</sub> (46.77 to 86.46%) and F<sub>6</sub> (40.29 to 83.12%) generation. Highest mean value was recorded in F<sub>5</sub> (75.59%) generation and lowest was in F<sub>6</sub> (57.00%) generation. The GCV and PCV were moderate in F<sub>3</sub> (17.23 and 19.14), F<sub>4</sub> (13.81 and 14.18), F<sub>5</sub> (11.21 and 11.33) and F<sub>6</sub> (14.66 and 16.87) generations. High heritability coupled with moderate GAM was found in F<sub>4</sub> (94.25 and 27.72), F<sub>5</sub> (97.88 and 22.85) and F<sub>6</sub> (75.54 and 26.24) generations, where as high heritability (81.02) and high GAM (31.94) observed for this character in all the four generations.

#### **4.3.3 Association studies**

The phenotypic correlation co-efficient among growth parameters, traits related to WUE, yield and its component characters was recorded in 108 F<sub>3</sub>, 84 F<sub>4</sub>, 72 F<sub>5</sub> and 52 F<sub>6</sub> segregating generations of the cross NRCG 12274 × ICG12370 and results are presented in Table 18.

##### **4.3.3.1 Correlation coefficient of pod yield per plant with growth parameters, traits related to WUE and its component traits.**

The phenotypic correlation values between traits were calculated by regressing phenotypic values of one trait on those of other. Pod yield per plant showed significantly positive association in all the four generations *i.e.*, F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> populations with SCMR (0.68, 0.56, 0.65 and 0.94), pods per plant (0.62, 0.74, 0.68 and 0.95) and kernels per plant (0.69, 0.70, 0.77 and 0.97) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations respectively, where as

shelling percentage (-0.17, -0.11, -0.43 and -0.33) and SLA ( -0.66, -0.53, -0.63 and -0.35) was exhibited significantly negative correlation with pod yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations respectively.

#### **4.3.3.2 Association among growth parameters, traits related with WUE and yield attributing characters.**

Trait SCMR showed significant positive association with pods per plant (0.59, 0.84, 0.88 and 0.86), kernels per plant (0.63, 0.94, 0.70 and 0.88), kernel yield per plant (0.51, 0.95, 0.90 and 0.92) and pod yield per plant (0.68, 0.56, 0.65 and 0.94) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations respectively, where as significantly negative association was seen with SLA (-0.93, -0.92, -0.94 and -0.76) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations respectively.

SLA exhibited the significant negative correlation with pod per plant (-0.56, -0.74, -0.78 and -0.27), kernels per plant (-0.60, -0.87, -0.42 and -0.33) kernel yield per plant (-0.48, -0.92, -0.62 and -0.35) and pod yield per plant (-0.66, -0.53, -0.63 and -0.35) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations respectively.

Pod per plant exhibited significant positive correlation with kernels per plant (0.93, 0.94, 0.78 and 0.86), kernel yield per plant (0.90, 0.86, 0.87 and 0.76) and pod yield per plant (0.62, 0.74, 0.68 and 0.95) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations respectively.

Kernels per plant showed significant positive correlation with kernel yield per plant (0.93, 0.95, 0.92, and 0.96), pods per plant (0.93, 0.94, 0.78 and 0.86) and pods yield per plant (0.69, 0.70, 0.77 and 0.97).

Kernel yield per plant exhibited the significant positive correlation with pods per plant (0.90, 0.86, 0.87 and 0.76 in), SCMR (0.51, 0.95, 0.90 and 0.92) and pod yield per plant (0.57, 0.59, 0.65 and 0.98) in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations respectively. Significant negative correlation with SLA (-0.48, -0.92, -0.62 and -0.35) was observed in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations respectively.

**Table 18: Phenotypic correlation coefficients among growth parameters, traits related to WUE, yield and its component traits in four segregating generations (F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub>) of the cross NRCG12274 × ICG12370 in groundnut.**

Characters	Generations	Pods /plant	Kernels / plant	Kernel yield/ plant (g)	Shelling percentage	SLA (cm <sub>2</sub> /g)	SCMR	Pod yield (g)
Pods / plant	F <sub>3</sub>	<b>1.00</b>	0.93**	0.94**	0.20*	-0.24*	0.28*	0.84**
	F <sub>4</sub>	<b>1.00</b>	0.93**	0.89**	0.07	-0.45**	0.55**	0.83**
	F <sub>5</sub>	<b>1.00</b>	0.94**	0.81**	0.01	0.59**	-0.34*	0.81**
	F <sub>6</sub>	<b>1.00</b>	0.71**	0.95**	0.54**	-0.70	0.79**	0.87**
Kernels / plant	F <sub>3</sub>		<b>1.00</b>	0.91**	-0.03	-0.23*	0.26*	0.89**
	F <sub>4</sub>		<b>1.00</b>	0.89**	-0.25*	-0.53**	0.63**	0.89**
	F <sub>5</sub>		<b>1.00</b>	0.75**	-0.10*	0.62**	-0.35*	0.79**
	F <sub>6</sub>		<b>1.00</b>	0.76**	0.30*	-0.58**	0.66**	0.73**
Kernel yield / plant (g)	F <sub>3</sub>			<b>1.00</b>	0.15*	-0.26*	0.29*	0.92**
	F <sub>4</sub>			<b>1.00</b>	-0.11*	-0.52**	0.61**	0.94**
	F <sub>5</sub>			<b>1.00</b>	0.17*	0.59**	-0.38*	0.86**
	F <sub>6</sub>			<b>1.00</b>	0.40**	-0.78**	0.86**	0.97**
Shelling percentage	F <sub>3</sub>				<b>1.00</b>	0.01	-0.01	-0.18*
	F <sub>4</sub>				<b>1.00</b>	0.32*	-0.31*	-0.37*
	F <sub>5</sub>				<b>1.00</b>	-0.09	-0.05	-0.12*
	F <sub>6</sub>				<b>1.00</b>	-0.23*	0.25*	-0.23*
SLA (cm <sub>2</sub> /g)	F <sub>3</sub>					<b>1.00</b>	-0.88**	-0.24*
	F <sub>4</sub>					<b>1.00</b>	-0.72**	-0.55**
	F <sub>5</sub>					<b>1.00</b>	-0.56**	-0.64**
	F <sub>6</sub>					<b>1.00</b>	-0.92**	-0.81**
SCMR	F <sub>3</sub>						<b>1.00</b>	0.27*
	F <sub>4</sub>						<b>1.00</b>	0.63**
	F <sub>5</sub>						<b>1.00</b>	0.39*
	F <sub>6</sub>						<b>1.00</b>	0.88**
Pod yield / plant (g)	F <sub>3</sub>							<b>1.00</b>
	F <sub>4</sub>							<b>1.00</b>
	F <sub>5</sub>							<b>1.00</b>
	F <sub>6</sub>							<b>1.00</b>

\*Significant @ P =0.05

\*\* Significant @ P = 0.01

#### **4.3.1 Intergeneration correlation studies**

The analysis was made to determine the relationship among F<sub>3</sub> to F<sub>6</sub> segregating generations for the traits such as days to flowering, plant height (cm), number of primary branches per plant, SCMR, SLA, number of pods per plant, number of kernels per plant, pod yield per plant (g), kernel yield per plant (g), and shelling percentage. Result pertaining to this has been presented in Table 19.

Significant positive association of F<sub>3</sub> generation with F<sub>4</sub> generation for days to flowering (0.53), plant height (0.58), primary branches per plant (0.20), pods per plant (0.40), kernels per plant (0.32), shelling percentage (0.46), SLA (0.31), SCMR (0.41) and pod yield per plant (0.32) was observed. F<sub>3</sub> generation showed significant positive correlation with F<sub>5</sub> generation for primary branches per plant (0.23) and shelling percentage (0.21), where as significant negative correlation was observed for SLA (-0.20).

Days to flowering (0.48), plant height (0.0.61), primary branches per plant (0.35), pods per plant (0.48), kernels per plant (0.57), kernel yield per plant (0.42), shelling percentage (0.38), SLA (0.37), SCMR (0.47) and pod yield per plant (0.26) was found to be having significant positive correlation between F<sub>4</sub> and F<sub>5</sub> generations. F<sub>4</sub> generation exhibited significant positive correlation with F<sub>6</sub> generation for days to flowering (0.45), plant height (0.35), primary branches per plant (0.28) and shelling percentage (0.21).

F<sub>5</sub> generation was found to be significantly positively associated with F<sub>6</sub> generation for days to flowering (0.54), pods per plant (0.97), kernels per plant (0.84), kernel yield per plant (0.85), shelling percentage (0.21), SCMR (0.72) and pod yield per plant (0.76).

#### **4.3.5 Correlation and regression of pod yield on growth parameters, traits related to WUE and its components traits.**

Regression of pod yield on its component traits and traits related to WUE was carried out at phenotypic level taking pod yield per plant as the dependent character. Result pertaining to this has been presented in Table 20.

**Table 19: Intergeneration correlation coefficients for growth parameters, traits related to WUE, yield and its component traits from F<sub>3</sub> to F<sub>6</sub> segregating generations of the cross NRCG12274 × ICG12370 in groundnut.**

Characters	Generations	F <sub>3</sub>	F <sub>4</sub>	F <sub>5</sub>	F <sub>6</sub>
Days to flowering	F <sub>3</sub>	<b>1.00</b>	0.53**	-0.15	0.07
	F <sub>4</sub>		<b>1.00</b>	0.48**	0.45**
	F <sub>5</sub>			<b>1.00</b>	0.54**
	F <sub>6</sub>				<b>1.00</b>
Plant height (cm)	F <sub>3</sub>	<b>1.00</b>	0.58	0.02	0.12
	F <sub>4</sub>		<b>1.00</b>	0.61**	0.35*
	F <sub>5</sub>			<b>1.00</b>	0.19
	F <sub>6</sub>				<b>1.00</b>
Primary branches/plant	F <sub>3</sub>	<b>1.00</b>	0.20*	0.23*	-0.07
	F <sub>4</sub>		<b>1.00</b>	0.35*	0.28*
	F <sub>5</sub>			<b>1.00</b>	0.17*
	F <sub>6</sub>				<b>1.00</b>
Pods/ plant	F <sub>3</sub>	<b>1.00</b>	0.40**	-0.01	0.06
	F <sub>4</sub>		<b>1.00</b>	0.48**	0.13
	F <sub>5</sub>			<b>1.00</b>	0.97**
	F <sub>6</sub>				<b>1.00</b>
Kernels/ plant	F <sub>3</sub>	<b>1.00</b>	0.32*	-0.01	0.14
	F <sub>4</sub>		<b>1.00</b>	0.57**	0.04
	F <sub>5</sub>			<b>1.00</b>	0.84
	F <sub>6</sub>				<b>1.00</b>
Kernel yield / plant (g)	F <sub>3</sub>	<b>1.00</b>	0.17*	0.08	0.08
	F <sub>4</sub>		<b>1.00</b>	0.42**	0.04
	F <sub>5</sub>			<b>1.00</b>	0.85**
	F <sub>6</sub>				<b>1.00</b>
Shelling per cent age	F <sub>3</sub>	<b>1.00</b>	0.46**	0.21*	0.03
	F <sub>4</sub>		<b>1.00</b>	0.38*	0.21*
	F <sub>5</sub>			<b>1.00</b>	0.03
	F <sub>6</sub>				<b>1.00</b>
SLA (cm <sup>2</sup> /g)	F <sub>3</sub>	<b>1.00</b>	0.41**	-0.20	0.15
	F <sub>4</sub>		<b>1.00</b>	0.37	0.08
	F <sub>5</sub>			<b>1.00</b>	0.15
	F <sub>6</sub>				<b>1.00</b>
SCMR	F <sub>3</sub>	<b>1.00</b>	0.41**	-0.07	0.08
	F <sub>4</sub>		<b>1.00</b>	0.47**	0.07
	F <sub>5</sub>			<b>1.00</b>	0.72**
	F <sub>6</sub>				<b>1.00</b>
Pod yield / per plant (g)	F <sub>3</sub>	<b>1.00</b>	0.32*	0.08	0.06
	F <sub>4</sub>		<b>1.00</b>	0.26	0.02
	F <sub>5</sub>			<b>1.00</b>	0.76**
	F <sub>6</sub>				<b>1.00</b>

In F<sub>3</sub> segregating generation the traits such as kernel yield per plant (0.57 and 0.94) was found to be having highly significant positive association with maximum positive effect on pod yield per plant followed by pods per plant (0.62 and 0.83), kernels per plant (0.69 and 0.52) and SCMR (0.68 and 0.57), where as SLA (-0.66 and -0.13) and shelling percentage (-0.17 and -0.19) had significantly negative association and negative effect on pod yield per plant.

Pod yield per plant was positively associated and positively dependent on kernel yield per plant (0.59 and 0.86), pods per plant (0.74 and 0.94), kernels per plant (0.70 and 0.50) and SCMR (0.56 and 0.44) in F<sub>4</sub> generation. The trait SLA (-0.53 and -0.09) and shelling percentage (-0.11 and -0.15) were found to be having negative association and negative effect on pod yield per plant in F<sub>4</sub> generation.

The positive association and positive effect of kernel yield per plant (0.65 and 1.17) on determination of pod yield per plant in F<sub>5</sub> generation was observed to be very high compared to SCMR (0.65 and 0.61), kernels per plant (0.77 and 0.81) and pods per plant (0.68 and 0.98). The negative association and negative effect of SLA (-0.63 and -0.11 correlation) on pod yield per plant was more than the shelling percentage (-0.43 and -0.56) in F<sub>5</sub> generation.

In F<sub>6</sub> generation presence of positive association and positive effect of pods per plant (0.95 and 0.93), kernels per plant (0.97 and 0.59), kernel yield per plant (0.98 and 1.14) and SCMR (0.94 and 0.24) on pod yield per plant was observed. Negative association and negative effect of SLA (-0.35 and -0.85) and shelling percentage (-0.33 and -0.27) on pod yield per plant was noticed in F<sub>6</sub> generation.

#### **4.3.6 Comparisons of broad sense and narrow sense heritability for growth parameters, traits related WUE, yield and its component characters.**

The evaluation of parent and progeny provided an opportunity to compute heritability values following parent offspring regression method involving F<sub>3</sub> plant data and F<sub>4</sub> progeny mean for narrow sense heritability of F<sub>4</sub> generation, similarly narrow sense heritability were estimated for F<sub>5</sub> and F<sub>6</sub> generations. The heritability estimates

**Table 20: Correlation and regression of pod yield on growth parameters, traits related to WUE and yield component traits in four segregating generations of the NRCG12274 × ICG12370 in groundnut.**

Characters	F <sub>3</sub> generation		F <sub>4</sub> generation		F <sub>5</sub> generation		F <sub>6</sub> generation	
	r-value	b-value	r-value	b-value	r-value	b-value	r-value	b-value
<b>Days to first flowering</b>	-0.09	-0.09	0.17*	0.30	0.06	0.12	0.01	0.22
<b>Plant height (cm)</b>	-0.04	-0.11	-0.15*	-0.38	0.15*	0.37	-0.12*	-0.84
<b>Primary branches/ plant</b>	0.07	2.11	-0.01	-0.03	0.07	1.89	0.09	-0.04
<b>SLA (cm<sup>2</sup>/g)</b>	-0.66**	-0.13	-0.53**	-0.09	-0.63**	-0.11	-0.35*	1.11
<b>SCMR</b>	0.68**	0.57	0.56**	0.44	0.65**	0.61	0.94**	-0.14
<b>Pods / plant</b>	0.62**	0.83	0.74**	0.94	0.68**	0.98	0.95**	0.93
<b>Kernels / plant</b>	0.69**	0.52	0.70**	0.50	0.07	0.01	0.97**	0.59
<b>Kernel yield / plant (g)</b>	0.57**	0.94	0.59**	0.86	0.65**	1.17	0.98**	1.14
<b>Shelling percentage</b>	-0.17*	-0.19	-0.11*	-0.15	-0.43**	-0.56	-0.03	-0.27

\* Significant @ P=0.05    \*\* Significant @ P= 0.01

**Table 21: Comparison between broad sense and narrow sense heritability for growth parameters, traits related to WUE, yield and its component traits in segregating populations for four generations in the cross of NRCG12274 × ICG12370 in groundnut.**

Characters	F <sub>3</sub> -F <sub>4</sub>		F <sub>4</sub> -F <sub>5</sub>		F <sub>5</sub> -F <sub>6</sub>	
	Broad sense heritability	Narrow sense heritability	Broad sense heritability	Narrow sense heritability	Broad sense heritability	Narrow sense heritability
<b>Days to first flower</b>	89.56	37.02	93.51	41.16	82.17	43.68
<b>Plant height (cm)</b>	98.27	38.02	82.59	55.74	94.13	46.80
<b>Primary branches/plant</b>	95.91	14.42	58.72	27.77	91.84	13.41
<b>Pods /plant</b>	95.57	26.57	97.33	34.51	96.55	27.82
<b>Kernels / plant</b>	98.01	20.01	90.07	37.74	91.34	37.59
<b>Kernel yield / plant (g)</b>	96.94	11.51	83.93	27.58	96.65	57.39
<b>Shelling percentage</b>	94.25	26.71	75.54	37.96	97.88	46.88
<b>SLA (cm<sup>2</sup>/g)</b>	85.40	30.86	88.74	32.43	91.70	18.74
<b>SCMR</b>	89.72	28.54	95.55	35.19	97.55	49.91
<b>Pod yield/ plant (g)</b>	98.18	20.92	96.43	20.07	88.07	40.66

computed by regression method can be utilized for predicting the response to selection in early and advanced generations. The results obtained from the study are presented in Table 21.

The results depicted that broad sense heritability recorded high for all the characters in F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations except primary branches per plant in F<sub>5</sub> generation which showed the presence of moderate heritability.

Narrow sense heritability was moderate for primary branches per plant (14.42%), pods per plant (26.57%), kernels per plant (20.01%), kernel yield per plant (11.51%) pod yield per plant (20.92%) and shelling percentage (26.71%) in F<sub>4</sub> generation. Where as SLA (30.86), days to flowering (37.02) and plant height (38.02) were noticed with high heritability in F<sub>4</sub> generation. Difference between broad sense and narrow sense heritability was less for days to flowering, plant height, primary branches per plant and shelling percentage in F<sub>4</sub> generation.

Higher broad sense coupled with higher narrow sense heritability was found in F<sub>5</sub> generation for days to flowering (93.51% and 41.16%), plant height (82.59% and 55.74%), pods per plant (97.33% and 34.51%) and shelling percentage (75.54 %and 37.96%).

Higher broad sense and moderate narrow sense heritability was noticed for kernel yield per plant (83.93 and 27.58%) and pod yield per plant (96.43 and 20.07%) in F<sub>5</sub> generation.

For days to flowering (82.17 and 43.68%), plant height (94.13 and 46.80%), kernels per plant (91.34 and 37.59%), kernel yield per plant (96.65 and 57.39%), shelling percentage (97.88 and 46.88%) and SCMR (97.55 and 49.91%) exhibited the higher broad sense and narrow sense heritability respectively and the difference between broad sense and narrow sense heritability for these characters was found to be less in F<sub>6</sub> generation.

#### **4.3.7 Assessment of productive segregants in F<sub>6</sub> generation.**

Superior progenies were selected based individual mean  $\pm$  SE for number of pods per plant, number of kernels per plant, pod yield, kernel yield and shelling percentage and which are presented in Table 22.

The line 30 4 g per plant) among the top ten selected superior segregants in F<sub>6</sub> generation of the cross NRCG 12274  $\times$  ICG 12370.

**Table 22: Performance of superior segregants for growth, traits related to WUE, yield and yield component traits in F<sub>6</sub> segregating generations of the cross NRCG12274 × ICG12370 in groundnut**

Line no	Days to first flowering	Plant height (cm)	Primary branches/plant	SLA (cm <sup>2</sup> /g)	SCMR	Pods/plant	Kernels/plant	Pod yield/plant (g)	Kernel yield/plant (g)	Shelling percentage
13A1A1	30.35	25.23	5	156.25	45.25	45	71	38.59	20.12	52.14
23B1A1	33.75	20.25	6	145.25	49.25	62	84	46.91	38.23	81.63
32A1A1	42.73	18.65	7	123.25	54.21	59	93	53.77	43.63	80.92
40A1A1	39.79	32.20	5	145.25	40.23	56	99	69.64	34.27	49.21
52A1A1	43.71	18.25	4	165.25	39.25	44	93	53.25	33.19	62.32
60A1A1	35.00	33.25	8	176.25	47.21	50	88	61.43	28.13	45.79
63A1A1	30.57	25.20	5	142.65	56.25	52	90	50.18	40.12	79.95
73A1A1	29.64	15.20	6	132.25	62.32	48	84	48.25	29.38	60.88
83A1A1	32.27	26.36	4	165.25	48.25	53	80	48.41	40.31	83.26
96A1A1	40.64	33.25	7	125.23	50.12	63	98	60.03	49.42	83.00
98A1A1	44.00	18.20	5	175.42	48.56	59	64	44.12	33.19	75.22
101A1A1	42.21	29.25	6	125.23	52.32	63	76	52.21	38.56	73.85
NRCG12274	45.00	30.25	5	174.25	30.20	36	68	35.23	29.12	82.65
ICG12370	44.45	18.25	4	201.25	25.32	20	39	25.36	20.12	79.38
TMV-2	39.36	36.25	6	142.25	36.25	28	55	25.23	16.25	64.47
KCG-2	44.60	25.20	5	125.56	42.36	32	59	36.25	26.25	72.44

## *Discussion*



## V. DISCUSSION

The success of any crop improvement programme depends on the magnitude of genetic variability and the extent to which the desirable trait is heritable. The estimate of variability of yield and yield contributing characters and their heritable components in the material is more important in any crop breeding programme. The presence of genetic variability in breeding material has been emphasized by Falconer (1981), so as to exercise critical selection pressure. The information on the nature and magnitude of variation in segregating population of a cross where selection is actually practiced will be more meaningful and it is of immediate practical utility. Moreover correlation studies provide information about the relative contribution of various component traits on pod yield per plant and help in effective identification and selection of superior plants.

Since yield is polygenically controlled and highly influenced by environment, selection based on yield alone is not effective. Therefore, improvement in yield can be brought about by effecting indirect selection through yield attributes whose heritability is high and show strong association with yield.

Groundnut is an important oil seed crop grown in arid and semi arid regions of the country where availability of water for crop growth is limited because of this, production level comes down. Scarcity of water during critical stage of groundnut *i.e.*, flowering and peg penetration time causes drastic reduction of pod yield in groundnut. So it is necessary to breed the varieties which should be tolerant to drought and having high Water Use Efficiency is one of the important criteria for the plant breeders.

Whenever, plant selected for high Water Use Efficiency it reduces the yield because when stomata is opened for carbon-di-oxide exchange at the same time transpiration also occurs, so whenever we go for selecting high Water Use Efficient genotypes which will reduces the yield. Because of this reason breeding for Water Use Efficiency is unsuccessful (Udaykumar *et al.*, 1998). Measurement of Water Use Efficiency by gas exchange studies and gravimetric approach is difficult under field condition, when we have to screen large number of plants, so surrogate traits could be

used for the measurement of Water Use Efficiency. WUE is one of the physiological traits which contribute for the productivity when water is scarce. Importance of WUE explained in yield model proposed by Passuoria (1986), where yield is a function of transpiration rate, WUE and harvest index.

In groundnut surrogate traits like carbon isotope discrimination ( $\Delta^{13}C$ ) has inverse relation with pod yield and negative association of SLA with SPAD. SLA indicates the expansion of leaf area and thickness of leaf. The plants which having higher leaf surface and thinner leaf will be having higher SLA values. Since, the plants which having higher SLA values will be having lower WUE because, loss of water through transpiration will be more hence SLA is negatively correlated with WUE. SCMR indicates the chlorophyll content of the leaf and thickness of leaf. Those plants which having higher chlorophyll content and thicker leaf will be having higher SCMR values. Since, the plants having higher SCMR value will be have the water retention capacity of the plant by thickening of cell wall and down regulation of intervals between stomata opening, hence SCMR is positively associated with WUE. SCMR is a low cost rapid non destructive criteria for selecting groundnut genotypes for improved productivity under drought prone environments (Nageshwar rao *et al.*, 2001; sheshashayee *et al.*, 2006). Hence, these traits could be used for selecting groundnut genotypes having high Water Use Efficiency.

### **5.1 Phenotypic evaluation of F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL populations of the cross NRCG12568 × NRCG12326 for growth, traits related to Water Use Efficiency, yield and its component characters.**

Recombinant inbred populations derived from single seed descent method have many advantages. RILs find wide usage in both breeding and molecular work owing to the various purposes they serve. RILs are the breeding output from which good stabilized segregants can be directly used as breeding lines with desirable traits from both the parents involved in the cross. In RILs the early genetic variability realized in the population is maintained and serve as a stable mapping population.

All forms of plant improvement activities through breeding contemplate an eventual boost in genetic potential for yield. Since, yield is polygenically controlled and highly influenced by environment, selection based on yield alone is not effective. Hence, the breeder develops into proposition of selecting for high yield indirectly through yield associated and highly heritable characters after eliminating environmental components of phenotypic variance. An attempt to improve a character by selection would be futile unless a major portion of variation is heritable which depends entirely on the magnitude of genetic variability in the source progeny. With respect to yield and its component traits, most of the genetic variability available today in plant collection is the result of spontaneous mutation, recombination and exposure to natural selection over centuries. The agriculturist or farmers right from pre-historic days has chosen plants and grown them according to his needs. As time passed and man's pursuit for better genotypes progressed, the concept of hybridization evolved as a means to generate more variability through recombination. This variability generated is a pre-requisite for any breeding programme aimed at improving the yield and other characters. Thus it is imperative to have information on both genotypic and phenotypic coefficients of variation to get an idea regarding the heritability of character. Information on genotypic and phenotypic coefficient of variation, heritability together with GAM will be handy for prediction of the possible genetic advance by selection for the character. Besides the knowledge of correlation and path coefficient analysis would assist in setting up selection indices. The genetic parameter such as genotypic coefficient of variability and genetic advance helps to split the total variability into heritable and non-heritable components.

The material chosen for the present study consisting of 553 F<sub>3</sub> RILs, 456 F<sub>4</sub> RIL, 340 F<sub>5</sub> RIL and 325 F<sub>6</sub> RIL populations of the cross NRCG12568 × NRCG12326 along with two parents NRCG12568, NRCG12326 and two checks TMV 2 and KCG 2 . Since, these two parents are contrast (Table 1) for pod yield per plant, kernel yield per plant, pods per plant, shelling percentage, SLA and SCMR. These two parents were selected for development of RILs. Since, these RIL's were developed through single seed descent method. More number of cross over break point suppresser could have leads to more RILs and each RIL will be having specific length of parental chromosome. Therefore, it

under lies the importance to know the extent of variability, nature of correlation and regression among the characters in the given material. Variability studies in RILs helps to use this population for selecting some good performing Water Use Efficient high yielding lines for further breeding programmes.

The results obtained in this study are briefly discussed in the light of available literature under the following headings to draw valid conclusions.

5.1.1 Analysis of variance.

5.1.2 Genetic variability parameters.

5.1.3 Correlation coefficient studies.

5.1.4 Intergeneration correlation and regression

5.1.5 Comparison of correlation and regression

5.1.6 Comparison of broad sense and narrow sense heritability

5.1.7 Skewness and kurtosis.

5.1.8 Assessment of productive segregants in F<sub>6</sub> RIL

### **5.1.1 Analysis of Variance in RILs of the cross NRCG 12568 × NRCG 12326**

Analysis of variance in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL populations of the cross NRCG12568 X NRCG12326 revealed significant differences among the recombinant inbred lines (progenies) in all the four generations for days to first flowering, plant height, pods per plant, kernels per plant, pod yield per plant and kernel yield per plant. Where as SLA and SCMR showed the presence of variability only in F<sub>5</sub> and F<sub>6</sub> generations. The presence of variability in both checks and progenies were noticed for all characters except SLA, SCMR and shelling percentage in all the four generations. Even checks *verses* progenies were also exhibited significant amount of variability for all the traits except plant height and pod yield per plant in F<sub>5</sub> and F<sub>6</sub> generations which indicating the presence of enormous genetic variability and the choice of the material for the investigation is appropriate. This was further supported by the fact that range has also been quite wider for all the characters also pointing out extreme Recombinant Inbred Lines are available for selection.

### 5.1.2 Genetic variability parameters:

The range and mean values does not reflect the total variability in the material being studied. Hence, actual variance has to be estimated for the characters to know the extent of variability existing in them. The phenotypic variance indicates the amount of variance which is due to the differences in phenotypic value where as the genotypic variance indicates the magnitude of variance arising due to differences in genotypic values.

The absolute values of phenotypic and genotypic variance cannot be used for comparing the degree of variability for different characters because the units in which the characters are measured are different. Hence the Co-efficient of Variation which expresses variance as per cent of mean is to be used for the comparisons. Higher estimates of these characters indicate greater variability and vice-versa. In similar context narrow difference between the phenotypic co-efficient of variability (PCV) and genotypic co-efficient of variability (GCV) implies lesser impact of environment in the expression of characters.

The range was quite high for all the characters among the recombinant inbred lines in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations of the cross NRCG12568 × NRCG12326 studied suggesting that the RILs which are found in all the four generations are divergent for all the traits.

The mean value for SCMR and shelling percentage showed higher variation over the four generations. Since, these RILs were grown in *kharif* and *summer* season, where in the availability of rainy days, day length, rain fall and temperature are various in different seasons, therefore this kind of variation is obvious and these are the quantitative characters governed by polygenes with high genotype × environmental interaction.

Despite the presence of extreme RILs in all the generations the mean was so similar for number of pods per plant, number of kernels per plant, kernel yield per plant, pod yield per plant, SCMR and SLA in all the four generations studied suggesting that range alone is not sufficient to make valid conclusion regarding existing variability

among RILs for these traits in all the generations. This implies the need of estimation of GCV and PCV to know the extent of variability present in RILs of all the generations.

The higher magnitude of GCV and PCV was observed for plant height, SCMR, SLA, total number of pods per plant, pod yield per plant, number of kernels per plant and kernel yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs. It suggests that presence of enormous variation for these traits in all the four generations. Hence, there is scope for practicing of individual plant selection for the above mentioned characters to get higher yields. The magnitude of GCV and PCV for these traits among the RILs in four generations, expressing similar trend indicating that these characters are quite stable across different generations and different seasons. Higher estimates of GCV and PCV were obtained by Sharma and Varshney (1995), Sumathi and Ramanathan (1995), Gowda *et al.* (1996), Makhan Lal *et al.*, (2003), Golakia *et al.*, (2005), Ganeshan and Sudhakar (1995), Veeramani *et al.*, (2005), John *et al.*, (2007) and Parameshwarappa *et al.*, (2007) in groundnut for pods per plant, kernel yield per plant and pod yield per plant.

Moderate difference between GCV and PCV were observed for the characters like days to flowering, plant height, shelling percentage, number of branches per plant, shelling percentage, and specific leaf area in all the four generations. This indicates the existence of comparatively moderate variability, which could be exploited for improvement through selection in advanced generations for these characters. Similar kind of results was observed by Rudraswamy *et al.*, (1999) in groundnut for pods per plant, pod yield per plant and kernel yield per plant.

The close correspondence between the estimates of GCV and PCV for SCMR, specific leaf area, and number of pods per plant in RILs of four generations, indicated less environmental influence on expression of these traits. Hence selection for these characters could be made based on their phenotypic performance. Since, these traits are less controlled by environmental factors, therefore, these characters can be used for further selection for higher yields and Water Use Efficiency related traits like SLA and SCMR as surrogate traits.

Moderate difference between PCV and GCV estimates were observed for yield attributing characters like number of kernels per plant, kernel yield and Pod yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL populations. Hence, these traits could be used for further selection for higher yield.

#### **5.1.2.1 Heritability and Genetic Advance as *per cent* mean in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs for growth, traits related to WUE, yield and yield contributing characters**

To have an exact idea of the heritable portion of variability, it is necessary to estimate heritability for each character. Broad sense heritability estimates represent the relative strength of the characters and it indicates the efficiency of selection systems. Broad sense heritability gives an idea of about observed variability attributable to genetic differences. The difference between PCV and GCV estimates indicate the extent of heritability. If the difference is low it indicates high heritability. While wide differences indicate considerable influence of the environment leading to low heritability estimates.

Heritability value alone cannot provide information on the amount of genetic progress that would result from selection of best individuals. Johnson *et al.*, (1955) reported that heritability estimates along with genetic gain would be more useful than alone in predicting the effectiveness of selecting the best individuals. Therefore it is necessary to consider the predicted genetic advance along with high heritability estimates as a tool in selection programme for better efficiency in the selection.

A relative comparison of heritability values and expected genetic gain expressed as *per cent* of mean gives an idea about the nature of gene action governing a particular character. High heritability coupled with high genetic advance reveals the presence of lesser environmental influence and prevalence of additive gene action in expression of the trait. But lower values of genetic advance indicates the prevalence of narrow range of variability, high gene interaction or non additive gene action for moderate values of genetic advance indicates both additive and non-additive gene actions might be responsible for their expression.

High heritability coupled with high genetic advance as *per cent* of mean was reported for characters like, plant height, SCMR, number of pods per plant, pod yield per plant, number of kernel per plant and kernel yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL populations. This shows that these characters are under the control of additive gene action. Hence, there is lot of scope for improvement of these traits in further breeding programme and single plant selection could be advisable to breed for high yielding and Water Use Efficient genotypes in groundnut. Alan Cruickshan *et al.*, (2005) reported high heritability coupled with high genetic advance as *per cent* of mean for kernel yield and pod yield and also Veeramani *et al.*, (2005) reported high broad sense heritability coupled with high genetic advance for pod and kernel yield Golkia *et al.*, (2005) and John *et al.*, (2007) reported high heritability coupled with higher GAM for sound mature kernel percentage along with kernel yield and pod yield in groundnut.

Moderate heritability coupled with high genetic advance as *per cent* of mean was observed for number of primary branches per plant only in F<sub>3</sub> RIL population, high heritability and moderate GAM was observed in F<sub>4</sub> and F<sub>6</sub> RILs where as low heritability and low GAM was noticed in F<sub>5</sub> indicating presence narrow range of variability and prevalence of non additive gene action. This suggested that limited scope for further improvement of this character in F<sub>3</sub> RILs. Reddy and Guptha (1992), Ganeshan and Sudhakar (1995), Mukhan *et al.*, (2003) and Praveen Kumar (2004) were observed the presence of moderate heritability and moderate GAM for shelling percentage and primary branches per plant in Groundnut.

From the present investigation in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL populations, it revealed that heritability and genetic advance as *per cent* of mean was high for yield and its attributing traits like pods per plant, shelling percentage and kernel yield per plant indicating the presence of additive gene action. Hence, single plant selection is effective in further breeding programme.

Non additive gene action was observed for days to flowering, primary branches per plant and SLA which indicates the lower variability in these characters. Therefore, it

needs separate hybridization followed by selecting superior sergegants in further breeding programme.

Among the surrogate traits studied, SPAD chlorophyll meter reading was found to be a better trait for selecting high Water Use Efficient genotypes compared to SLA because of additive gene action involved in expression of this character. Hence, this characters could be used in further breeding program of development of high water use efficient variety.

### **5.1.3 Character associations in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs for growth, traits related to WUE and yield contributing characters**

It will be more meaningful if the structure of yield is probed through its component traits rather than directly, since there are many genes for yield as such but operates only through component characters. Hence, it is anticipated to break genetic barriers of the yield by the study of character association and such associations are best ascertained by phenotypic correlations.

In the present study phenotypic correlations coefficient between pod yield per plant with component characters and also with traits related to WUE were studied in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL populations of the cross NRCG 12568 × NRCG12326.

#### **5.1.3.1 Correlation of pod yield per plant with growth parameters, traits related to WUE and its component characters**

Phenotypic correlation coefficient revealed that pod yield per plant had strong positive correlation with pods per plant, kernels per plant, kernel yield per plant and SCMR in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL population, indicating that improvement of pod yield could be possible by improving pods per plant and SCMR. These results are in agreement with the results of Sharma and Varsheny (1995), Moinuddin (1996), Singh (1999), Sabeta (2000), Nagda *et al.*, (2001), Mahalakshmi *et al.*, (2005), Kalmeshwar *et al.*, (2006), John *et al.*, (2007), Mane *et al.*, (2008), Sudhir *et al.*, (2008) in groundnut. Association of pod yield, kernel yield and pods per plant suggests that individual plant

selection can be practiced for plants with higher number of pods which ultimately leads to improvement in both pod and kernel yield in the later generations.

Significant negative association of pod yield per plant with days to flowering, shelling percentage and SLA was observed in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs population studied. This suggests that selection for higher yield results in reduced shelling percentage indicates photosynthates are more utilized for the pod development rather than to vegetative growth. Hence, early maturing ones coupled with higher yielding could be selected by individual plant selection. Similar results were observed by Alam (1985), Deshmukh (1986), Abragan (1990) and Praveen Kumar (2006) in groundnut.

#### **5.1.3.2. Association among growth parameters, traits related to WUE, yield and yield attributing characters in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs**

Number of pods per plant was found to be having highly significant and positive association with kernel yield per plant, number of kernels per plant, pod yield per plant and SCMR at phenotypic level. Suggesting that individual plant selections can be practiced for a plant with higher number of pods which ultimately leads to improvement in both pod and kernel yield. Reports of Moinuddin (1997), Vindhiya Varman and Raveendran (1996), Singh & Singh (1999), Sabeta (2000), Nagda *et al.*, (2001) also confirmed the existence of positive correlation between pods per plant and pod yield per plant in groundnut. Number of pods per plant also expressed significant negative association with shelling percentage at phenotypic level in RILs of all the four generations. Similar results were obtained by Moinuddin (1997), Sab *et al.*, (2000) in groundnut.

Kernels per plant exhibited significant positive association with number of pods per plant, pod yield plant, number kernels per plant and SCMR, where as it was found negative association with shelling percentage and SLA in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL population at phenotypic level. This positive association between kernel yield and pod yield with other yield components indicates the possibility of simultaneous improvement of these traits by single selection programme. Kavani *et al.*, (2004), Canilal *et al.*, (2005),

Golokia *et al.*, (2005), Sudhir kumar *et al.*, (2008) confirmed similar association for pod yield and kernel yield in groundnut.

Shelling percentage showed significant negative association with number of pods per plant, pod yield per plant, number of kernels per plant and kernel yield per plant at phenotypic level in RIL populations of four generations. This implies that, as shelling percentage increases there will be reduction in yield. Therefore, selection of plant which is having thinner shell would be one of the ways for reducing shelling percentage. Similar results were reported by Alam (1985), Abraham (1990), Moinuddin *et al.*, (1997) and Vasanth *et al.*, (1998), Kalmeshwar *et al.*, (2006).

Specific leaf area exhibited significant negative association with SCMR, number of pods per plant, pod yield per plant, number of kernels per plant and kernel yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RIL populations. Thus, the plants which are having thicker leaf coupled with less leaf surface area would result in increasing the water retention potential of leaf by avoiding the loss of water through transpiration and thickening of cell wall and such plants will be having lower SLA. Hence selection of individual plant with low SLA will result in higher yield coupled with high Water Use Efficient types in groundnut. Since, SLA is negatively associated with yield attributing traits These results were in confirmation with the reports of Wright *et al.*, (1994), Arjunan *et al.*, (1997), Reddy *et al.*, and Jaiwar *et al.*, (2004), Swarna *et al.*, (2004), Songrit *et al.*, (2008) and Painwadee *et al.*, (2009b) in groundnut.

SPAD chlorophyll meter reading showed significant positive association with yield characters like pod yield per plant, kernel yield per plant, kernels per plant and pods per plant. Thus the plant which has higher SCMR value will be having higher chlorophyll content hence, more will be the photosynthates which manifest the higher yield. However, SCMR also associated with down regulation of stomata opening hence it will avoid the loss of water through transpiration. Therefore, we can go for selection of individual plant with high SCMR, which leads to improvement of yield and WUE in groundnut. The reports of Nageshwar Rao *et al.*, (2004), Talwar *et al.*, (2004), Rekha (2005), Praveen

kumar (2006), John *et al.*, (2007) and Krishna murthy *et al.*, (2007) conformed the same association in groundnut.

Yield attributing characters like kernel yield per plant, pods per plant and kernel per plant and kernel yield per plant are positively associated with pod yield, surrogate traits of Water Use Efficiency like SCMR which is positively associated with pod yield per plant and SLA which is negatively associated with yield suggest that selection of groundnut with high number of pods per plant, more number of kernels per plant, higher kernel yield per plant, higher values for SCMR and lower values for SLA can be used for selection of higher pod yield per plant coupled with high Water Use Efficiency progenies in single selection programme.

#### **5.1.4 Intergeneration correlation and regression studies among F<sub>3</sub>, F<sub>4</sub> F<sub>5</sub> and F<sub>6</sub> RIL for growth, traits related to WUE and yield attributing characters**

In a crop like groundnut improvement of pod yield will be achieved by early and advanced generations through selection. The rate of success of crop improvement mainly relies on two factors such as stage at which and trait on which selections will be carried out. The information obtained from intergeneration correlation will help the breeder to get an idea regarding genetic behavior of a particular trait at particular stage of crop improvement. Thus one can easily make a decision regarding selection of particular trait and particular stage and thereby rate of success of crop improvement could be increased.

This will also give an idea about effectiveness of single plant selection and nature of gene action. If the correlation coefficient is high, it would mean high heritable portion and probably the additive component involved in expression of such traits.

In this study the Significant and positive correlation were obtained between F<sub>3</sub> to F<sub>4</sub>, F<sub>3</sub> to F<sub>5</sub>, F<sub>3</sub> to F<sub>6</sub>, F<sub>4</sub> to F<sub>5</sub>, F<sub>4</sub> to F<sub>6</sub> and F<sub>5</sub> to F<sub>6</sub> generations for days to flowering was observed which indicating that this trait is positively progressed from generation to generation, mostly governed by additive gene action and alleles which are involved in expression of this trait are getting fixed in early generation. Hence, selection could be

made on this trait from F<sub>3</sub> generation. These findings were supported by Kulkarni *et al.*, (1976) and Reddy *et al.*, (1985) in okra for plant height and nodes per plant.

There was no significance relationship among F<sub>3</sub> to F<sub>6</sub> generations for characters such as number of pods per plant, pod yield per plant, kernels per plant, kernel yield and shelling percentage. Rahman and Bahl (1986) also found similar result in chickpea. This lack of associations were attributed either could be genotypic effect, environmental effect or it may be due to interaction between genotype and environment. Hence, making selection for such traits in early generation will be of little or no value since genetic difference is masked by genotype × environment interaction.

Significant and positive correlation was obtained between F<sub>5</sub> to F<sub>6</sub> for number of pods per plant, pod yield per plant, kernels per plant, kernel yield per plant, SCMR, SLA, days to flowering and primary branches per plant. This indicated that prediction can be made from F<sub>5</sub> generation to identify the lines that will give higher pod yield and higher kernel yield and their by help the breeder for selection of superior progenies in the later segregating generation.

#### **5.1.5 Comparison of correlation and regression for growth parameters, traits related to WUE and yield component characters in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> RILs**

Improvement of yield is the main goal of the plant breeder. As such improving yield is difficult and it may not be successful mainly because, yield is controlled by polygenes with high magnitude of Genotype × environmental interaction and coordination of action of its component traits. In most of the crop improvement programme, the measurement of relative importance of each factor involved in contributing to the yield is so important in order to bring improvement in yield. Comparison of correlation and regression of yield on its component traits will provide the information regarding relative importance of each component traits on yield and direct the breeder to target for specific component traits to accelerate improvement on yield.

Results obtained from this study revolved that kernel yield per plant had high positive association and positive effect on pod yield followed by pods per plant, kernels

per plant and SCMR in all the four generations in RIL population. Where as other traits like, SLA and shelling percentage showed negative association and negative effect on pod yield per plant in RILs of all the four generations which suggested the contribution of pods per plant, kernel yield per plant and SCMR towards increase of pod yield was higher and positive. .

Effect and association of these traits have shown consistence trend over the generations. Hence selection for kernel yield per plant, kernels per plant, pods per plant and SCMR could be exercised to develop high yielding with high water use efficient genotypes. Results are in agreement with Varshney (1995) moinnedin (1996) and also Singh (1999), Sabeta (2000), Nagda *et al.*, (2001), Mahalakshmi *et al.*, (2005), Kalmeshwar *et al.*, (2006), John *et al.*, (2007), Mane *et al.*, (2008) and Sudhir *et al.*, (2008) in groundnut and they concluded that effect of pods per plant and kernel yield per plant on development of pod yield per plant was more.

#### **5.1.6 Comparison of narrow sense and broad sense heritability.**

Lush (1940) defined heritability in broad and narrow sense and emphasized that characters are subjected to different amount of non heritable variation. The broad sense heritability includes genotypic variance and phenotypic variance, but genotypic variance includes both dominance and additive variance and hence it is not a reliable index for practicing selection. While narrow sense heritability includes additive variance and phenotypic variance, so additive variance is a reliable index of the total genotypic variance, and selections will be effective for forwarding the lines to next generation. Hence, a comparison was made between narrow sense and broad sense heritability.

High broad sense heritability was observed for all the characters  $F_3$ ,  $F_4$ ,  $F_5$  and  $F_6$  RIL populations for all the characters, indicating the presence of high magnitude of genetic variability for the characters and environmental influence was low on the expression of the characters.

Low to moderate narrow sense heritability was observed for most of the traits, which contribute to pod yield *i.e.* number of pods per plant, kernels per plant, kernel yield

and shelling percentage in F<sub>4</sub> and F<sub>5</sub> RIL population. This indicates both dominance and additive epistasis were involved in expression of these traits. Hence, selection based on phenotypic observations may not be effective. Under such situation, the progeny tests will be required to confirm the worth of genotypes.

High narrow sense heritability was observed for days to flowering, number of pods per plant, kernels per plant, kernel yield, SLA, SCMR and shelling percentage in F<sub>6</sub> RIL population, which indicated that these characters were governed by additive variance. Therefore, selection will be effective for such traits based on phenotypic observations.

#### **5.1.7 Test for normality for growth, yield and traits related to WUE and its attributing traits in F<sub>6</sub> RIL population of the cross NRCG12568 × NRCG12326.**

##### **5.1.7.1 Shapiro-Wilk's W test:**

Shapiro-Wilk's W test was done to check the normality. W is the correlation between given data and their corresponding normal scores, if W=1 when the given data is perfectly with normal distribution.

If W is significantly smaller than one indicates that the data is not normally distributed (Shapiro *et al.*, 1968).

Shapiro-Wilks 'W' test of normality revealed that characters like specific leaf area, SPAD chlorophyll meter reading and pod yield per plant were approaching to value one indicating close to normal distribution in F<sub>6</sub> RIL studied. However, none of the other traits were fit to normal distribution. Hence, still one more generation need to be forwarded to get perfect normal distribution for all the traits.

##### **5.1.7.2 Skewness and Kurtosis:**

Skewness and kurtosis are third and fourth degree statistics respectively. The study of distribution properties such as co-efficient of Skewness and Kurtosis provides

insight about the nature of gene action (Fisher, 1932) and number of genes controlling the traits (Robinson, 1956) respectively.

Skewness and Kurtosis are more powerful than variance which reveals interaction of genetic effects. For a normal distribution Skewness and Kurtosis should be zero. Deviation from normality is very informative and can be used to make inferences about the genetic control of a trait. The skewed distribution of a trait in general suggested that the trait is under the control of non-additive gene action, especially epistasis and influenced by environmental variables (Poorni *et al.*, 1977).

While positive skewness is associated with complementary gene interactions, negative skewness is associated with duplicate (additive  $\times$  additive) gene interactions. The gene controlling the trait with skewed distribution tend to be predominantly dominant irrespective of whether they have increasing or decreasing effect on trait.

The trait with leptokurtic and platykurtic distribution are controlled by fewer and large number of genes respectively. Kurtosis is negative or close to zero in the absence of gene interaction and is positive in the presence of gene interaction (Poorni *et al.*, 1997).

Days to flowering, specific leaf area, SCMR, pod yield per plant are positively skewed and platykurtic. This indicates the involvement of large number of segregating genes with majority of them having decreasing effect and dominance based complementary type of interaction in  $F_6$  RILs of the cross NRCG12568  $\times$  NRCG12326. Here stringent selection has to be followed for further breeding programme. In the same cross plant height and kernel yield per plant and shelling percentage showed negatively skewed platykurtic. This is an evidence for involvement of large number of dominant genes with majority of them having increasing effect and duplicate type of epistasis (additive  $\times$  additive). This indicates selection would be rapid under mild selection from the existing variability among the lines.

Traits like Number of branches per plant, pods per plant, kernel yield per plant and shelling percentage showed positively skewed leptokurtic, this indicates the involvement of fewer number of genes with majority of them having decreasing effect

and dominance based complementary type of interaction in the cross NRCG12568 × NRCG12326. To maximize the genetic gain in respect of these traits requires intense selection from the existing generation.

#### **5.1.8 Selection of productive segregants from F<sub>6</sub> RIL population of the cross NRCG 12568 × NRCG12326**

Top high yielding progenies were selected from F<sub>6</sub> RIL populations based on important traits like SCMR, SLA, pods per plant, kernels per plant, kernel yield per plant, pod yield per plant and shelling percentage. From the selection it was observed that high yielding progenies are having higher SCMR coupled with lower SLA value and higher pod yield per plant. Since, these progenies were still segregating hence one more generation need to be test predict their performance before releasing for either station trial or multi location trail.

#### **5.2 Phenotypic evaluation F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations of the cross NRCG12273 X ICG12370 for growth, traits related to Water Use Efficiency, yield and its component traits.**

##### **5.2.1 Analysis of Variance for growth, traits related to WUE and yield attributing traits F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations**

Analysis of variance in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations of the cross NRCG12473 × ICG12370 revealed significant differences among the lines in all the four generations for all the characters except shelling percentage in F<sub>3</sub>, F<sub>4</sub> and F<sub>6</sub> generations, where as both segregating progenies and checks also recorded presence of high variability for all the characters except primary branches per plant and shelling percentage in all the four generations, which indicating the presence of enormous genetic variability and the choice of the material for the investigation is appropriate. This was further supported by the fact that range has been also quite wider for all the characters pointing out extreme segregates are found in population for selection.

## **5.2.2 Genetic variability parameters**

The range was quit high for all characters in selected superior progenies of F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregation generations studied suggested that characters may be improved by individual plant selection.

GCV and PCV estimate were relatively high for plant height, SCMR, total number of pods per plant, pod yield per plant, number of kernels per plant and kernel yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations. Similar findings of higher estimates of GCV & PCV for pods per plant, kernel yield per plant and pod yield per plant were observed by Sharma & Varshney (1995), Sumathi & Ramanathan (1995), Gowda *et al.*, (1996), Makhan lal *et al.*, (2003), Golkia *et al.*, (2005), Ganeshan and Sudhakar (1995) Veeramani *et al.*,(2005), John *et al.*, (2007) and Parameshwarappa *et al.*, (2007) in groundnut.

The deference between estimates of GCV and PCV was narrow for SCMR, specific leaf area, and number of pods per plant in four segregating generations indicating less environmental influence of expression of these traits. Hence, these traits can be used for further selection for higher yield and Water Use Efficiency using SLA and SCMR as a surrogate traits. Moderate difference between PCV and GCV estimates were observed for yield attributing characters like number of kernels per plant, kernel yield and pod yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations. Hence, pods per plant, kernel yield per plant, SLA and SCMR could be used for further selection for higher yield with high WUE.

### **5.2.2.1 Heritability and Genetic Advance as Per cent mean for growth, traits related to WUE and yield contributing characters in F<sub>3</sub> , F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations**

The characters like plant height, SCMR, number of pods per plant, pod yield per plant, number of kernels per plant, and kernel yield per plant in all the generations had higher GCV and PCV. This shows that these characters are under the control of additive gene action. Hence, single plant selection could be followed to breed for high yielding

and higher Water Use Efficient genotypes in groundnut. Higher GCV and PCV for pods per plant, kernels yield per plant were obtained by Alan Cruickshan *et al.*, (2005), Veeramani *et al.*, (2005), Golkia *et al.*, (2005) and John *et al.*, (2007) in groundnut.

Moderate heritability coupled with high genetic advance as *per cent* of mean was observed for number of primary branches per plant and shelling percentage in F<sub>4</sub> segregating population, indicating the presence of narrow range of variability and prevalence of non additive gene action. This suggested that limited scope for further improvement of this character. Similar result was reported by Reddy and Guptha (1992), Ganeshan and Sudhakar (1995), Mukhan *et al.*, (2003) and Praveen Kumar (2004) in groundnut.

Hence from the present investigation on F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations, it revealed that heritability and genetic advance as *per cent* of mean was high for yield and its attributing traits like pods per plant, shelling percentage, kernel yield per plant. It indicates the presence of additive gene action. Hence, single plant selection could be effectively made as environment does not have any influence in the variation of traits.

### **5.2.3 Correlation studies**

#### **5.2.3.1 Correlation of pod yield per plant with growth parameters, traits related to WUE and yield component characters.**

Phenotypic correlation coefficients studies revealed that pod yield per plant had strong positive correlation with pods per plant, kernels per plant, kernel yield per plant and SCMR in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations indicating that improvement pods per plant, kernel yield per plant, SCMR will leads to improvement in yield. These results are in agreement with the results of Sharma and Varsheny(1995), Moinuddin (1996) and also Singh(1999), Sabeta (2000), Nagda *et al.*, (2001), Mahalakshmi *et al.*, (2005), Kalmeshwar *et al.*, (2006), John *et al.*, (2007), Mane *et al.*, (2008), Sudhir *et al.*, (2008) in groundnut. Association of pod yield, kernel yield and pods per plant suggests that individual plant selection can be practiced for plants with higher number of pods which ultimately leads to improvement in both pod and kernel yield in the later generations.

Significant negative association of pod yield per plant with days to flowering and shelling percentage and SLA was observed in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations studied. Indicates that negative relationship of pod yield per plant with SLA, selection for high yielding and water use efficient segregates can be done in a single selection programme.

#### **5.2.3.2 Association among growth parameters, traits related to WUE and yield attributing characters**

SPAD chlorophyll meter reading showed significant positive association with yield characters like pod yield per plant, kernel yield per plant, kernels per plant and pods per plant. This shows that we can go for selection of genotypes with high SCMR, which indirectly leads to improvement of yield in groundnut. However, higher SCMR also leads to increasing of water retention capacity of the plant their by increase the WUE. The reports of Nageshwar Rao *et al.*, (2004), Talwar *et al.*, (2004), Rekha (2005), Praveen kumar (2006), John *et al.*, (2007) and Krishna murthy *et al.*, (2007) conformed the same association in groundnut.

Specific leaf area exhibited significant negative association with SCMR, number of pods per plant, pod yield per plant, number of kernels per plant and kernel yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations. Thus selection for the individual plants with low SLA will result in higher yield coupled with high Water Use Efficient types in groundnut. Since, SLA is negatively associated with yield attributing traits and SPAD is positively associated with yield attributing traits resulting in improvement of both traits can be done in single selection programme. These results were in confirmation with the reports of Wright *et al.*, (1994), Arjunan *et al.*, (1997), Reddy *et al.*, Jaiwar *et al.*, (2004), Swarna *et al.*, (2004), Songrit *et al.*, (2008) and Painwadee *et al.*, (2009b) in groundnut.

Number of pods per plant was found to be having highly significant and positive association with kernel yield per plant, number of kernels per plant, pod yield per plant SCMR at phenotypic levels. Suggest that individual plant selections can be practiced for a plant with higher number of pods which ultimately leads to improvement in both pod and kernel yield. Reports of Moinuddin (1997), Vindhiya Varman and

Raveendran(1996), Singh & Singh (1999), Sabeta (2000), Nagda *et al.*, (2001), Moinuddin (1997) and Sab *et al.*, (2000) also confirmed significant positive association between pods per plant and pod yield per plant in groundnut and they said that pod yield per plant can be improved by selecting plant which is having more number of pods.

Kernels per plant exhibited significant positive association with number of pods per plant, pod yield plant, number kernels per plant and SCMR and negative association with shelling percentage and SLA in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating population studied at phenotypic level. This positive association between kernel yield and pod yield with other yield components traits indicating the possibility of simultaneous improvement of these traits by single selection programme. Kavani *et al.*, (2004), Canilal *et al.*, (2005), Golokia *et al.*, (2005) and Sudhir kumar *et al.*, (2008) confirmed similar association for pod yield and kernel yield in groundnut.

Shelling percentage exhibited significant negative association with number of pods per plant, pod yield per plant, number of kernels per plant and kernel yield per plant at phenotypic level in all segregating populations studied which implies that as shelling percentage increases there will be reduction in yield. Similar results were reported by Alam (1985), Abraham (1990), Moinuddin *et al.*, (1997) Vasanth *et al.*, (1998) and Kalmeshwar *et al.*, (2006).

#### **5.2.4 Intergeneration correlation and regression studies.**

In this study the significant and positive correlation was obtained between F<sub>3</sub> to F<sub>4</sub>, F<sub>3</sub> to F<sub>5</sub> and F<sub>3</sub> to F<sub>6</sub> generations for days to flowering, plant height and primary branches per plant which indicating that prediction would be made from F<sub>3</sub> generation and these trait are mostly governed by additive gene action and suitability of these traits for selection in individual plant basis in the advanced generations of segregating progenies. These findings were supported by Kulkarni *et al.*, (1976) and Reddy *et al.*, (1985). They also find the existence of significant correlation between F<sub>3</sub> to F<sub>4</sub> and F<sub>3</sub> to F<sub>5</sub> for plant height in okra.

There was no significant relationship among F<sub>3</sub> to F<sub>6</sub> generation for characters such as number of pods per plant, pod yield per plant, kernels per plant, kernel yield and shelling percentage was observed. Rahman and Bahl (1986) also found similar result in chickpea. This lack of associations was attributed to environmental, genotypic effect and nature of gene action involved in expression of trait which had a pronounced effect on such association. Hence, making selection for such traits in early generation will be of little or no value since genetic difference is masked by genotype × environment interaction.

Significant and positive correlation were obtained for F<sub>4</sub> to F<sub>5</sub>, F<sub>4</sub> to F<sub>6</sub> and F<sub>5</sub> to F<sub>6</sub> for pods per plant, kernels per plant, pod yield per plant, kernel yield per plant, SCMR and SLA. This indicated that prediction can be made for these characters from F<sub>4</sub> generation to identify the lines that will give higher pod yield and higher water use efficiency.

#### **5.2.5 Comparison between correlation and regression for growth parameters, traits related to WUE and yield component traits in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations**

Study revealed that kernel yield per plant, pods per plant, kernels per plant and SCMR consistently showed the positive correlation and positive effect in all the four segregating generations. Hence selection for these traits could be excised to develop high yielding with high water use efficient genotypes. Similar conclusion were made by Varsheny (1995) Moinuddin (1996) and also Singh (1999), Sabeta (2000), Nagda *et al.*, (2001), Mahalakshmi *et al.*, (2005), Kalmeshwar *et al.*, (2006), John *et al.*, (2007), Mane *et al.*, (2008) and Sudhir *et al.*, (2008) in groundnut. Where as other traits like, SLA and shelling percentage showed negative association and negative effect on pod yield per plant in of all the four generations.

### **5.2.6 Comparison of narrow sense and broad sense heritability for growth parameters, traits related to WUE and yield component traits in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations**

High broad sense heritability was observed for all the characters in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregation populations for all the characters indicating that presence of high magnitude of genetic variability for the characters.

Moderate narrow sense heritability was observed for most of the traits, which contribute to pod yield *i.e.* number of pods per plant, kernels per plant, kernel yield and shelling percentage only in F<sub>4</sub> and F<sub>5</sub> segregating populations.

This indicates both dominance and additive variance (epistasis) for these traits. Hence, selection based on phenotypic observations may not be effective. Under such situation, the progeny test will be required to confirm the worth of genotypes.

High narrow sense heritability was observed for days to flowering, number of pods per plant, kernels per plant kernel yield per plant, SLA, SCMR and shelling percentage in F<sub>6</sub> segregating population, which indicates that these characters were governed by additive variance. Therefore, selection will be effective for such traits based on phenotypic observations.

### **5.2.7 Selected superior segregants in F<sub>6</sub> segregating generations**

Top high yielding progenies were selected from F<sub>6</sub> segregating populations based on important traits like SCMR, SLA, pods per plant, kernels per plant, kernel yield per plant, pod yield per plant and shelling percentage. From the selection it was observed that high yielding progenies are having higher SCMR coupled with lower SLA value and higher pod yield per plant. Since, these progenies were still segregating hence one more generation need to be test to predict their performance before releasing for either station trial or multi location trail.

### **5.3 Phenotypic evaluation F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations of the cross NRCG12274 × ICG12370 for growth, traits related to Water Use Efficiency, yield and its attributing traits.**

The results obtained in this study are briefly discussed in the light of available literature under the following headings to draw valid conclusions.

#### **5.3.1 Analysis of Variance:**

Analysis of variance in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations of the cross NRCG12374 × ICG1 in 2370 were suggested that existing of significant differences among the segregating lines in all the four segregating generations for all the characters. Where as progenies and checks was also exhibited significant variability in all the generation except primary branches per plant and kernel yield per plant in F<sub>3</sub> segregating population which indicates the presence of high genetic variability and the choice of the material for the investigation is ideal. This was further supported by the fact that range has been also quite wider for all the characters also pointing out extreme segregates are found in population for selection.

#### **5.3.2 Genetic variability parameters:**

Wider range of variability was observed for all the characters in selected superior progenies of F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations studied which reveled that individual plant selection can be employed for improvement of these characters.

Higher GCV and PCV estimates were noticed for plant height, SCMR, total number of pods per plant, pod yield per plant, number of kernels per plant and kernel yield per plant in all the four segregating generations. The findings of higher estimates of GCV & PCV were also noticed in the reports of Sharma & Varshney (1995)., Sumathi & Ramanathan(1995), Gowda *et al.*, (1996), Makhan lal *et al.*, (2003), Golkia *et al.*, (2005), Ganeshan and Sudhakar (1995) Veeramani *et al.*, (2005), John *et al.*, (2007) and Parameshwarappa *et al.*, (2007) in groundnut.

GCV and PCV estimates were relatively moderate for the characters like days to flowering, plant height, shelling percentage, number of branches per plant, shelling percentage and specific leaf area in all the four generations. Hence, individual plant selection can be postponed to advance generation to exploit moderate variability. Rudraswamy *et al.*, (1999) in groundnut were also drawn such conclusion.

The difference between GCV and PCV estimates was narrow for traits like SCMR, specific leaf area, and number of pods per plant in four segregating populations. This indicated less environmental influence on the expression of these traits. Hence, selection for these characters would be made based on their phenotypic performance. Further, moderate difference between PCV and GCV estimates were observed for yield attributing characters like number of kernels per plant, kernel yield and pod yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations. Hence, these traits also can be considered for selection of higher yield.

#### **5.3.2.1 Heritability and Genetic Advance as *Per cent* mean for growth, traits related to WUE and yield component traits in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations**

Due to presence of high heritability coupled with high genetic advance as *per cent* of mean for plant height, SCMR, number of pods per plant, pod yield per plant, number of kernel per plant, and kernel yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations, suggest the involvement of additive gene action in the expression of these characters. Hence, there is lot of scope for improvement of these traits in further breeding programme and Single plant selection can be followed to breed for high yielding and higher Water Use Efficient genotypes in groundnut. Alan Cruickshan *et al.*, (2005) reported high heritability coupled with high genetic advance as *per cent* of mean for kernel yield and pod yield and also Veeramani *et al.*, (2005) reported high broad sense heritability coupled with high genetic advance for pod and kernel yield Golkia *et al.*, (2005) and John *et al.*, (2007) reported high heritability coupled with GAM for sound mature kernel percentage along with kernel yield and pod yield and involvement of additive gene action for expression of these traits in groundnut.

Moderate heritability coupled with high genetic advance as *per cent* of mean was observed for number of primary branches per plant and shelling percentage in F<sub>4</sub> segregating population indicating the presence of narrow range of variability and prevalence of non additive gene action. This suggested that limited scope for further improvement of this character. Similar result was reported by Reddy and Guptha (1992), Ganeshan and Sudhakar (1995), Mukhan *et al.*, (2003) and Praveen Kumar (2004) in groundnut.

From the present investigation from F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating population, revealed that heritability and genetic advance as *per cent* of mean was high for pod yield and its attributing traits like pods per plant, shelling percentage and kernel yield per plant indicating the presence of additive gene action. Hence, single plant selection can be effectively made as environment does not have any influence on variation of traits.

### **5.3.3 Correlation studies**

#### **5.3.3.1 Correlation of pod yield per plant with growth parameters, traits related to WUE and yield component characters**

Phenotypic correlation coefficients revealed that pod yield per plant had strong positive correlation with pods per plant, kernels per plant, kernel yield per plant and SCMR in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating generations indicating that improvement in these characters will lead to improvement in yield. These results are in agreement with the results of Sharma and Varsheny (1995), Moinuddin (1996), Singh(1999), Sabeta (2000), Nagda *et al.*, (2001), Mahalakshmi *et al.*, (2005), Kalmeshwar *et al.*, (2006), John *et al.*, (2007), Mane *et al.*, (2008), Sudhir *et al.*, (2008) in groundnut. Positive association of pod yield, kernel yield and pods per plant suggests that individual plant selection can be practiced for plants with higher number of pods which ultimately leads to improvement in both pod and kernel yield in the later generations.

Significant negative association of pod yield per plant with days to flowering and shelling percentage and SLA was observed in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating population studied. This suggests negative relationship of SLA with pod yield per plant, selection for high yielding and water use efficient segregates can be done in a single selection

programme by making selection of plant which is having lower SLA and higher pod yield.

### **5.3.3.2 Association among growth parameters, traits related to WUE and yield attributing characters**

Specific leaf area exhibited significant negative association with SCMR, number of pods per plant, pod yield per plant, number of kernels per plant and kernel yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations. Thus, the plants which are having thicker leaf coupled with less leaf surface area would be results in increasing the water retention potential of leaf by avoiding the loss of water through transpiration and thickening of cell wall and such plants will be having lower SLA. Hence selection of individual plant with low SLA will result in higher yield coupled with high Water Use Efficient types in groundnut. Since, SLA is negatively associated with yield attributing traits These results were in confirmation with the reports of Wright *et al.*, (1994), Arjunan *et al.*,(1997), Reddy *et al.*, Jaiwar *et al.*, (2004), Swarna *et al.*, (2004), Songrit *et al.*, (2008) and Painwadee *et al.*,. (2009b) in groundnut.

SPAD chlorophyll meter reading showed significant positive association with yield characters like pod yield per plant, kernel yield per plant, kernels per plant and pods per plant. Thus the plant which having higher SCMR value will be having higher chlorophyll content hence, more will be the photosyntates which manifest the higher yield. However, SCMR also associated with down regulation of stomata opening hence it will avoid the loss of water through transpiration. Therefore, we can go for selection of individual plant with high SCMR, which leads to improvement of yield and WUE in groundnut. The reports of Nageshwar Rao *et al.*, (2004), Talwar *et al.*, (2004), Rekha (2005), Praveen kumar (2006), John *et al.*, (2007) and Krishna murthy *et al.*, (2007) conformed the same association in groundnut.

Number of pods per plant was found to be having highly significant and positive association with kernel yield per plant, number of kernels per plant, pod yield per plant and SCMR at phenotypic level. This suggest that individual plant selections can be practiced for a plant with higher number of pods which ultimately leads to improvement

in both pod and kernel yield. Reports of Moinuddin (1997), Vindhiya Varman and Raveendran (1996), Singh & Singh (1999), Sabeta (2000) and Nagda *et al.*, (2001) also confirmed the same results in groundnut. Number of pods per plant also showed significant negative association with shelling percentage at phenotypic level. Similar results were obtained by Moinuddin (1997) and Sab *et al.*, (2000) in groundnut.

Kernels per plant exhibited significant positive association with number of pods per plant, pod yield plant, number kernels per plant and SCMR. Negative association with shelling percentage and SLA in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregations population studied at phenotypic level. This positive association between kernel yield and pod yield with other yield component indicating the possibility of simultaneous improvement of these traits by single selection programme. Kavani *et al.*, (2004), Canilal *et al.*, (2005), Golokia *et al.*, (2005) and Sudhir kumar *et al.*, (2008) confirmed same association for pod yield and kernel yield in groundnut.

Shelling percentage exhibited significant negative association with number of pods per plant, pod yield per plant, number of kernels per plant and kernel yield per plant at phenotypic level in four segregating populations which implies that as shelling percentage increases there will be reduction in yield. Similar results were reported by Alam (1985), Abraham (1990), Moinuddin *et al.*, (1997), Vasanth *et al.*, (1998) and Kalmeshwar *et al.*, (2006).

#### **5.3.4 Intergeneration correlation and regression studies.**

In this study Significant and positive correlation were obtained between F<sub>3</sub> to F<sub>4</sub>, F<sub>3</sub> to F<sub>5</sub> and F<sub>3</sub> to F<sub>6</sub> generations for days to flowering and primary branches per plant, indicating that prediction could be made from F<sub>3</sub> generation and this trait is mostly governed by additive gene action and suitability of these traits for selection on individual plant basis in the advanced generations of segregating progenies. These findings were supported by Kulkarni *et al.*, (1976) and Reddy *et al.*, (1985).

Significant and positive correlation was obtained between F<sub>5</sub> to F<sub>6</sub> generations for number of pods per plant, pod yield plant, kernels per plant, kernel yield per plant,

SCMR, SLA, days to flowering and primary branches per plant. This indicated that prediction can be made from F<sub>5</sub> generation to identify the lines that will give higher pod yield and higher kernel yield and their by help the breeder for selection of superior progenies in the F<sub>5</sub> segregating generation.

### **5.3.5 Comparison between correlation and regression for growth, traits related to WUE and yield component traits**

Results obtained from this study revealed that kernel yield per plant has high positive association and positive effect on pod yield followed by pods per plant, kernels per plant and SCMR in all the four generations. Where as other traits like, SLA and shelling percentage showed negative association and negative effect on pod yield per plant in of all the four generations.

Effect and association of these traits has shown consistence trend over the generations. Hence selection of kernels yield per plan, kernels per plant, pods per plant and SCMR could be excises to develop high yielding with high water use efficient genotypes. The report of Varsheny (1995), Moinuddin (1996), Singh (1999), Sabeta (2000), Nagda *et al.*, (2001), Mahalakshmi *et al.*, (2005), Kalmeshwar *et al.*, (2006), John *et al.*, (2007), Mane *et al.*, (2008) and Sudhir *et al.*, (2008) in groundnut were also observe the higher effect of pods per plant, kernel yield on development of pod yield per plant.

### **5.3.6 Comparison of narrow sense and broad sense heritability.**

High broad sense heritability was observed for all the characters in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> segregating populations for all the characters, indicating the presence of high magnitude of genetic variability for the characters.

High narrow sense heritability was observed for days to flowering, number of pods per plant, kernels per plant kernel yield per plant, SLA, SCMR and shelling percentage in F<sub>6</sub> segregating population, which indicates that these characters were governed by additive variance. Therefore, selection will be effective for such traits based on phenotypic observations.

### **5.3.7 Assessment of superior progenies in F<sub>6</sub> generation**

Top high yielding progenies were selected from F<sub>6</sub> segregating populations based on important traits like SCMR, SLA, pods per plant, kernels per plant, kernel yield per plant, pod yield per plant and shelling percentage. From the selection it was observed (Table 25) that high yielding progenies are having higher SCMR coupled with lower SLA value and higher pod yield per plant. Since, these progenies were still segregating hence one more generation need to be tested to predict their performance before releasing for either station trial or multi location trial.

## **5.4 Comparison among RILs and two other crosses for growth parameters, traits related to WUE and yield attributing traits in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation**

### **5.4.1 Genetic variability**

Higher magnitude of GCV and PCV was observed for plant height, SCMR, SLA, pods per plant, pod yield per plant, kernels per plant and kernel yield per plant in all the four generations of RIL and other two crosses. It suggests that presence of enormous variability for these traits; hence there is scope for practicing individual plant selection for above mentioned to get higher yield in both RILs and other two crosses.

Narrow difference between GCV and PCV estimates were observed for SCMR, SLA and pods per plant in all the four generations of RILs and other two crosses, indicated less environmental influence on expression of these traits. Hence selection could be made based on their phenotypic performance in RILs and other two crosses.

High heritability coupled with high GAM was observed for plant height, SCMR, pods per plant, pod yield per plant and kernel yield per plant in all the four generations of RILs and other two crosses. This shows that these characters are under the control of additive gene action. Therefore, single plant selection could be advisable for these traits.

Involvement of non additive gene action was observed in expression of primary branches per plant in all four generations of RILs and other two crosses which indicated the presence of low heritability coupled with low GAM. Therefore, for improvement of

this trait need separate hybridization followed by selecting superior segregants in further breeding programme.

#### **5.4.2 Correlation coefficient of pod yield with growth parameters, traits related to WUE and yield component characters in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations of RILs and other two crosses**

Results from the investigation of F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generations in RILs and other two crosses revealed that pod yield per plant had significant positive correlation with pods per plant, kernels per plant, kernel yield per plant and SCMR. Hence, pod yield per plant can be improved by selecting the plant which is having more number of pods per plant, higher kernel yield and plant with higher SCMR values. Where as SLA and shelling percentage showed negative correlation with pod yield per plant, hence plant with lower SLA value has to be selected for improving pod yield per plant in RILs and other two crosses.

##### **5.4.2.1 Correlation among growth parameters, traits related to WUE and yield attributing characters in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation of RILs and other two crosses**

Specific leaf area exhibited significant negative association with SCMR, pods per plant, pod yield per plant, kernels per plant and kernel yield per plant in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation of RIL and other two crosses. Hence, plant which having lower SLA has to be select for improving pods per plant and pod yield per plant.

SPAD chlorophyll meter reading showed significant positive association with yield characters like pod yield per plant, kernel yield per plant, kernels per plant and pods per plant. Therefore, we can go for selection of individual plant with high SCMR, which leads to improvement of yield and WUE in groundnut.

#### **5.4.3 Intergeneration correlation among F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation for growth parameters, traits related to WUE and yield component traits in RILs and other two crosses**

Significant and positive correlation was obtained between F<sub>5</sub> to F<sub>6</sub> generation in RILs and other two crosses for number of pods per plant, pod yield per plant, kernels per plant, kernel yield per plant, SCMR, SLA, days to flowering and primary branches per plant. This indicated that prediction can be made from F<sub>5</sub> generation to identify the lines that will give higher pod yield and higher kernel yield and their by help the breeder for selection of superior progenies in the early segregating generations.

#### **5.4.4 Comparison of correlation and regression for growth parameters, traits related to WUE and yield component traits in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation of RILs and other two crosses**

Results obtained from this study revealed that kernel yield per plant has high positive association and positive effect on pod yield followed by pods per plant, kernels per plant and SCMR in all the four generations of RIL and other two crosses. Where as other traits like, SLA and shelling percentage showed negative association and negative effect on pod yield per plant which suggesting the contribution of pods per plant, kernel yield per plant and SCMR towards increasing of pod yield was higher and it was positive.

#### **5.4.5 Comparison of broad sense and narrow sense heritability for growth parameters, traits related to WUE and yield component traits in F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>6</sub> generation of RILs and other two crosses**

High narrow sense heritability was observed for days to flowering, number of pods per plant, kernels per plant kernel yield per plant, SLA, SCMR and shelling percentage in F<sub>6</sub> generation of RIL and other two crosses, which indicates that these characters were governed by additive variance. Therefore, selection will be effective for such traits based on phenotypic observations in this generation.

**Table 23: Top ten selected superior plants in F<sub>6</sub> recombinant inbred lines of the cross NRCG12568 × NRCG12326 in groundnut**

<b>Line No</b>	<b>Days to first flowering</b>	<b>Plant height (cm)</b>	<b>Primary branches/ Plant</b>	<b>SLA (cm<sup>2</sup>/g)</b>	<b>SCMR</b>	<b>Pods/ Plant</b>	<b>Pod yield/ Plant (g)</b>	<b>Kernels / Plant</b>	<b>Kernel yield/ Plant (g)</b>	<b>Shelling percentage</b>
C1-F <sub>6</sub> - 30	44.85	24.62	4.31	171.36	53.48	55.51	42.39	71.80	29.01	72.48
C1-F <sub>6</sub> - 42	39.79	11.93	5.36	104.61	68.61	57.17	67.29	100.42	41.89	61.77
C1-F <sub>6</sub> - 45	33.64	24.36	5.07	108.86	64.74	48.81	57.37	85.25	35.06	60.59
C1-F <sub>6</sub> - 135	32.87	14.13	4.80	130.50	60.11	37.80	48.47	68.40	27.48	55.69
C1-F <sub>6</sub> - 245	40.89	18.95	4.84	142.83	59.01	58.93	44.59	82.43	33.79	73.48
C1-F <sub>6</sub> - 260	34.67	18.07	4.47	127.75	57.00	41.29	51.35	73.81	29.92	57.02
C1-F <sub>6</sub> - 270	31.64	15.64	4.21	128.72	55.79	46.33	66.37	89.46	36.96	54.77
C1-F <sub>6</sub> - 271	28.78	20.06	4.22	111.76	60.64	40.91	57.65	77.99	31.79	54.43
C1-F <sub>6</sub> - 349	42.36	23.07	4.57	149.75	47.82	47.26	55.67	82.52	33.84	59.61
C1-F <sub>6</sub> - 405	51.06	17.06	4.69	150.25	43.81	40.61	47.17	69.99	28.20	57.96
MEAN	39.64	19.57	4.70	212.00	38.31	25.06	24.46	39.30	14.03	55.15
SE±	0.32	0.32	0.12	0.98	0.75	0.56	0.65	0.86	0.41	0.48
NRCG12568	36.00	34.92	5.85	105.58	55.32	38.45	36.73	56.23	26.75	74.31
NRCG12326	25.91	22.00	4.64	245.18	25.28	22.38	18.09	33.00	12.25	58.66
TMV-2	35.94	25.00	7.24	136.32	15.80	40.11	47.65	63.27	30.23	63.39
KCG-2	48.69	35.06	6.50	165.32	15.14	61.48	43.63	91.18	33.25	67.42

**Table 24: Top ten superior segregants for pod yield and its component traits from F<sub>6</sub> segregating generations of the cross NRCG12473 × ICG12370 in groundnut**

<b>Line No.</b>	<b>Pods/plant</b>	<b>Kernels/plant</b>	<b>Kernel yield/plant (g)</b>	<b>Pod yield/plant (g)</b>	<b>Shelling percentage</b>	<b>SCMR</b>	<b>SLA (cm<sup>2</sup>/g)</b>
14A2A	55	99	46.28	54.30	85.23	40.58	134.76
20B1B	49	98	31.97	68.80	46.47	43.18	118.77
30A1A	65	115	45.23	60.61	74.62	45.14	151.39
54A2A	55	96	40.12	50.21	79.90	50.64	98.76
56A1A	48	66	32.25	44.75	72.06	46.78	136.12
62A2B	62	95	55.24	67.72	81.58	39.94	140.86
72B2A	52	78	40.95	48.98	83.61	51.60	132.60
80B1B	63	96	35.44	55.21	64.19	49.14	138.43
101A2A	45	67	32.10	45.53	70.50	51.98	107.18
121A1A	55	83	45.79	55.13	83.06	46.84	142.98
139A2A	58	115	48.66	65.25	47.74	55.21	136.25
NRCG 12273	39	58	26.56	32.25	82.36	36.20	185.25
ICG12370	23	42	17.71	25.23	70.21	29.32	210.35
TMV 2	40	55	28.25	41.52	74.25	40.25	142.25
KCG 2	49	70	34.36	54.06	69.25	41.36	136.56

**Table 25: Top ten superior segregants for pod yield and its component traits from F<sub>6</sub> segregating generations of the cross NRCG12273 × ICG12370 in groundnut**

<b>Line No.</b>	<b>Pods/plant</b>	<b>Kernels/plant</b>	<b>Kernel yield /plant (g)</b>	<b>Pod yield /plant (g)</b>	<b>Shelling percentage</b>	<b>SCMR</b>	<b>SLA (cm<sup>2</sup>/g)</b>
4A2A	40	58	37.42	41.54	79.18	45.25	156.25
30B1B	62	84	46.91	38.23	81.63	49.25	145.25
360A1A	58	83	42.69	38.18	89.46	54.21	123.25
414A2A	62	89	56.23	42.50	56.96	40.23	145.25
66A1A	50	88	61.43	28.13	45.79	39.25	165.25
92A2B	43	79	42.01	35.26	83.98	47.21	176.25
95B2A	52	85	54.23	46.23	63.16	56.25	142.65
98B1B	38	80	26.33	31.89	83.12	62.32	132.25
101A2A	52	90	50.18	60.12	79.95	48.25	165.25
132A1A	65	68	40.48	30.21	74.69	50.12	125.23
142A2A	43	70	32.75	43.00	69.28	48.56	175.42
NRCG12274	36	52	28.56	35.25	83.36	30.20	174.25
ICG12370	28	40	21.71	30.23	72.21	25.32	201.25
TMV 2	34	49	22.25	38.52	70.25	36.25	142.25
KCG 2	38	56	24.36	34.06	65.25	42.36	125.56

### **5.5 Outcome of the Research**

1. 325 F<sub>6</sub> RILs were developed which were exhibited near normal distribution for SLA, SCMR, pod yield per plant and pods per plant
2. Selected superior progenies in F<sub>6</sub> generation of RILs and other two crosses having few desirable features like higher pod yield, more number of pods per plant, lower SLA and higher SCMR compared to parents and checks.

### **5.6 Future line of work**

1. 325 F<sub>6</sub> RILs can be used for mapping of characters like SLA, SCMR and pod yield per plant.
2. 32, 26 and 18 selected superior progenies in F<sub>6</sub> generation of RILs and other two selected crosses (NRCG 12473 × ICG 12370 and NRCG 12274 × ICG 12370) could be forwarded one more generation before used for multi location test.

*Summary*



## VI. SUMMARY

Recombinant inbred populations derived from single seed descent method upon continuous selfing of  $F_2$  derived progenies have many advantages over other mapping populations. RILs find wide usage in both breeding and molecular work owing to the various purposes they serve. Recombinant inbred lines are the breeding output from which good stabilized segregants can be directly used as breeding lines with desirable traits from both the parents involved in the cross. In RILs the early genetic variability realized in the population is maintained and serve as a stable mapping population. RILs could be effectively used for mapping and tagging of markers related to different traits.

So an investigation was carried out to estimate variability present in early generation recombinant inbred lines and segregating populations. Parameters like GCV, PCV, heritability, genetic GAM, to understand the interrelationship among the component traits of pod yield through correlation and regression and to assess the breeding potential using parameters like intergeneration correlation, broad sense and narrow sense heritability estimates in groundnut.

Analysis of variance for ten characters studied in RILs and other two crosses of all the four segregating generations indicated highly significant differences among the progenies, progenies and checks, even progenies verses checks for all traits except primary branches per plant and shelling percentages in  $F_4$  and  $F_5$  generation of RILs and other two crosses suggesting the presence of enormous amount of variability.

Higher GCV and PCV were observed for number of pods per plant, kernels per plant, kernel yield per plant, pod yield per plant, SLA and SCMR in RILs of all the four generations as well as four segregating generations of other two crosses. Some traits like, days to flowering, primary branches per plant and shelling percentage exhibited low to moderate GCV and PCV in all the four generations of RILS and other two crosses which indicated that low variability available for these traits in these studied populations.

High heritability coupled with high genetic advance as *per cent* of mean for number of pods per plant, kernels per plant, kernel yield per plant, pod yield per plant,

SLA and SCMR indicated the involvement of additive gene action for expression of these traits in all the four generations of RILS and other two crosses. Where as, days to flowering, plant height, primary branches per plant and shelling percentage had low to moderate heritability coupled with moderate GAM in all the four generations of RILS and other two crosses suggesting the involvement of the non-additive gene action with high environmental influence.

Phenotypic correlation coefficient indicated that SCMR, pods per plant, kernels per plant and kernel yield per plant had strong positive correlation with pod yield per plant at phenotypic level. However, SLA and shelling percentage exhibited strong negative association with pod yield per plant at phenotypic level. This relationship helps in selection of superior high yielding progenies with high water use efficient progenies.

Higher intergeneration correlations were recorded for pods per plant, kernels per plant, kernel yield per plant, pod yield per plant, SCMR, SLA, days to flowering and plant height between  $F_4$  to  $F_5$ ,  $F_4$  to  $F_6$  and  $F_5$  to  $F_6$  in all the studied populations. Hence, these traits can be used as criteria for selection of high yielding with high water use efficient genotypes from  $F_4$  generation onwards.

Pod per plant, kernels per plant, kernel yield per plant and SCMR had higher positive effect and higher positive association on pod yield per plant in RILs of four generations and in four segregating generations of other two crosses, which indicates the importance of these traits to incorporate as selection criteria for development of high yielding and high water use efficient segregants.

High broad sense and high narrow sense heritability coupled with close correspondence between broad sense and narrow sense heritability for all the traits in  $F_6$  RILs as well as  $F_6$  segregates of other two crosses, were observed which suggests that alleles involved in the expression of these characters are fixed, heritable and less influenced by environmental factors.

Top superior high yielding coupled with high water use efficient segregates like, CI- $F_6$ -45 in RIL, 30B1B segregating line in the cross of NRCG 12273  $\times$  ICG 12370 and

80B1B segregating line in the cross of NRCG 12274 × ICG 12370 were selected based on some important traits like, higher SCMR, lower SLA, higher pod yield per plant, higher kernel yield per plant, more number of pods per plant and higher shelling percentage in comparison with parents and checks. From the selection it was observed that high yielding progenies are having higher SCMR coupled with lower SLA value and higher pod yield per plant. Since, these progenies were still segregating hence one more generation need to be tested to predict their performance before releasing for either station trial or multi location trial.

Based on all the above information the study suggested, the need of further multi-row progeny testing for these traits of these selected segregates before testing either at station trial or multi-location trial.

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# *Appendices*



**Appendix 1: Mean performance of F<sub>6</sub> Recombinant Inbred Lines for Growth parameters, traits related to WUE, yield and yield attributing characters in cross NRCG 12568 × NRCG12326 in groundnut**

Line no	Days to first flowering	Plant height (cm)	Primary branches per plant	SCMR	SLA (cm <sup>2</sup> /g)	Pods per plant	Kernels per plant	Kernel yield per plant (g)	Pod yield per plant (g)	Shelling percentage
4	34.36	18.27	5.09	26.72	281.74	21.05	31.14	10.70	17.82	56.29
5	35.08	21.00	4.23	21.82	290.78	15.48	21.40	6.54	12.00	50.41
6	34.20	14.07	4.33	26.41	277.79	19.30	28.22	9.10	15.88	60.07
9	33.65	18.65	4.41	27.74	237.82	20.53	30.59	12.06	17.77	63.56
10	41.53	26.80	4.73	28.75	233.28	20.07	28.81	10.97	16.84	65.09
11	42.71	13.33	4.86	36.38	193.95	23.39	36.64	11.92	23.01	51.83
14	34.12	22.35	5.06	53.63	154.49	27.58	47.89	17.32	30.97	59.29
15	33.21	13.89	5.11	48.04	164.32	32.56	57.88	19.56	34.71	56.43
19	33.00	14.77	5.08	31.17	222.99	17.24	27.31	10.75	19.05	53.82
20	32.92	12.92	5.17	57.28	127.30	32.31	57.11	21.49	34.99	60.24
22	34.50	33.28	4.67	38.41	172.99	25.04	42.54	12.30	23.19	53.99
25	40.33	12.25	5.17	31.06	217.49	24.47	35.42	12.64	19.98	62.64
29	42.60	13.67	5.13	37.73	173.32	23.43	35.84	12.83	23.12	55.62
30	42.42	24.17	5.25	48.00	155.29	30.00	46.79	17.76	30.07	59.36
32	42.27	13.64	5.09	59.41	118.63	36.58	63.96	25.48	44.80	57.95
35	45.06	19.78	4.78	45.05	167.17	43.77	53.68	20.86	26.57	76.18
36	38.31	31.77	5.00	49.31	155.44	37.75	54.50	21.23	33.23	69.49
38	44.85	24.62	4.31	53.48	171.36	55.51	71.80	29.01	42.39	72.48
39	32.67	14.00	5.53	40.87	172.99	23.85	37.38	13.52	24.49	54.92
42	35.00	22.73	4.67	33.31	219.66	34.47	40.49	14.92	19.86	71.60
45	27.82	13.53	5.18	19.42	326.32	19.12	21.15	6.22	11.02	54.97
48	31.80	15.25	5.45	32.75	217.49	17.13	26.82	8.77	18.50	47.15
51	38.79	14.79	4.43	42.53	184.29	20.69	34.81	12.36	24.72	48.67
52	38.11	23.00	5.17	47.11	150.94	24.17	39.01	14.25	26.16	53.44
55	44.63	14.13	5.50	48.02	151.82	35.14	57.19	22.43	36.99	57.01

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58	39.79	11.93	5.36	68.61	104.61	57.17	100.42	41.89	67.29	61.77
59	33.64	24.36	5.07	64.74	108.86	48.81	85.25	35.06	57.37	60.59
61	30.78	31.56	4.89	35.14	200.82	22.60	33.29	11.68	21.07	55.47
62	31.82	14.27	5.27	20.04	305.29	16.43	20.03	6.24	11.42	53.91
65	39.47	14.41	6.12	32.90	237.61	26.98	35.60	12.72	19.76	58.82
68	44.75	24.70	5.25	23.23	275.86	19.01	23.75	7.39	13.39	55.09
69	43.77	32.15	5.00	19.01	350.79	15.93	19.17	5.33	10.90	48.84
71	45.80	23.87	5.27	16.21	365.79	14.41	16.55	4.15	9.32	44.40
74	42.64	15.14	4.93	21.06	305.23	17.02	20.96	7.59	11.95	65.94
75	43.94	18.89	4.94	49.48	236.93	35.42	49.07	18.78	27.45	60.94
78	38.76	14.29	5.82	33.67	256.29	25.13	33.71	11.87	19.18	57.22
79	42.87	17.20	5.73	17.02	355.25	15.12	17.87	4.74	10.16	46.41
81	35.71	13.12	5.47	19.45	307.44	14.85	18.64	6.00	11.14	54.02
82	36.08	12.25	5.67	46.76	203.29	38.08	60.92	24.11	38.52	54.83
83	48.47	14.93	5.00	37.22	200.82	22.49	33.45	11.75	21.11	53.63
84	44.09	27.73	5.64	34.95	192.79	21.03	31.34	10.80	20.03	53.72
85	44.93	34.67	4.73	27.45	248.79	17.42	24.43	9.21	15.37	62.84
86	44.85	24.23	6.00	34.80	238.75	22.54	33.39	11.73	21.00	49.26
89	40.22	34.50	5.33	25.20	278.74	15.83	22.23	7.29	14.27	50.23
92	32.65	13.24	5.47	38.22	200.82	23.93	35.56	12.70	22.24	54.39
93	31.92	11.85	5.62	43.96	210.82	25.46	38.80	14.16	24.59	55.83
95	32.82	14.00	4.91	46.40	150.78	23.19	39.15	14.32	27.44	52.13
96	40.70	14.10	5.30	42.68	233.79	22.66	36.65	14.69	24.78	59.54
99	44.73	32.33	5.60	37.50	249.31	18.21	29.47	11.72	20.63	61.56
101	45.75	23.83	6.00	42.57	184.29	20.27	33.88	11.95	23.99	48.10
102	47.31	23.31	5.50	46.55	183.78	22.29	37.66	13.65	26.58	49.63
104	41.65	13.41	6.24	48.68	227.49	23.47	39.31	14.39	27.31	45.33
105	45.17	13.44	5.67	38.26	172.12	19.57	31.76	10.99	22.07	49.81
108	34.77	19.15	5.85	49.09	145.99	23.06	39.46	14.46	28.00	50.49
109	39.00	22.93	4.87	33.08	256.29	17.88	29.29	11.21	20.80	54.96

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110	32.35	34.35	4.82	36.03	195.24	17.75	29.17	9.83	20.82	47.13
112	35.75	23.67	4.75	43.81	155.29	20.30	34.96	12.43	25.40	48.33
114	44.73	15.00	4.80	61.23	123.79	24.67	46.46	17.61	35.71	48.22
118	41.79	14.57	5.86	29.00	250.82	13.89	22.40	6.78	16.49	41.11
119	45.71	16.88	5.65	46.46	145.79	20.03	34.99	12.45	25.78	46.50
120	41.88	14.35	4.88	41.32	167.49	36.60	69.17	27.83	51.18	49.30
121	37.00	14.00	5.42	53.99	145.49	25.38	45.02	16.96	32.57	49.77
122	32.57	17.93	4.71	46.20	189.77	28.76	43.31	16.19	26.71	56.82
123	31.64	23.64	4.91	65.08	108.05	42.50	69.37	27.92	44.30	62.79
124	34.27	14.33	5.13	41.97	171.25	24.55	37.22	13.45	23.59	57.01
125	42.64	15.27	4.00	60.00	152.44	36.81	59.10	23.29	37.62	59.92
126	46.00	22.86	3.86	51.03	215.32	27.17	40.53	14.94	25.18	57.61
128	44.21	13.79	3.86	40.75	244.25	29.96	39.99	14.70	22.07	59.35
129	47.00	12.13	4.31	49.67	198.61	36.00	50.87	19.59	28.96	62.51
131	46.45	12.27	4.45	22.17	321.91	17.10	20.72	6.02	11.66	50.97
133	41.36	21.36	4.21	30.16	217.49	24.17	31.01	10.65	17.09	62.18
135	46.60	18.00	4.53	28.99	233.24	20.64	26.70	8.72	15.23	56.81
136	31.14	20.29	3.93	32.50	227.45	23.31	30.40	10.38	17.10	60.00
139	37.31	18.15	3.85	21.96	305.45	17.89	21.83	6.52	12.24	51.70
145	29.75	14.58	3.92	30.55	223.28	22.59	29.35	9.91	16.54	59.79
146	29.67	16.47	4.07	47.86	165.65	28.63	43.10	16.10	27.00	59.77
149	40.29	20.71	3.71	51.94	171.94	23.49	39.97	14.69	28.16	49.70
150	39.20	26.40	4.53	33.72	211.99	17.38	27.45	9.05	19.03	47.55
151	41.93	16.20	4.80	45.02	150.79	21.10	35.08	12.48	24.59	50.60
152	41.85	18.00	4.77	42.54	189.79	19.89	33.46	11.76	23.89	47.82
154	37.58	17.33	5.00	56.81	126.32	25.21	43.82	16.42	31.18	51.57
158	32.87	14.13	4.80	60.11	130.50	37.80	68.40	27.48	48.47	55.69
159	28.75	12.33	4.92	33.30	206.32	15.81	24.89	7.90	17.51	42.95
160	29.36	15.36	4.57	55.44	138.76	37.78	68.24	27.41	48.28	55.49
161	34.69	21.75	5.25	35.81	200.82	16.85	27.08	8.89	19.16	45.93

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162	39.25	16.31	5.31	41.24	210.79	19.24	31.52	10.89	22.13	47.06
163	38.62	14.31	5.38	43.47	161.95	19.72	32.74	11.43	23.16	49.29
164	40.14	20.21	5.50	21.70	315.24	19.38	22.44	6.80	11.84	53.20
165	41.46	25.00	5.08	10.43	391.90	11.68	11.30	3.10	6.03	55.10
166	35.43	24.00	5.07	40.53	216.86	36.03	47.39	18.02	25.30	67.32
167	40.00	14.07	5.00	11.93	355.25	13.50	13.65	4.24	7.15	60.64
168	38.92	16.58	5.17	27.58	260.75	19.15	182.75	9.75	17.53	52.49
169	44.24	21.59	5.41	23.43	277.78	14.47	20.97	7.54	14.06	55.56
171	38.07	26.13	5.07	22.64	260.79	14.24	20.64	5.99	13.89	42.98
172	37.38	18.69	5.31	42.35	165.32	23.67	38.61	14.07	26.19	53.67
174	48.00	13.41	4.00	18.47	305.29	12.31	17.19	6.23	11.65	57.85
175	46.60	14.13	4.40	23.49	275.29	15.09	22.32	7.73	15.08	51.79
176	50.39	15.33	4.83	46.36	155.29	22.68	39.85	14.63	28.99	50.31
178	47.81	19.00	4.81	51.95	171.28	33.31	61.82	24.52	45.31	51.37
179	43.07	12.57	4.79	37.13	167.49	18.55	31.84	11.03	23.38	46.77
181	41.47	11.60	4.60	56.04	147.62	25.89	47.58	18.11	35.43	48.86
182	40.93	17.67	4.93	34.04	193.49	16.70	28.66	9.60	21.42	44.68
185	38.80	23.47	5.07	35.21	200.94	17.29	29.37	9.92	21.63	45.73
189	46.80	25.20	5.00	59.48	112.76	37.86	72.10	29.14	53.56	53.73
191	46.63	27.56	5.00	18.88	326.29	14.39	19.41	5.44	12.34	43.94
192	48.08	24.31	4.85	19.33	333.25	14.12	18.94	5.22	12.05	43.09
193	48.72	13.78	5.00	29.55	265.25	19.11	27.94	9.28	17.88	48.84
195	43.73	12.53	4.80	34.57	228.75	21.92	33.01	11.55	21.16	52.05
196	48.06	22.88	4.75	51.35	170.28	33.43	53.64	20.84	34.46	57.14
198	43.73	21.67	4.47	25.24	271.81	18.05	25.78	8.30	16.34	50.68
201	41.80	26.40	4.93	35.03	215.24	22.17	31.17	10.73	18.82	56.57
202	41.17	21.33	5.06	33.75	238.73	22.87	32.49	11.32	19.68	52.72
203	33.67	16.20	4.53	20.45	288.79	16.50	21.25	6.26	12.63	48.73
205	38.06	12.71	5.35	21.30	255.28	15.68	20.17	5.78	12.12	47.61
206	32.07	14.07	4.67	50.16	150.05	38.69	58.40	22.98	35.01	64.52

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208	31.13	20.20	4.93	26.22	250.78	16.87	23.51	7.28	14.81	48.35
209	44.12	24.71	5.12	40.08	156.29	21.95	35.39	12.62	24.02	52.18
210	40.53	25.53	4.71	33.91	205.29	18.52	28.85	9.68	19.55	48.57
211	45.58	24.17	4.67	45.11	150.24	24.98	40.83	15.07	27.56	54.67
215	42.62	18.38	4.69	38.06	166.95	21.22	33.35	11.71	22.26	51.91
218	39.73	13.18	5.27	34.15	198.74	20.90	32.17	11.17	21.14	52.42
219	33.06	33.71	5.18	49.32	150.95	26.19	43.30	16.18	29.34	54.41
220	30.59	13.35	4.59	36.92	193.24	22.04	34.14	12.06	22.37	52.22
221	33.29	14.14	4.79	58.22	122.75	38.42	58.10	22.85	34.91	65.38
222	42.57	24.00	5.00	62.48	125.66	39.93	59.89	23.65	35.59	65.71
225	44.73	24.27	4.91	38.01	221.95	32.29	47.84	18.23	28.74	58.52
226	39.56	33.83	4.83	53.63	128.79	42.44	63.89	25.45	37.88	66.11
227	37.46	14.77	4.92	34.60	211.79	24.11	34.40	12.18	20.75	58.32
228	28.17	14.92	4.83	35.14	205.29	24.12	33.89	11.95	20.17	58.19
229	37.45	19.18	5.27	18.81	325.75	16.87	19.84	5.63	10.94	48.65
231	45.23	32.62	4.38	22.71	302.74	20.02	23.12	7.11	12.10	41.36
233	37.03	20.20	4.86	22.51	287.61	18.49	21.51	9.00	12.70	75.17
234	36.41	20.82	4.88	30.57	233.23	29.94	37.75	13.69	19.86	68.70
239	49.47	28.87	5.27	49.57	151.82	45.43	61.24	24.26	32.63	72.41
241	45.71	18.00	4.14	26.39	281.95	23.93	29.08	9.79	15.35	62.32
242	46.65	27.71	4.76	14.72	381.75	15.83	17.30	4.48	9.17	47.54
243	40.89	18.95	4.84	59.01	142.83	58.93	82.43	33.79	44.59	73.48
245	33.23	11.08	5.31	58.73	125.99	41.72	60.07	23.73	34.25	68.50
246	31.42	12.75	4.92	40.49	233.79	29.67	40.73	15.03	23.10	58.67
247	32.67	23.72	4.67	26.50	265.23	21.19	27.43	9.05	15.58	56.36
248	41.67	13.00	4.92	18.16	320.78	19.97	21.53	6.39	10.77	58.46
249	45.67	23.00	4.87	55.13	149.91	41.60	58.61	23.08	32.77	68.05
252	44.00	14.92	5.08	43.08	217.80	34.23	48.08	18.34	27.36	61.33
258	46.64	14.27	4.82	34.75	244.24	26.68	36.09	12.94	20.50	54.80
259	47.06	17.11	4.83	31.29	215.32	23.11	28.96	12.01	19.47	61.73

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261	40.31	13.77	4.85	25.42	281.95	20.73	26.30	8.53	14.75	57.51
262	46.85	13.77	5.23	60.12	127.79	29.65	52.43	20.29	37.19	54.57
263	34.67	18.07	4.47	57.00	127.75	41.29	73.81	29.92	51.35	57.02
265	37.00	21.67	5.00	63.51	112.26	48.72	89.40	36.93	63.03	58.40
266	29.82	12.76	4.94	46.79	157.93	35.17	60.77	24.05	41.77	57.38
269	33.80	21.50	4.60	30.86	285.25	16.78	27.02	8.86	19.13	43.97
271	40.79	13.93	3.79	54.98	167.78	25.57	45.49	17.17	33.01	48.48
272	40.11	11.39	4.06	39.36	170.75	19.63	34.08	12.04	25.05	47.40
273	42.63	17.00	3.81	45.67	197.50	34.68	64.20	25.59	46.80	50.18
274	37.79	22.50	4.57	57.56	123.82	45.37	86.11	35.45	62.93	54.71
275	31.64	15.64	4.21	55.79	128.72	46.33	89.46	36.96	66.37	54.77
276	28.78	20.06	4.22	60.64	111.76	40.91	77.99	31.79	57.65	54.43
278	29.82	14.45	3.36	47.18	161.23	22.81	40.41	14.89	29.58	47.59
279	42.75	21.85	3.50	28.78	258.79	30.97	51.97	21.05	35.01	57.00
281	41.77	26.00	4.69	30.73	233.28	17.53	26.74	8.73	17.99	48.39
282	43.80	14.67	3.67	29.93	247.78	17.06	26.17	8.48	17.76	47.61
283	40.64	18.64	4.43	52.97	144.29	28.57	47.32	17.99	31.79	55.90
284	41.94	15.67	4.33	44.69	164.29	24.17	39.39	14.42	26.62	53.01
285	36.76	12.24	3.41	46.75	173.78	23.20	37.31	13.49	25.07	51.85
289	40.87	15.33	4.33	56.36	147.66	50.54	86.51	35.63	57.04	59.09
291	33.71	22.59	4.41	25.81	265.82	16.49	22.76	6.94	14.29	47.73
292	34.08	15.00	4.42	26.43	249.94	16.97	24.28	7.63	15.60	48.46
293	46.47	14.33	4.13	26.36	256.23	16.70	23.16	7.12	14.56	47.92
295	42.09	20.45	3.64	28.82	254.44	17.17	24.55	7.75	15.72	49.13
296	45.93	24.60	4.40	45.61	200.69	27.05	41.62	15.43	26.38	54.37
298	45.85	24.92	5.23	37.64	195.32	21.96	33.22	11.65	21.36	54.12
301	41.22	14.00	4.67	55.38	136.79	29.30	51.23	19.75	36.02	53.37
302	33.65	18.00	4.00	41.53	165.45	19.56	32.72	11.42	23.32	48.97
303	32.92	24.00	4.08	36.85	205.29	19.29	31.71	10.97	22.31	48.56
305	33.82	26.45	4.00	52.16	134.17	24.18	41.77	15.50	29.71	52.09

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306	41.70	18.20	4.00	57.19	129.29	27.17	46.80	17.76	32.74	53.57
310	46.15	15.23	3.54	32.69	260.75	16.36	25.91	8.36	18.17	42.68
312	45.73	14.07	4.87	43.70	165.24	21.26	35.16	12.52	24.51	51.04
313	46.75	14.50	5.00	26.63	259.73	22.87	27.49	9.07	14.49	62.55
314	48.31	15.88	4.63	49.11	142.47	40.44	53.49	20.77	28.33	72.80
315	42.65	17.76	4.59	23.89	257.31	21.04	25.01	7.95	13.26	56.41
319	46.17	12.06	4.06	23.60	283.29	22.17	25.71	8.27	13.24	62.39
321	35.77	14.00	4.77	23.41	320.74	20.64	24.46	7.71	12.99	58.77
323	40.00	19.47	3.67	25.74	265.32	22.29	26.98	8.84	14.37	61.43
324	33.35	23.71	4.94	25.30	271.63	24.64	30.02	10.21	15.81	63.03
325	36.75	26.92	4.50	39.94	171.25	26.17	36.24	13.01	21.26	61.86
326	45.73	27.60	4.60	26.45	270.25	17.07	23.70	7.36	14.84	41.41
328	42.79	20.57	5.00	59.06	132.45	38.80	63.33	25.20	40.74	60.05
329	46.71	13.71	5.12	38.35	237.75	22.71	33.65	11.84	21.14	55.56
330	42.88	12.06	5.35	25.43	333.25	16.97	23.82	7.42	15.08	48.04
331	38.00	27.42	3.67	31.01	231.95	18.48	26.74	8.73	17.06	50.98
333	33.57	21.79	5.50	22.65	315.41	16.20	20.82	6.07	12.41	48.25
334	32.64	26.91	4.64	23.78	295.24	17.87	23.24	7.16	13.70	51.80
335	35.27	24.07	5.33	30.51	206.24	20.48	28.52	9.53	17.30	55.08
336	43.64	17.91	5.00	21.11	310.75	16.25	20.96	6.13	12.53	48.97
339	47.00	15.00	5.00	50.00	182.50	37.97	57.46	22.55	34.58	59.25
368	45.21	12.50	4.00	34.73	205.25	23.64	33.43	11.74	20.08	57.68
375	48.00	14.38	3.56	55.01	154.95	36.87	54.72	21.33	32.47	63.93
379	47.45	19.55	4.09	55.00	136.74	42.99	72.81	29.46	48.21	61.38
385	42.36	23.07	4.57	47.82	149.75	47.26	82.52	33.84	55.67	59.61
389	47.60	27.40	4.27	50.75	122.24	43.00	74.93	30.42	50.78	59.61
391	28.14	23.79	4.00	40.23	148.75	30.48	50.71	19.52	33.99	55.85
395	34.31	23.23	3.69	57.39	140.75	29.94	48.62	18.58	31.92	56.76
396	26.75	13.75	4.17	40.02	184.24	21.58	33.86	11.93	22.50	50.88
397	26.67	12.40	3.40	36.33	195.25	19.81	31.12	10.71	21.00	50.12

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398	37.29	22.43	4.14	62.83	105.87	40.88	65.25	26.06	41.05	62.79
399	36.20	28.40	4.07	26.54	355.25	17.65	23.60	7.32	14.27	44.26
400	38.93	28.73	3.60	46.81	235.25	26.30	247.33	17.18	26.48	63.73
401	38.85	23.85	4.92	38.95	188.74	23.31	33.30	11.68	20.22	56.53
402	34.58	23.58	4.50	28.54	275.44	20.00	26.60	8.67	15.59	43.54
403	29.87	23.07	3.40	41.65	170.74	25.80	36.95	13.33	22.15	60.18
404	25.75	24.42	3.92	62.94	113.50	49.58	68.88	27.70	37.58	73.21
405	26.36	15.00	4.43	27.94	255.24	21.57	25.82	10.20	14.98	66.62
408	31.69	16.31	4.25	30.12	183.28	25.39	31.03	10.66	16.29	64.87
409	39.06	21.56	4.63	28.13	270.28	21.41	25.64	10.28	15.33	61.47
410	38.62	24.85	3.54	25.91	256.26	22.07	26.37	8.57	13.92	57.51
411	40.14	23.64	4.21	26.32	255.26	22.17	26.52	10.53	14.54	74.11
412	41.46	24.08	5.08	42.83	193.26	31.17	41.92	15.57	23.26	64.97
413	35.43	26.36	4.93	61.32	111.25	49.28	71.25	28.76	40.23	71.37
414	40.00	26.73	4.13	33.31	219.73	23.35	30.68	10.51	17.36	60.18
415	38.92	22.08	4.08	35.94	231.29	25.60	34.21	12.09	19.35	58.53
416	44.24	26.35	4.12	37.54	190.75	28.33	37.93	13.77	21.17	64.68
418	38.07	25.33	3.93	49.35	171.24	39.47	67.69	27.16	46.05	47.18
419	37.38	46.08	3.54	49.12	171.25	21.60	36.60	13.17	26.00	49.39
420	48.00	22.88	4.94	62.00	137.24	26.54	46.43	17.59	33.02	53.28
421	46.60	13.27	4.80	68.63	113.74	36.52	66.13	26.46	47.01	56.26
423	50.39	13.44	4.89	62.47	111.25	31.40	55.14	21.51	38.66	55.46
425	47.81	16.06	4.25	66.14	118.73	36.54	66.22	26.50	47.11	55.79
426	43.07	14.14	3.93	51.77	152.76	27.59	47.64	18.14	33.34	54.35
428	37.47	12.53	4.47	43.50	182.26	21.85	37.11	13.40	26.35	48.20
429	36.93	18.07	4.13	46.33	148.74	26.49	44.00	16.50	29.92	55.13
431	41.80	22.40	4.67	33.79	227.25	19.35	30.29	10.33	20.44	44.74
435	49.80	26.60	4.13	49.74	128.75	26.50	43.70	16.36	29.50	55.43
436	49.63	26.00	4.75	34.14	216.26	20.93	32.60	11.37	21.65	51.66
437	51.08	17.92	4.46	24.75	233.25	15.46	22.96	7.03	15.48	37.09

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438	51.72	19.67	3.94	30.63	260.75	19.50	30.01	10.20	19.95	47.97
439	46.73	18.53	4.53	38.85	179.76	22.33	35.65	12.74	23.93	53.22
441	51.06	17.06	4.69	43.81	150.25	40.61	69.99	28.20	47.17	57.96
442	46.73	18.80	4.87	38.60	197.76	22.67	36.00	12.90	24.02	53.66
443	44.80	21.13	4.47	15.41	336.26	14.93	17.44	4.55	9.86	46.15
445	44.17	20.89	5.17	27.86	242.24	23.84	31.25	10.76	17.58	61.02
446	36.67	16.00	4.73	26.96	255.26	22.02	28.82	11.02	16.41	68.50
447	36.35	13.65	5.18	21.04	299.24	18.54	22.74	6.93	12.69	54.59
448	30.07	15.93	4.00	29.24	244.76	23.17	30.71	10.52	17.52	59.88
449	29.13	18.33	3.47	31.91	225.26	25.77	34.56	12.25	19.58	61.91
451	42.12	23.35	3.82	27.89	235.29	23.67	31.24	10.76	17.70	60.55
452	38.53	27.41	4.24	49.81	182.45	51.30	79.09	32.29	47.27	62.30
453	43.58	14.33	5.00	33.99	210.75	24.40	35.15	12.52	21.34	57.04
454	40.62	12.62	4.46	37.76	175.26	27.08	38.36	13.96	22.62	61.04
455	37.73	15.64	3.73	33.95	230.26	23.05	32.58	11.36	19.63	57.71
457	31.06	13.29	4.29	42.30	150.29	27.91	40.58	14.96	24.38	61.28
458	28.59	13.65	3.76	30.16	270.23	21.36	29.54	9.99	17.72	51.98
459	31.29	19.36	4.36	42.45	150.44	28.04	40.20	14.79	23.85	61.92
461	40.57	24.79	3.86	61.63	102.75	38.96	60.19	23.79	36.88	64.51
462	42.73	22.64	3.82	26.48	269.75	15.45	21.39	8.29	13.66	69.67
463	37.56	13.11	3.83	54.84	153.76	32.07	49.99	19.20	31.43	60.42
464	35.46	16.54	4.38	45.08	179.76	26.37	41.09	15.19	26.41	57.24
465	26.17	21.25	4.25	57.54	121.76	33.55	52.90	20.50	33.43	60.64
468	35.53	21.20	4.20	34.06	249.75	21.71	32.40	11.28	20.66	48.17
469	41.91	22.55	4.64	70.20	105.26	36.33	62.89	25.00	43.10	58.41
472	34.07	25.73	4.20	41.65	183.26	19.18	32.83	11.47	23.92	46.99
473	33.38	22.92	3.85	38.22	210.76	18.62	32.17	11.18	23.74	46.29
474	44.72	14.50	3.83	43.29	205.41	20.29	35.13	12.51	25.62	46.88
475	42.53	16.18	4.12	36.79	170.75	17.40	29.31	9.89	21.41	45.77
478	47.15	22.54	3.69	46.53	199.26	21.01	36.52	13.13	26.60	47.82

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479	44.91	26.91	4.55	56.38	150.26	24.25	43.81	16.42	32.40	50.24
481	37.08	14.00	4.85	23.70	304.76	11.60	17.83	7.25	13.18	55.40
482	33.07	15.73	4.93	32.99	215.27	16.57	26.81	8.76	19.12	42.44
483	33.33	14.83	4.83	32.35	232.74	17.04	27.74	9.18	19.77	44.05
484	38.06	21.31	4.81	39.64	176.23	20.03	33.01	11.55	23.15	49.47
485	46.00	25.65	4.76	39.30	188.38	19.56	31.97	11.09	22.33	47.81
486	45.72	13.78	5.17	36.93	175.24	18.39	30.12	10.25	21.29	48.00
487	47.54	17.23	5.15	42.78	198.76	25.16	38.20	13.89	24.75	57.40
489	47.00	18.67	5.47	23.28	293.25	21.79	25.78	8.30	13.54	60.55
491	44.29	15.29	5.53	30.09	231.76	26.31	33.09	11.59	17.70	64.96
492	44.50	17.75	4.83	12.80	348.75	12.38	12.04	2.12	6.32	28.13
493	33.80	22.93	5.27	14.36	337.76	16.17	17.28	4.47	8.97	40.89
495	35.93	19.57	5.00	12.94	355.26	16.50	12.75	5.00	7.31	68.48
496	30.59	16.41	5.47	14.74	337.26	11.63	9.04	3.13	5.16	60.30
497	37.12	23.06	5.00	13.88	358.76	12.18	11.95	3.76	7.98	46.89
498	41.50	16.50	5.25	13.63	365.26	8.25	9.44	3.45	7.87	42.86
499	40.00	13.64	4.86	37.68	210.95	20.20	31.91	11.06	21.55	48.43
500	44.82	14.27	3.73	22.61	299.41	13.72	19.56	6.58	13.11	49.89
501	41.20	23.60	4.40	33.85	240.76	19.04	29.29	11.45	19.54	60.76
502	38.73	20.73	4.91	40.09	234.76	22.00	35.19	14.85	23.71	71.58
503	31.07	20.21	4.86	27.05	270.76	17.68	26.79	11.75	17.87	62.86
504	29.57	21.64	4.71	54.67	154.65	37.59	60.56	24.25	38.59	60.82
505	30.69	16.31	4.75	16.91	320.22	12.00	15.23	5.61	9.70	65.08
506	40.64	22.82	4.73	44.76	173.25	28.33	43.61	16.32	27.48	58.11
509	43.57	23.79	4.93	46.11	183.25	27.70	43.11	16.10	27.53	58.14
510	42.40	33.80	5.07	22.69	292.79	16.04	21.71	7.42	13.50	55.43
511	44.57	33.57	4.86	15.18	370.25	10.10	11.94	5.21	7.63	70.35
512	45.46	22.85	5.08	17.55	308.74	12.03	15.31	5.60	9.78	64.47
513	38.33	13.25	4.92	26.56	255.25	17.79	25.51	8.18	16.27	49.95
514	44.47	17.27	4.93	24.16	281.75	20.33	25.89	8.35	14.63	55.05

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516	37.21	22.00	5.00	32.61	232.75	25.93	34.61	12.27	19.50	58.54
518	42.00	16.00	4.80	21.66	288.25	19.83	25.20	8.04	14.28	52.17
519	35.07	20.53	4.73	34.87	156.29	27.69	37.45	13.55	21.16	63.97
520	34.38	12.92	4.46	16.72	178.25	15.20	17.86	4.74	10.10	46.93
523	44.75	13.58	4.92	52.50	136.53	40.10	56.11	21.95	31.28	69.27
524	44.73	13.93	5.33	22.32	283.14	18.53	23.28	7.17	13.24	51.59
523	44.42	23.58	3.83	29.43	236.75	21.35	29.48	9.97	17.66	56.30
524	48.86	30.79	5.50	34.40	205.23	25.58	36.00	12.90	21.28	59.97
526	43.50	34.63	5.19	19.98	310.22	15.16	19.41	5.44	11.74	38.83
528	37.56	24.00	4.50	22.95	292.25	16.67	21.25	7.77	12.50	65.12
529	33.69	24.08	5.00	29.59	255.25	21.14	28.71	10.01	17.40	52.16
531	34.64	14.00	5.29	59.11	138.48	40.96	60.37	23.87	35.23	66.20
532	39.92	12.62	4.54	50.83	174.88	37.51	52.35	20.26	29.31	62.82
534	47.07	17.36	4.79	34.87	217.58	25.94	34.81	12.36	19.72	60.80
535	46.73	23.53	4.60	59.31	122.69	36.85	58.88	23.20	37.33	61.21
536	45.00	34.08	5.50	25.39	265.32	17.00	23.51	7.28	14.70	49.40
537	36.71	23.88	4.82	39.57	228.64	23.31	35.57	12.71	22.85	45.54
538	36.13	23.53	4.73	22.55	310.79	15.53	21.11	6.20	13.27	46.31
539	32.38	13.46	4.85	26.45	283.25	13.93	21.26	6.27	14.98	35.60
540	38.59	14.82	5.00	51.10	138.24	24.58	42.44	15.80	30.11	52.43
541	43.33	23.60	5.00	50.28	148.67	37.45	66.00	26.40	45.68	55.21
542	43.83	23.61	4.83	43.85	154.29	21.43	36.27	13.02	25.76	49.72
543	44.56	33.75	4.69	58.54	122.66	39.59	71.61	28.92	50.55	56.81
544	40.86	33.00	5.14	54.59	142.11	26.86	44.27	16.62	29.83	55.65
546	31.47	12.73	5.13	51.95	139.79	26.86	43.71	16.37	29.13	56.12
547	38.33	13.25	4.92	26.58	270.29	15.70	23.32	7.20	15.71	39.73
548	37.47	12.53	4.47	55.58	133.45	41.11	70.26	28.32	46.92	58.99
549	39.64	19.58	4.71	38.15	212.57	25.00	39.09	13.97	24.33	55.19
550	34.56	20.45	4.24	44.20	188.25	21.56	50.68	9.87	22.55	58.51
551	42.46	22.11	5.01	34.52	231.69	27.33	30.89	15.55	25.58	52.45

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**Appendix 2: Mean performance of F<sub>6</sub> selected superior segregants for Growth parameters, traits related to WUE, yield and yield attributing characters in cross NRCG 12473 × ICG12370 in groundnut**

Line No.	Days to first flowering	Plant height (cm)	Primary branches per plant	SCMR	SLA (cm <sup>2</sup> /g)	Pods per plant	Kernels per plant	Kernel yield per plant (g)	Pod yield per plant (g)	Shelling percentage
1B1A	32.36	21.27	5.09	36.23	198.25	33.56	60.58	28.24	34.11	82.81
1B2A	33.08	24.00	4.23	57.77	120.62	47.74	79.34	37.10	45.27	81.58
1B2B	32.20	17.07	4.33	51.01	140.76	62.28	99.52	44.29	54.50	81.36
3A1A	31.65	21.65	4.41	40.09	185.25	25.23	47.55	22.48	30.21	74.40
3A1B	39.53	29.80	4.73	29.64	265.23	23.84	40.89	19.10	23.72	80.53
3A2A	40.71	16.33	4.86	20.31	296.36	21.90	30.32	14.29	17.25	82.80
4B1A	32.12	25.35	5.06	24.46	285.32	20.99	24.88	11.81	17.46	67.62
4B1B	31.21	16.89	5.11	16.56	365.23	14.10	18.25	8.63	12.81	67.32
5A1A	31.00	17.77	5.08	23.40	310.25	19.89	23.37	11.10	16.74	66.29
5A2A	30.92	15.92	5.17	16.63	325.23	15.50	18.37	8.72	13.09	66.59
5B1A	32.50	36.28	4.67	29.94	256.37	25.41	48.66	16.58	20.21	82.04
5B2A	38.33	15.25	5.17	61.72	120.23	32.95	62.44	29.36	39.15	75.00
5C1A	40.60	16.67	5.13	27.15	265.23	23.09	27.13	12.99	19.05	68.19
5C2A	40.42	27.17	5.25	15.36	325.20	13.70	17.74	8.39	12.33	68.02
6A1A	40.27	16.64	5.09	45.54	156.25	26.27	31.13	24.00	30.22	79.42
7A2A	43.06	22.78	4.78	28.07	285.23	23.09	41.21	12.99	19.25	67.47
8A1A	36.31	34.77	5.00	49.60	165.25	26.53	45.50	23.64	32.25	73.31
10A1A	42.85	27.62	4.31	20.73	310.25	19.48	35.16	12.71	15.45	82.26
10A2A	30.67	17.00	5.53	56.57	128.75	36.84	54.87	23.98	37.41	62.17
10C1A	33.00	25.73	4.67	29.89	256.23	25.25	29.92	18.07	26.21	68.94
10C2A	25.82	16.53	5.18	30.62	210.25	24.01	28.45	18.25	22.13	82.47
10D2A	29.80	18.25	5.45	32.57	196.36	26.38	31.25	20.06	26.25	76.41
11A1A	36.79	17.79	4.43	27.09	256.36	24.91	42.73	17.71	24.30	72.89
11A2A	36.11	26.00	5.17	30.18	212.23	15.00	27.23	13.70	19.90	68.87

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12A1A	42.63	17.13	5.50	59.54	129.76	66.89	98.50	51.09	64.41	79.19
13A1A	37.79	14.93	5.36	15.47	365.25	18.52	33.05	12.08	17.25	70.03
13B2A	31.64	27.36	5.07	10.23	375.25	12.64	21.68	7.11	9.76	72.89
13B2B	28.78	34.56	4.89	12.25	356.25	13.88	24.77	8.49	12.13	70.03
14A1A	29.82	17.27	5.27	13.25	375.21	9.87	18.00	5.50	8.04	68.49
14A1B	37.47	17.41	6.12	7.27	385.25	15.57	27.79	8.76	12.50	70.03
15B1A	42.75	27.70	5.25	45.96	168.74	38.02	68.15	26.16	37.56	69.64
15B1A	41.77	35.15	5.00	12.25	365.32	9.94	17.85	5.55	7.97	69.64
15B1B	43.80	26.87	5.27	15.21	325.20	20.84	37.61	12.75	18.41	69.25
16A1A	40.64	18.14	4.93	7.67	396.25	15.80	28.68	8.89	12.90	68.87
16B1A	41.94	21.89	4.94	47.07	165.25	27.34	49.08	22.76	32.69	69.64
18A2A	36.76	17.29	5.82	35.91	185.45	23.25	41.97	18.62	26.89	69.25
18B1A	40.87	20.20	5.73	59.84	127.98	53.97	84.77	37.58	51.61	73.14
19A1A	33.71	16.12	5.47	14.89	365.20	24.65	36.36	13.87	20.12	68.91
19A2A	34.08	15.25	5.67	10.09	345.25	17.60	26.66	9.90	15.32	64.62
20B1A	46.47	17.93	5.00	56.01	134.26	39.42	58.25	29.60	38.54	78.21
20B1B	42.09	30.73	5.64	34.27	185.26	20.52	30.89	18.10	23.10	78.36
21A1A	42.93	37.67	4.73	36.13	178.25	22.14	33.54	19.72	23.91	82.51
23A1A	42.85	27.23	6.00	37.88	186.25	22.08	33.45	19.48	25.21	77.26
24B1A	38.22	37.50	5.33	62.45	114.51	57.19	86.38	43.81	57.08	76.85
25B1A	30.65	16.24	5.47	23.75	265.25	17.49	25.97	14.87	17.67	84.18
26A1A	29.92	14.85	5.62	41.16	156.23	28.93	43.54	20.32	29.00	70.08
28A1A	30.82	17.00	4.91	67.51	104.01	55.91	84.71	45.90	56.79	80.54
28B1A	38.70	17.10	5.30	16.84	356.20	13.20	20.00	11.17	13.54	82.51
30A1A	43.15	27.38	5.38	16.11	365.20	11.54	19.79	9.66	13.25	72.89
31A1A	42.73	35.33	5.60	30.54	210.23	19.47	32.80	16.38	22.08	74.18
31B1A	43.75	26.83	6.00	46.41	165.25	27.45	47.36	20.12	31.88	63.11
31B1B	45.31	26.31	5.50	51.52	154.73	44.57	75.78	34.23	42.90	78.67
33A1A	39.65	16.41	6.24	69.01	104.27	59.91	99.62	43.57	56.27	77.52
37A1A	43.17	16.44	5.67	63.05	123.59	54.87	93.66	38.51	52.37	73.81

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37B1A	32.77	22.15	5.85	13.97	365.25	14.80	25.38	9.60	14.44	66.49
38A1A	37.00	25.93	4.87	21.76	296.36	20.69	35.68	12.32	20.30	60.70
38A1B	30.35	37.35	4.82	12.61	365.20	14.48	24.25	9.36	13.62	68.74
46A1A	33.75	26.67	4.75	17.19	325.23	18.05	30.05	12.75	16.98	75.08
46A1B	42.73	18.00	4.80	25.26	210.25	23.64	40.30	16.81	22.92	73.31
54A1A	39.79	17.57	5.86	23.93	296.32	22.70	38.02	16.24	21.76	74.63
54A2A	43.71	19.88	5.65	23.48	112.25	21.19	39.58	14.78	22.09	66.92
54A2B	35.00	17.00	5.42	64.41	104.93	52.24	97.68	37.07	55.46	66.98
62A1A	30.57	20.93	4.71	55.96	138.75	42.71	81.06	30.34	46.06	65.97
66A2A	29.64	26.64	4.91	13.25	356.20	9.65	18.29	6.86	10.40	65.96
66A2B	32.27	17.33	5.13	33.21	210.25	20.47	39.20	16.40	25.12	65.27
72A1A	40.64	18.27	4.00	36.39	185.54	23.00	44.05	20.12	27.75	72.51
74A1A	44.00	25.86	3.86	17.53	345.25	12.36	22.93	13.25	14.78	89.65
75A1A	42.21	16.79	3.86	56.63	127.25	43.67	81.44	34.69	51.75	67.02
83A1A	45.00	15.13	4.31	22.46	310.20	15.23	28.24	12.20	18.10	67.39
86B1A	44.45	15.27	4.45	21.49	322.20	14.71	27.59	11.72	17.58	66.67
88A2A	39.36	24.36	4.21	22.11	362.25	15.08	28.58	11.94	18.11	65.96
91A1A	44.60	21.00	4.53	43.83	165.25	28.00	53.90	25.32	33.37	75.87
93A1A	29.14	23.29	3.93	21.48	311.20	15.02	28.62	13.25	17.93	73.92
94A1A	35.31	21.15	3.85	24.91	301.23	16.25	31.12	15.32	19.83	77.25
94A2A	27.75	17.58	3.92	18.83	365.20	13.09	24.54	11.32	15.72	72.00
99B1A	27.67	19.47	4.07	27.53	296.25	16.80	33.01	13.53	21.27	63.61
101A1A	38.29	23.71	3.71	34.30	195.25	21.77	42.35	17.05	26.53	64.27
102B1A	37.20	29.40	4.53	34.22	185.56	21.78	42.80	16.96	26.66	63.61
106A1A	39.93	19.20	4.80	23.29	210.25	15.22	29.45	14.23	18.76	75.83
107A1A	39.85	21.00	4.77	53.85	145.25	27.58	63.30	25.32	39.65	63.85
108C2A	35.58	20.33	5.00	49.71	145.26	23.75	46.91	26.25	32.64	80.41
110A1A	30.87	17.13	4.80	47.36	135.25	21.96	43.59	19.37	30.76	62.97
110A2A	26.75	15.33	4.92	60.60	112.75	35.28	70.10	38.05	48.80	75.23
110A2B	27.36	18.36	4.57	48.93	145.20	23.00	45.89	20.08	32.05	62.66

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117A1A	32.69	24.75	5.25	14.67	366.25	8.21	16.14	10.32	11.51	89.70
122A1A	37.25	19.31	5.31	24.17	265.25	12.53	24.36	13.25	17.19	77.08
122A2A	36.62	17.31	5.38	15.60	325.20	8.69	16.89	10.36	12.04	86.03
123A1A	38.14	23.21	5.50	22.06	210.25	13.53	22.13	12.06	15.77	76.45
124A1A	39.46	28.00	5.08	14.77	365.23	10.28	17.33	8.88	11.98	74.18
124B1A	33.43	27.00	5.07	33.73	156.32	19.46	33.38	16.90	23.19	72.89
127A1A	38.00	17.07	5.00	18.30	345.20	12.03	20.16	12.32	14.00	87.97
127B1A	36.92	19.58	5.17	38.43	165.25	21.93	37.83	20.36	26.15	77.87
128A2A	42.24	24.59	5.41	48.93	123.25	26.76	45.89	23.36	32.05	72.89
128A1A	36.07	29.13	5.07	68.87	102.23	36.67	61.42	30.25	43.34	69.80
128B1B	35.38	21.69	5.31	23.04	348.25	13.22	22.68	10.23	16.25	62.97
128B1A	46.00	16.41	4.00	10.91	385.26	7.75	13.23	8.25	9.38	87.93
129A1A	44.60	17.13	4.40	40.71	165.25	26.11	37.26	23.26	26.56	87.60
129B1A	48.39	18.33	4.83	39.43	210.25	22.17	37.84	19.35	26.43	73.23
133A1A	45.81	22.00	4.81	38.38	196.25	21.95	33.52	20.05	24.50	81.86
135A1A	41.07	15.57	4.79	19.79	385.26	13.87	19.65	12.54	14.22	88.21
138A1A	39.47	14.60	4.60	27.93	298.25	13.65	25.49	12.47	18.63	66.95
139A1A	38.93	20.67	4.93	29.98	278.25	22.82	46.95	15.33	20.12	76.20
143B1A	36.80	26.47	5.07	58.39	122.25	33.64	51.38	25.36	30.15	84.11
145A1A	44.80	28.20	5.00	67.78	107.64	41.98	71.20	34.01	40.68	84.78
152A1A	44.63	30.56	5.00	24.43	210.25	17.53	22.56	12.30	16.57	79.66
152A1B	46.08	27.31	4.85	16.00	348.26	14.55	15.82	10.25	11.73	85.23
154A1A	46.72	16.78	5.00	31.62	201.25	22.93	27.45	16.32	20.36	79.86
155A1A	41.73	15.53	4.80	12.23	375.25	8.44	9.09	4.23	6.65	80.91
155A2A	46.06	25.88	4.75	26.64	3013.25	23.02	25.02	12.25	18.11	74.62
155A2B	41.73	24.67	4.47	47.78	145.25	24.60	44.71	22.25	30.12	79.90
156A2A	39.80	29.40	4.93	17.73	366.22	14.40	25.88	11.02	15.84	90.02
156A2B	39.17	24.33	5.06	17.67	345.20	22.50	24.23	10.56	15.27	74.40

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**Appendix 3: Mean performance of F<sub>6</sub> selected superior segregants for Growth parameters, traits related to WUE, yield and yield attributing characters in cross NRCG 12274 × ICG12370 in groundnut**

Line No.	Days to first flowering	Plant height (cm)	Primary branches per plant	SCMR	SLA (cm <sup>2</sup> /g)	Pods per plant	Kernels per plant	Kernel yield per plant (g)	Pod yield per plant (g)	Shelling percentage
4A1A	30.21	22.21	5.18	18.71	364.25	24.27	33.21	15.21	22.23	68.42
6B1A	33.20	26.32	4.95	27.61	242.04	40.88	62.26	23.21	35.19	67.44
8B1A	36.25	20.12	5.28	37.52	187.27	53.84	83.67	38.23	46.91	81.63
10A1A	30.25	25.23	5.48	30.48	210.25	34.53	51.81	22.12	30.51	72.49
13A1A	36.25	20.12	4.14	41.48	171.25	59.22	93.12	43.63	53.77	80.92
13A2A	30.21	22.32	5.34	36.79	207.76	50.67	88.80	29.89	62.34	47.77
15A1A	36.25	30.02	5.37	28.62	253.90	48.63	85.00	28.73	48.60	59.16
18A1A	38.25	15.26	5.36	35.21	190.75	45.34	78.62	30.19	50.84	62.96
23A1A	30.25	16.25	4.18	36.62	225.39	49.46	85.23	34.42	47.48	72.04
24A1A	32.25	20.12	4.25	23.11	296.32	34.17	57.65	19.22	41.09	46.77
25A1A	33.12	20.21	3.79	38.98	178.25	36.44	61.07	32.47	43.75	74.22
28A1A	36.25	19.32	4.28	30.13	237.50	43.79	75.00	27.60	47.67	57.87
29A1A	32.20	26.25	4.61	41.67	145.25	50.00	83.50	42.08	49.52	84.97
30A1A	36.25	20.21	4.34	21.52	310.20	39.33	52.54	20.12	30.07	66.90
32A1A	30.25	23.20	4.21	37.87	203.73	47.55	74.14	37.86	47.33	79.92
35A1B	38.25	25.36	3.91	13.88	366.25	28.06	34.33	12.25	19.53	62.74
36A1A	32.12	32.20	4.10	30.33	210.20	34.31	59.64	26.25	33.20	79.07
38A2A	36.25	20.25	3.41	49.08	157.69	61.00	93.30	49.19	60.29	82.47
40A1A	33.20	23.25	4.64	24.26	290.88	53.78	62.15	30.00	40.29	74.47
41B1A	36.12	25.21	3.78	33.87	222.21	58.62	77.46	36.75	50.20	72.84
45A2A	32.20	22.23	5.33	29.63	243.47	60.06	66.82	34.57	51.47	66.98
48A1A	45.21	25.32	4.98	42.39	166.38	49.70	79.92	40.46	52.05	77.74
49A1A	36.25	15.25	5.02	27.10	285.21	30.93	47.84	26.03	32.20	80.82
52A1A	35.25	16.20	4.12	35.13	195.73	60.58	75.55	38.50	55.00	70.29

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54B2A	45.21	15.25	4.37	45.09	166.16	60.23	93.94	43.72	58.25	74.94
54B2B	4.25	15.36	4.52	57.58	137.54	67.20	116.97	53.56	67.97	79.73
55A1A	35.20	25.32	4.61	24.71	210.23	29.50	44.58	24.56	29.69	82.73
55B1A	32.25	20.12	4.53	36.32	185.45	38.50	62.77	32.74	42.71	76.67
53A2A	32.21	23.25	4.94	30.82	220.21	35.45	55.59	29.52	37.02	79.72
55A2A	36.25	25.21	3.75	28.73	296.25	32.47	50.72	27.32	34.14	80.02
56A1A	40.21	20.21	4.92	30.97	201.20	35.60	55.86	29.64	37.20	79.66
57A1A	36.25	15.25	4.45	30.08	213.20	34.23	53.67	28.65	35.94	79.73
57B1A	42.12	20.21	3.75	40.14	179.90	48.50	80.96	39.04	47.58	82.36
59A1A	40.21	19.25	3.96	31.10	210.20	35.21	55.50	29.47	37.16	79.31
60A1A	42.21	26.25	3.88	18.71	385.26	27.78	41.94	18.45	22.23	83.00
60A1B	32.25	22.21	5.08	32.35	196.25	35.88	57.10	30.20	38.44	78.55
62B1A	36.25	22.25	4.36	17.95	345.25	35.60	45.54	20.15	25.57	78.79
63A1A	41.21	23.21	4.13	27.82	290.75	49.41	68.33	33.66	39.00	86.10
63A1B	32.21	26.25	4.72	16.52	345.20	34.42	43.00	18.45	23.84	77.39
63A2A	36.25	26.32	3.85	17.30	366.21	33.40	42.77	19.56	24.33	80.40
73A1A	36.25	32.25	5.05	20.58	310.20	33.00	47.75	25.99	30.08	86.39
73A1B	36.25	30.21	4.51	34.20	219.59	50.82	79.91	40.46	48.37	83.65
83A1A	32.22	25.23	4.59	20.64	310.25	31.07	45.31	24.89	29.03	85.72
83A1B	36.25	14.25	4.72	20.54	312.20	31.59	45.91	25.16	29.25	86.00
93A1A	30.12	20.21	4.04	35.97	178.23	52.22	80.77	40.85	50.55	80.93
96A1B	36.25	23.12	4.33	19.81	365.20	30.83	44.58	24.56	28.40	86.46
96A2A	32.25	20.21	4.51	20.51	301.02	31.07	45.31	24.89	29.03	85.72
97A2A	36.25	20.25	3.41	49.08	157.69	61.00	93.30	49.19	60.29	82.47
98A1A	33.20	23.25	4.64	24.26	290.88	53.78	62.15	30.00	40.29	74.47
100A1A	36.12	25.21	3.78	33.87	222.21	58.62	77.46	36.75	50.20	72.84
101A1A	32.20	22.23	5.33	29.63	243.47	60.06	66.82	34.57	51.47	66.98
101A2A	45.21	25.32	4.98	42.39	166.38	49.70	79.92	40.46	52.05	77.74