# SCREENING OF GROUNDNUT (*Arachis hypogaea* L.) GENOTYPES FOR HEAT TOLERANCE

**By**

**ASHNA AKBAR**

**A Thesis Submitted to**

**The Bihar Agricultural University,**

**Sabour, Bhagalpur**

**In Partial Fulfillment of the Requirements**

**for Award of the Degree**

**Of**

**MASTER OF SCIENCE IN AGRICULTURE**

**(PLANT BREEDING & GENETICS)**

**DEPARTMENT OF PLANT BREEDING & GENETICS**

**BIHAR AGRICULTURAL UNIVERSITY SABOUR, BHAGALPUR, BIHAR- 813 210**

**2014**

**Reg No: M/PBG/84/BAC/2012-13**

# Acknowledgement

All acclamation and praises are for "ALMIGHTY ALLAH", most Gracious, most Merciful and most Beneficent. I set my unfeigned and meek thanks giving before Him Who favored in invigorated me with the fortitude and capability to aptly complete my research work. It is He Who blessed me with potential, thoughts, talented teachers, cooperated friends and opportunity to make some contribution to the already existing ocean of knowledge.

At the outset of this epistle, I consider myself fortunate and greatly privileged to have worked under the supervision and guidance of Dr. P. Janila Scientist, Groundnut Breeding-ICRISAT. Words are inadequate to express my sincere and deepest feelings of gratitude originating from the innermost core of my heart for her benevolent guidance, meticulous supervision, whole hearted encouragement, critical appreciation in the execution of my work and for all the trust she had in my abilities, primarily responsible for the present accomplishment.

I humbly place on record my respect and gratitude to Dr. R. N. Sharma Univ. Prof.-cum-Chief-Scientist and chairman of PBG, department BAU, Sabour for his care and encouragement throughout my post-graduation programme.

With stupendous ecstasy and profundity of complacency, I pronounce utmost of gratitude to members of my advisory committee Sri Shashikant, Jr.Scientist-cum-Asstt.Proffessor, and chairman of my advisory committee, department of Plant Breeding and Genetics, Sri. Manoj Kumar, Asstt.Prof.-cum-Jr.Scientist, PBG department for his generous help for taking up my thesis work at ICRISAT, Dr.Chanda Kushwaha Asstt.Prof.-cum-Jr.Scientist (Plant Pathology), Dr. R. N Jha Senior Assoc. Prof. -cum- Sr. Scientist (SMCA), and Dr. Md. Feza Ahmed, Univ.Prof.-Cum-Chief Scientist (Fruit & Fruit Tech, Hort.), BAU, Sabour. I am grateful to them for their salutary advice, kind co-operation and congenial discussion on an array of topics.

I avail this opportunity to express my heartfelt gratitude to Dr. Chandan Roy, Asstt.Prof.-cum-Jr.Scientist PBG department BAU Sabour, who has been there to listen and give advice. I am deeply grateful to him for the long discussions that helped me to sort out the technical details of my work. I am also thankful to him for carefully reading and revisions of this manuscript in spite of his busy schedule and offered valuable suggestions for the betterment of this research which helped me cranked out this thesis writing in a month. I am grateful to Dr. S. P. Singh, Asst. Prof.-cum-Jr. Scientist and academic in charge of PBG deptt.BAU Sabour for his kind co-operation and encouragement throughout my post-graduation programme.

I am highly thankful to Dr. M. L. Chaudhary honorable vice-chancellor BAU, Sabour Dr. Ravi Gopal, Director Research, Dr. B. C. Saha, Dean post-graduate studies, BAU, Sabour for their administrative support and allowing me to conduct my research at ICRISAT

I feel elated and overwhelmed with rejoice to avail this opportunity to divulge my innate sense of gratitude and reverence to all my teachers, office staff, seniors and juniors of PBG department, BAU, Sabour *for extending their helpful hands in a cooperative manner. I would like to express my sincere thanks to Mr. Surendera Singh Scientific Officer Groundnut Breeding ICRISAT, and Dr. T V Murali, Research Associate, groundnut breeding ICRISAT for their keen interest, invaluable guidance, inspiration and constant encouragement extended at all time during the course of this investigation.*

*I express my utmost regards to Mr. T. Ravindra kumar, ICRISAT for his genuine and proactive support whenever I needed during my work. I also wish thanks to Mr.Yadagiri, Mr. Nawaz, Mr. Sacchanand, Mr. Rafi and Aparna who have been pretty supportive during my work.*

*I express my special thanks and heartfelt indebtedness to Dr. Abhishek Rathore IRS ICRISAT and Mr. Ravikanth Maraboina, for their priceless help, suggestions and guidance towards biometric analysis.*

*Thanks to Mr. Sadaiya and Mr. Anil for making a good atmosphere and also for their advice, help and their friendly assistance with various problems.*

*Friends always knew how to pep me up during my bad days and how to celebrate when I used to achieve something. It is difficult to express the gratitude I owe to all my friends especially to Shruti, Reshma, Amita and Swati very heartfelt thanks for their whole hearted solidarity. Special thanks owned by Prity for being there in all my sad and glad days and her moral support.*

*The financial assistance and needed resources during the study from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru is thankfully acknowledged which in fact made me to accomplish this voyage successfully.*

*Words fail to express my indebtedness to my divine parents. I am eternally grateful to my beloved, parents for their unconditional love, personal sacrifices, encouragement and giving me liberty to choose what I desired. They have been selfless in giving me the best of everything. My thanks are not adequate to repay the tender love that my sisters, Sumbul, Neha, Roman, Hera, Arman and brothers, Shayan, Faham and Sharique have filled me with. I extend my respect to my Nannammi and Nanabbu and all elders to me in the family for their support and blessings.*

*With God's grace and the timely help of many, I was able to complete the task in time and when I start to thank all, I fear, I may miss a few. So, I like to keep my sincere thanks to all in my heart rather than scribbling few words of formality.*

Ashna

***Sabour***

***20 June 2014*** ***Ashna Akbar***

# Bihar Agricultural University, Sabour

Department of Plant Breeding and Genetics

| | |
|---|---|
| Title of the thesis | : **Screening of groundnut (*Arachis hypogaea* L.) genotypes for heat tolerance.** |
| Name of the student | : Ashna Akbar |
| Registration no. | : M/PBG/84/BAC/2012-13 |
| Chairman Advisory Committee | : Sri. Shashikant, Jr. Scientist-cum-Assistant Professor |
| Degree Programme | : M.Sc. (Ag.) |
| Major Subject | : Plant Breeding and Genetics |
| Minor Subject | : Plant Pathology |
| Year | : 2014 |

## ABSTRACT

Groundnut (*Arachis hypogaea* L.), a self-pollinated legume is an important source of oil and protein. Abiotic and biotic stresses interludes in groundnut production environments. High temperature stress is one of the least well understood and is one of the major uncontrollable factors affecting plant growth, development and productivity. Recognizing the constraints imposed by high temperature to crop adaptation and productivity the present study was planned to screen groundnut genotypes tolerant to heat stress. The experiment was laid out in Alpha-lattice design in two replications. 63 genotypes were evaluated under four different environments *viz.*, E1 ($25^{th}$ Jan'13), E2 ($6^{th}$ Feb'13), E3 ($18^{th}$ Feb'13) and E4 ($2^{nd}$ Mar'13) for the conduct of the experiment. Significant differences for genotypes were found for all the traits under study. Higher magnitude of genotypic and phenotypic coefficient of variation was reported for pod yield, kernel yield, oil yield and haulm weight. High heritability along with high genetic advance as percent of mean was was exhibited by pod yield, kernel yield, hundred kernel weight oil yield, haulm weight, harvest index, pod growth rate, crop growth rate and partioning factor across the four environments. Pod yield was positively and significantly associated with days to maturity, kernel yield, oil yield, oil content, hundred kernel weight, harvest index, haulm weight, crop growth rate, pod growth rate and partitioning factor. Genotype x environment interactions were significant for six traits among which days to 75% flowering, days to maturity and sound mature kernel percentage were highly influenced by heat stress. Based on the mean pod yield for each environment, seven genotypes were identified as top yielders. ICGV 06420 was most stable across the stressed and non-stressed environments. STI was considered more reliable parameter for screening of heat tolerant groundnut genotypes under both stress and non-stress environment. Six genotypes (ICGV 07246, ICGV 07012, ICGV 06039, ICGV 06040, ICGV 03042 and ICGV 06424) were identified as heat tolerant based on STI.

# CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| $^0C$ | : | Degree Centigrade |
| $^0E$ | : | Degree East |
| $^0N$ | : | Degree North |
| % | : | Percent |
| AEA | : | Average Environment Axis |
| AEC | : | Average Environment Coordinate |
| ANOVA | : | Analysis of variance |
| CGR | : | Crop Growth Rate |
| CV | : | Coefficient of variation |
| d.f | : | Degrees of freedom |
| DF 75% | : | Days to 75% flowering |
| DM | : | Days to Maturity |
| E | : | Environment |
| FAO | : | Food and Agricultural Organization |
| g | : | Gram |
| G×E | : | Genotype × Environment |
| GAM | : | Genetic advance as percent of mean |
| GCV | : | Genotypic Coefficient of variation |
| GGE | : | Genotype and Genotype by Environment interactions |
| $h^2_{bs}$ | : | Broad-sense heritability |

| | | |
|---|---|---|
| ha | : | Hectare |
| HI | : | Harvest index |
| HKW | : | Hundred Kernel weight |
| Hrs | : | Hours |
| ICGV | : | ICRISAT Groundnut Variety |
| ICRISAT | : | International Crop Research Institute for Semi-Arid Tropics |
| Kg $ha^{-1}$ | : | Kilograms per hectare |
| KY | : | Kernel Yield |
| m ha | : | million hectare |
| OC | : | Oil content |
| OY | : | Oil yield |
| PC | : | Principal Component |
| PCV | : | Phenotypic coefficient of variation |
| PF | : | Partioning Factor |
| PGR | : | Pod Growth Rate |
| PY | : | Pod Yield |
| SI | : | Susceptibility Index |
| SMK % | : | Sound Mature Kernel Percentage |
| SP | : | Shelling percentage |
| SSI | : | Stress Susceptibility Index |
| STI | : | Stress Tolerance Index |
| Var. | : | Variety |
| Wt. | : | Weight |

# Chapter I

# INTRODUCTION

**Chapter-I**

# INTRODUCTION

Groundnut (*Arachis hypogaea* L.), a self-pollinated legume belonging to the family Leguminosae, is an important source of oil and protein rich food and feed for the people and livestock in the world. The cultivated groundnut probably originated in Bolivia at the base of the Andes (Krapovickas, 1968) extending into north Argentina (Rao, 1988). The genus *Arachis* has more than 70 species existing in nature, of which only *A. hypogaea* is cultivated (Rao, 1988). Cultivated groundnut has two subspecies, *hypogaea* and *fastigiata*, which in turn have two (var. *hypogaea* and var. *hirsuta*) and four (var. *fastigiata*, var. *vulgaris*, var. *peruviana* and var. *aequatoriana*) botanical varieties as shown in Fig.1.1. *A. hypogaea* is a segmental amphidiploid (2n=4x=40) with a basic chromosome number (x) of 10, but it behaves cytologically like a diploid. Groundnut is also known as peanut, earthnut, monkey nut, goober, pinda and manila nut.

Groundnut seed contains 44 to 56 % oil and 22-30 % protein on a dry seed basis (Savage and Keenan, 1994) and provides 12 % recommended nutrients and has 3 % dietary fiber that reduces the risk of some kinds of cancer and helps in controlling blood sugar. Among 13 essential vitamins necessary for growth, nearly half of them are present in groundnut, that include Folate, Niacin, Thiamin ($B_1$), Pyridoxine ($B_6$), Riboflavin ($B_2$) and Vitamin E. Similarly, out of 20 minerals necessary for body growth and maintenance, seven are present in groundnut *i.e.*, Copper, Phosphorous, Magnesium, Iron, Potassium, Zinc, and Calcium. Being a leguminous crop, it enriches the soil with nitrogen and is therefore valuable in cropping system.

Groundnut is grown on nearly 24.70 million ha worldwide with global production of 41.18 million tons and an average yield of 1667 Kg $ha^{-1}$ (FAO, 2012; accessed on 2014, June). China leads in production of groundnut with 40.97 % of overall world production, followed by India (14.04 %) and the United States of America (7.43 %), (FAO, 2012; accessed on 2014, June). The groundnut production in India was 5.78 million tons cultivated in an area of 4.90 million ha with an average yield 1179 Kg $ha^{-1}$

(FAO, 2012; accessed on 2014, June). In India, 70 % of the groundnut area and 75 % of the production is concentrated in the four states *viz.*, Gujarat, Andhra Pradesh, Tamil Nadu and Karnataka. Most of the irrigated area under groundnut is in Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra (http://agricoop.nic.in/statistics 2003/ chap 4b.html). In India the area under groundnut cultivation has been reduced by over 50% since 1990 (8.3 million ha) which declined to 4.90 m ha in 2012, (FAO, 2012; accessed on 2014, June). To meet the growing demand for oil and food, crop is increasingly grown outside its traditional area of adaptation and outside their natural growing seasons. There is ample scope to expand groundnut cultivation in non-traditional areas where the profitability is expected to be higher compared to traditional areas. Bihar state in particular has vast potential for area expansion under groundnut in both spring and rainy seasons. Presently, in Bihar groundnut is cultivated over an area of 1020 ha with production of 1030 tons and a productivity of 1000 Kg $ha^{-1}$ (Directorate of Economics and Statistics, Dept. of Agriculture, Govt. of Bihar, 2012; accessed on 2014, June).

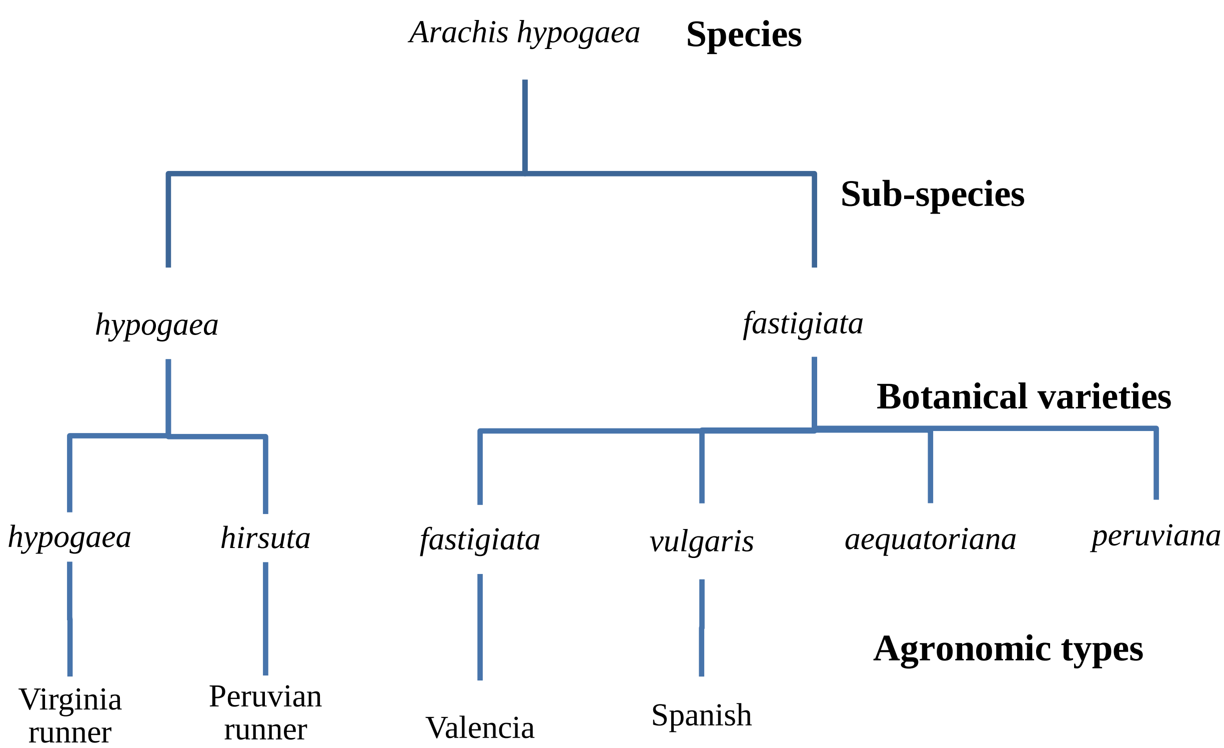


**Figure 1.1.** Classification of groundnut

About 90% of the world's groundnut production occurs in the tropical and semi-arid tropical regions, most of which are characterized by high temperature and low or erratic rainfall. Abiotic and biotic stresses interludes in groundnut production environments. High temperature stress is one of the least well understood of all the abiotic adversities that affects crops (Paulsen, 1994) and is one of the major uncontrollable factors affecting plant growth, development and productivity (Marshall, 1982; Ong, 1986). Groundnut is sensitive to temperature (Vara Prasad *et al.* 1999) with an optimum for most processes being between $27^0$C to $30^0$C (Ntare and Williams, 1998), hence crops grown in semi-arid tropics are often exposed to air and soil temperatures warmer than $35^0$C during the reproductive phase, circumstances which significantly reduce seed yields (ICRISAT, 1994; Summerfield *et al.* 1990). In groundnut, pods and kernels are underground and therefore their development is influenced by soil temperatures while air temperature plays a crucial role during flower development.

When groundnut is cultivated in spring season, tolerance to heat stress can be rewarding as the temperatures in summer can go to $35^0$C and above. It is therefore imperative to investigate and quantify the effects of periods of high temperature on the reproductive yield of groundnut, both to improve our ability to simulate and predict responses to environment and to help design screening methods for heat tolerance. Hence breeding for heat-tolerant genotypes in groundnut is therefore necessary.

Recognizing the constraints imposed by high temperature to crop adaptation and productivity the present study was planned to screen groundnut genotypes tolerant to heat stress with the following objectives:

(1) To study the variation for agronomic parameters of groundnut genotypes under heat stress.

(2) To study the association between and among agronomic and quality parameters of groundnut under different heat stress.

# Chapter II

# REVIEW OF LITERATURE

# Chapter-II

# REVIEW OF LITERATURE

Heat stress affects plant growth throughout its ontogeny, though heat-threshold level considerably at different developmental stages which may lead to a drastic reduction in economic yield. In groundnut, as well as other major staple crops such as rice (*Oryza sativa* L.; Matthews *et al*. 1995), heat tolerant genotypes will be needed to sustain production in such environments. Plant performance in an environment is a reflection of the interplay of genetic and non-genetic factors so that for many characters, the relative performance of genotype may vary in different environments (Byth, 1981). Therefore, genotype × environment (G×E) interaction arises when a given genotype is grown in environmentally diverse settings (Smith and Zobel, 1990). However, variability among groundnut genotypes for their response to climatic conditions has great significance in determining their adaptation.

Hence the literature relevant to the present study has been briefly reviewed in this chapter under the following headings-

2.1 Analysis of variance

2.2 Estimation of parameters of genetic variability

2.3 Determination of association between traits

24. Screening of heat tolerant genotypes

## 2.1 Analysis of variance

Ntare *et al*. (2001) evaluated groundnut genotypes for heat tolerance under field conditions using physiological traits and reported large variation in crop growth rate, partitioning and pod yield which indicated genetic differences among genotypes in their adaptation to high temperatures.

Nath and Alam (2002) conducted an experiment on fifteen exotic groundnut genotypes to study genetic variability for yield and yield contributing characters. They observed significant variations for characters such as days to flowering, shelling percentage, harvest index and pod yield per plant.

Vasanthi and Reddy (2002) conducted variability studies in $F_2$ generation of five groundnut crosses involving foliar disease resistant genotypes. They reported significant differences for all characters studied, except for sound mature kernels percentage. They also reported that the magnitude of PCV was greater than the GCV, indicating the influence of environment on all characters was observed.

Injeti *et al.* (2008) executed an experiment on 64 genotypes of groundnut under late *kharif* situation (39 accessions and 25 advanced breeding lines) and they reported wide range of variability for pod yield per plant, kernel yield per plant, shelling percentage, 100-kernel weight and harvest index.

Chauhan *et al*. (2009) studied heat stress effects on morpho-physiological characters of Indian mustard and reported genotypic differences were significant for all the characters except protein content and chlorophyll stability index whereas genotypes x environment interactions were significant only for 1000-seed weight, leaf area index and crop growth rate.

Dolma *et al.* (2010) studied variability parameters in 33 advanced breeding lines and genotypes of groundnut where they observed significant genotypic differences for kernel yield plant$^{-1}$, pod yield plant$^{-1}$ and test weight.

Shinde *et al.* (2010) evaluated fifty elite genotypes of groundnut and reported that analysis of variance revealed highly significant difference for all the characters studied including pod yield per plant, days to maturity, 100-kernel weight, oil content and days to 50% flowering.

Thakur *et al*. (2011) studied genetic variability of yield and its component traits in twenty five groundnut genotypes. Analysis of variance showed highly significant variation among the genotypes for days to 75% flowering, days to maturity, pod yield plot$^{-1}$, shelling percentage, and sound mature kernel percentage.

Hamidou *et al.* (2013) assessed groundnut genotypes under combined heat and drought stress and they reported wide genotypic variation for pod yield, haulm yield and harvest index.

Hamidou and Vadez (2012) evaluated 268 groundnut germplasms in four experiments over a period of two years which were exposed to moderate temperature during the rainy season while the two others were subjected to high temperature during summer. Analyses of variance (ANOVA) revealed significant differences for water treatment (Trt), genotype (G) and genotype by treatment (GxTrt) effects for pod yield (Py), haulm yield (Hy) and harvest index (HI) for both the experiments. The haulm weight during the high temperature regime was higher than that of moderate temperature seasons, whereas, HI in moderate temperature seasons (0.38 and 0.37) was slightly higher in the high temperature seasons (0.25 and 0.34).

Ezatollah *et al.* (2013) explored the effect of genotype (G) and genotype × environment interaction (GEI) on grain yield of 20 chickpea genotypes under two different rainfed and irrigated environments for four consecutive growing seasons (2008-2011). According to the results of combined analysis of variance, genotype × environment interaction was highly significant at 1% probability level, where G and GEI captured 68% of total variability. Yield data analyzed using the GGE biplot method showed that the first two principal components (PC 1 and PC 2) explained 68% of the total GGE variation.

Karimizadeh *et al*. (2013) studied GGE biplot analysis of yield stability in multi-environment trials of lentil genotypes under rainfed condition. Grain yield performances were evaluated for three years. The combined analysis of variance indicated that year and location were the most important sources affecting yield variation and these factors accounted for percentages of 50.0% and 33.3% respectively of total G+E+GE variation. The GGE biplot suggested the existence of three lentil mega-environments. The GGE biplot graphically displayed the interrelationships between test locations as well as genotypes and also facilitated visual comparisons.

Padmaja *et al*. (2013) studied genetic variability in $BC_1F_2$ population of (JL 24 x ICG 11337) x JL 24, groundnut genotypes and observed significant difference for the characters such as days to maturity, pod yield plant$^{-1}$, 100-kernel weight, shelling percentage and haulm yield plant$^{-1}$.

Ashutosh and Prashant (2014) evaluated 30 genotypes of groundnut for yield and quality traits during *kharif* season. Analysis of variance showed that there were significant differences for days to maturity, pod yield, sound mature kernel, 100-kernel weight, shelling percentage and kernel yield, suggesting the existence of high genetic variability among the genotypes.

GGE biplot is a data visualization tool, which graphically displays a genotype × environment (G×E) interaction in a two way table (Yan, 2000). GGE biplot is an effective tool for mega-environment analysis whereby specific genotype can be recommended to specific mega-environment, genotype evaluation and environmental evaluation (the power to discriminate among genotypes in target environments). GGE biplot analysis is increasingly being used in genotype × environment interaction data analysis in agriculture (Butron, 2004; Crossa *et al*., 2002; Samonte *et al*., 2005; Dehghani *et al*., 2006 and Kaya *et al*., 2006).

## 2.2 Estimation of parameters of genetic variability

Mahalakshmi *et al.* (2005) evaluated 57 groundnut genotypes for genetic parameters. They reported high heritability estimates combined with high genetic advance were observed for shelling percentage and 100-kernel weight indicating that these characters are governed by additive genes.

Gomes and Lopes (2005) estimated genetic parameters of agronomical traits of groundnut cultivars (Tatu, BR 1, L.7 Vermelha, CNPA 75 AM, CNPA 76 AM, CNPA 68 AM, L.8.14.12, L.8.14.01 and L.7 Bege) and they highest estimates of the coefficient of genotypic variation were observed for weight of 100 seeds, grain yield, and pod yield, indicating a greater possibility of achieving superior genotypes in the selection for these traits.

John *et al.* (2007) reported that 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 in $F_2$ population of six single crosses and also significant differences were observed for the same. They concluded that role of additive gene action were significant in the inheritance of these traits.

Injeti *et al.* (2008) executed an experiment to evaluate 64 groundnut (*Arachis hypogaea* L.) genotypes for quantitative characters and they reported moderate estimates of PCV and GCV for pod yield per plant, kernel yield per plant, shelling percentage, 100-kernel weight and harvest index. High heritability coupled with high genetic advance was noticed for all the characters studied except for days to 50% flowering, days to maturity, sound mature kernel per cent and oil content.

Khote *et al.* (2009) performed variability studies in 30 exotic groundnut genotypes and observed higher phenotypic and genotypic coefficients of variation for kernel yield per plant, fodder yield per plant, harvest index and pod yield per plant. They also reported high heritability for days to flowering, and dry matter per plant while highest genetic advance as percentage of mean was recorded for kernel yield per plant, harvest index and pod yield per plant.

Shinde *et al.* (2010) studied genetic variability in 50 elite genotypes of Virginia bunch groundnut and found higher genotypic coefficients of variation and phenotypic coefficients of variation estimates for pod yield per plant and biological yield per plant. They also found moderate GCV and PCV for oil content, hundred kernel weight and low for days to 50% flowering and days to maturity. High heritability associated with high genetic advance for pod yield per plant and biological yield per plant while days to maturity showed moderate heritability coupled with low genetic advance.

Meta and Monpara (2010) conducted an experiment using 50 elite genotypes of groundnut and reported high magnitude of genotypic coefficient of variation and phenotypic coefficient of variation for kernel yield per plant and pod yield per plant which indicated large extent of genetic variability. High heritability accompanied with high genetic advance was observed for 100-pod weight whereas; moderate heritability associated with high genetic advance and high genotypic coefficient of variation for pods per plant and kernel yield per plant.

Hiremath *et al.* (2011) induced genetic variability in groundnut for yield and 12 different component quantitative traits in the mutants derived from two Spanish Bunch groundnut cultivars, *viz*. TPG-41 and GPBD-4. He observed, high heritability estimates for 100-kernel weight, shelling per cent, sound matured kernel per cent, protein content, oil content, oil yield, pod yield and kernel yield in both the mutant groups. Also the estimated genetic advance was high for the traits like 100-kernel weight, oil yield, pod yield and kernel yield in both the mutant groups.

John *et al.* (2012) reviewed on genetic parameters for morphological, physiological and yield attributes related to moisture stress tolerance in groundnut. They concluded that genetic coefficient of variation is a useful measure of the magnitude of genetic variance present in the population. Also high heritability combined with high GAM was observed for shelling percentage, sound mature kernel weight and pod yield per plant. High heritability coupled with moderate genetic advance as percent of mean (GAM) was recorded for protein and sound mature kernel weight. Further, Oil showed high heritability with low GAM. High GCV, PCV and heritability and genetic advance were noticed for harvest index and its component traits viz., pod yield per plant, number of branches per plant and sound mature kernel percentage.

Madhura and Kenchanagoudar (2012) reported high heritability estimates for oil content, test weight and pod yield per plant in all four botanical types, but test weight was moderate in case of Virginia bunch. Moderate heritability was noticed for shelling per cent, sound mature kernels, and low for days to 50 percent flowering and days to maturity. High genetic advance was observed for test weight pod yield per plant, moderate for shelling per cent, sound mature kernel and oil content and for days 50 per cent flowering and days to maturity it was low.

Noubissie *et al.* (2012) performed heritability studies on protein and oil content in groundnut genotypes where he found that heritability across genotypes ranged from 0.13 to 0.78 for oil content and 0.37 to 0.86 for protein content while moderate heritability coupled with low genetic gain as per cent of mean was recorded for oil concentration ($h^2$ = 0.52; GA = 3.70 %).

Narasimhulu *et al.* (2012) conducted variability studies on 18 groundnut genotypes and they reported that the values for phenotypic coefficient of variation was generally higher than the respective genotypic coefficient of variation for all the characters except for some cases where the two values differed slightly. The lowest values of GCV and PCV were shown by SMK percent and shelling percentage and the highest values were shown by pod yield per plant, kernel yield per plant and test weight. They also observed high heritability and high genetic advance expressed as percent of mean for pod yield per plant, kernel yield per plant, test weight and shelling percentage.

Makinde and Ariyo (2013) performed experiments on 22 groundnut genotypes at two different locations Lagos and Abeokuta to determine genetic divergence among the genotypes. High heritability estimates were recorded for days to 50% flowering in both environments.

Thirumala *et al*. (2014) conducted variability studies on 50 groundnut genotypes. Analysis of variance revealed the existence of significant differences among genotypes for all characters studied. The magnitude of PCV and GCV was moderate to high for kernel yield, dry pod yield, hundred kernel weight, and dry haulm yield. Also high heritability coupled with high genetic advance as per cent of mean was observed for hundred kernel weight, dry pod yield, kernel yield, indicating the role of additive gene in expressing these traits.

## 2.3 Determination of association between traits

Venkataravana *et al.* (2000) conducted correlation studies for pod yield and 14 component characters in 144 germplasm accessions of groundnut. They reported positive and significant association of pod yield with shelling per cent, haulm yield, 100-kernel weight, sound mature kernel percentage, harvest index, kernel yield, and oil yield. The genotypic correlation coefficients were observed to be relatively of higher magnitude than the corresponding phenotypic correlation coefficient, indicating strong inherent association between the characters.

Roy *et al.* (2003) evaluated groundnut genotypes and reported days to 75% flowering, 100-kernel weight, and shelling percentage were significantly and positively correlated with yield per plot.

Frimpong (2004) worked on 23 accessions of groundnut collected from four ecological zones and found that significant positive relationship existed among , pod yield, grain yield, haulm yield, crop growth rate (CGR), pod growth rate (PGR), partition coefficient (ρ) and harvest index (HI). Also reported that CGR, PGR, HI and partition coefficient were the best or had the most discriminatory power for characterization and selection.

Golakia *et al*. (2005) studied associations in Virginia runner and Spanish bunch groundnut genotypes and found that pod yield per plant in both habit groups was significantly and positively correlated harvest index, indicating that simultaneous selection for these characters might bring an improvement in pod yield.

Gopinath Jatti *et al.* (2007) evaluated 100 accessions of groundnut and they reported that the oil yield possessed significant and positive association with pod yield per plant, shelling percentage, kernel yield per plant, haulm yield per plant, harvest index and oil content.

Sumathi and Muralidharan (2007) worked out genotypic and phenotypic correlation in 48 diverse genotypes of groundnut and reported that pod yield per plant had significant positive association with kernel yield, sound mature kernel weight and 100-seed weight, while shelling percentage and oil content had negative association with pod yield per plant at both the genotypic and phenotypic levels. They also reported that inter correlations of kernel yield with sound mature kernel weight, 100-seed weight were also positive and significant.

Korat *et al*. (2010) reported that 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. Phenotypic interrelationship between days to maturity and pod yield per plant was found to be negative and significant.

Sonone *et al*. (2010) worked out character association was for 40 genotypes of groundnut and revealed positive correlation between dry pod yield per plant and days to first flowering, days to 50 per cent flowering, days to maturity and 100 seed weight. While, negative correlation between dry pod yield and oil content was observed.

Meta and Monpara (2010) conducted correlation studies in summer groundnut and reported that pod yield per plant was strongly and positively associated with kernel yield per plant, shelling percentage and oil content while it was significantly negative with days to 50% flowering and days to maturity. They also reported positive and significant correlation between shelling percentage, hundred kernel weight and sound mature kernel indicated that an increase in shelling percentage would be responsible for higher SMK % and 100 kernel weights.

Vekariya *et al*. (2011) evaluated 50 diverse groundnut genotypes and they concluded that pod yield per plant had highly significant and positive correlations at phenotypic levels with 100-pod weight, 100-kernel weight, biological yield per plant, kernel yield per plant and harvest index.

Sudheer *et al.* (2011) conducted correlation studies to know the effect of sowing time and row spacing on growth of groundnut crop. They reported that the dry matter partitioned into pods at 90 DAS and at harvest had significant and positive correlation to final pod and haulm yields. However, the dry matter production and partitioning at 30 DAS did not show significant relation with pod and haulm yields.

Jogloy *et al.* (2011) estimated correlation coefficients for days to maturity and pod yield in large seeded groundnut constituting 200 breeding lines in the $F_6$ generation of ten peanut crosses. The magnitude of genotypic and phenotypic correlation coefficient showed that pod yield was significantly and positively associated with harvest index but was conversely associated with maturity.

Zaman *et al.* (2011) conducted an experiment on 34 groundnut genotypes for estimation of genetic parameters and correlation coefficients. They reported that kernel yield per plant and shelling percentage showed highly positive and significant association with days to 50% flowering.

Pradhan and Patra (2011) evaluated 460 genotypes of groundnut germplasm in four different seasons (*rabi* and post *rabi*). They concluded that shelling percentage was negatively correlated with hundred kernel weight.

Madhura and Kenchanagoudar (2012) conducted correlation studies on 182 groundnut genotypes and they reported that pod yield per plant had high positive correlation with test weight, oil content, shelling percent and sound mature kernels.

Babariya and Dobariya (2012) estimated correlation for pod yield per plant and its components by using 100 genotypes of Spanish bunch of groundnut. They concluded that pod yield per plant was significantly and positively correlated with days to maturity, kernel yield per plant, 100-kernel weight, biological yield per plant and harvest index.

Shoba *et al.* (2012) studied correlation coefficients among nine yield and yield attributing characters towards kernel yield in $F_3$ generation for three crosses of groundnut. From association studies they reported that kernel yield was significant and positively correlated with pod yield per plant, shelling percentage and hundred kernel weight for all the crosses.

Noubissie *et al.* (2012) investigated varietal differences for protein and oil contents of kernels in 12 promising groundnut (*Arachis hypogaea* L.) genotypes. They concluded that oil content was positively correlated with kernel weight (r = 0.67).

Sadeghi and Noorhosseini (2012) studied 23 groundnut genotypes to investigate the relationship among agronomic traits under drought stress and irrigated condition. The correlation coefficients in both conditions revealed that 100-seed weight and biomass had high positive significant correlation with seed yield.

Nandini and Savithramma (2012) while studying on 196 $F_8$ recombinant inbred line population developed by crossing NRCG 12568 and NRCG 12326 through single seed descent method and they reported strong positive phenotypic and genotypic correlation coefficients between pod yield per plant and kernel yield per plant and sound mature kernel percentage indicating that improvement in these characters will lead to improvement in yield whereas, significant negative association was observed for pod yield per plant with days to 50% flowering and shelling percentage.

Hamidou *et al.* (2013) evaluated two hundred and sixty-eight groundnut genotypes in four trials under both intermittent drought and fully irrigated conditions to study the combined effects of heat and drought on physiological traits, yield and its attributes. Correlation analysis between pod weight and traits measured during plant growth showed that the partition rate (the proportion of dry matter partitioned into pods) contributed with considerable extent in heat and drought tolerance and could be a reliable selection criterion for groundnut breeding programme.

## 2.4 Screening of heat tolerant genotypes

The optimum diurnal temperatures for vegetative growth ranged from 25/25$^0$C (Wood, 1968) to 30/26$^0$C (Cox, 1979) or 30 to 35$^0$C (Fortainer, 1957; Prasad *et al*., 2000a). In contrast, reproductive processes including peg formation, pod growth and development require somewhat cooler temperatures usually ranging from 23$^0$C (Cox, 1979) to 28$^0$C (Bolhius and de Groot, 1959), in common with other legumes such as common bean (*Phaseolus vulgaris* L.) (Gross and Kigel, 1994) and cowpea (*Vigna unguiculata* L.) (Walp) (Hall 1992) and cereals such as rice (Yoshida *et al*., 1981).

Wheeler *et al.* (1997) conducted experiments in groundnut to examine the dry matter partitioning upon exposure to high temperature and also to test whether or not differences in the tolerance of groundnut genotypes to high temperature episodes are due to genotypic differences in the rates of dry matter partitioning to yield. They concluded that genotypic differences in the response of groundnut yield to episodes of high temperature stress were due to difference in the timing of seed filling rather than to genotypic differences in the rate of dry matter partitioning to fruits.

Craufurd *et al*. (2000) studied the tolerance of groundnut genotypes to high temperature during flowering in eight groundnut genotypes varying in heat tolerance were grown in controlled environments and exposed to either high (40/28$^0$C) or near-optimum (30/24$^0$C) temperature from 32 days after sowing (DAS) to maturity. The results suggested that the most sensitive stage of development to high temperature in groundnut occurred around three days before opening of flowers.

Prasad *et al.* (2000 b) worked on the effects of high air and soil temperature on dry matter production and pod yield in groundnut under two experiments. They observed that exposure to high air and/or high soil temperature significantly reduced total dry matter production, partitioning of dry matter to pods, and pod yields in both the cultivars. High air temperature had no significant effect on total flower production but significantly reduced the proportion of flowers setting pegs (fruit-set) and hence fruit numbers. In contrast, high soil temperature significantly reduced flower production, the proportion of pegs forming pods and 100 seed weight and concluded that the effects of high air and soil temperature were mostly additive and without interaction.

Ntare *et al*. (2001) evaluated groundnut genotypes for heat tolerance under field conditions using physiological traits identified in a yield model (crop growth rate (C), reproductive duration (Dr) and partitioning (p). In his study 625 diverse genotypes were initially screened under irrigated conditions during the hottest months (February to May) and concluded that estimates of partitioning would be a more reliable selection criterion for identification of genotypes tolerant to heat than yield. They also reported that pod yield of groundnut genotypes declined by more than 50% when flowering and pod formation occurred at average temperature of 40$^0$C.

Kaya *et al.* (2002) reported that genotypes with larger PCA1 and lower PCA2 scores gave high yields (stable genotypes), and genotypes with lower PCA1 and larger PCA2 scores had low yields (unstable genotypes).

Craufurd *et al*. (2003) studied heat tolerance in groundnut to assess the tolerance to high air temperature during two key stages *viz*. microsporogenesis (3-6 days before flowering, DBF) and flowering. In the first experiment, 12 genotypes were exposed to short (3-6 days) episodes of high ($38^0$C) day air temperature at 6 DBF and at flowering. In the second experiment, 22 genotypes were exposed to $40^0$C day air temperature for one day at 6 DBF, 3 DBF or at flowering. Cellular membrane thermo stability (relative injury, RI) was also measured in these 22 genotypes and identified genotypes (796, 55-437, ICG 1236, ICGV 86021, ICGV 87281 and ICGV 92121) as heat tolerant based on their performance in all tests. They concluded that groundnut genotypes can be easily screened for reproductive tolerance to high air and soil temperature and also reported that several sources of heat tolerance are available in groundnut germplasm.

Porch (2006) applied stress indices *viz.*, geometric mean (GM), Stress Tolerance Index (STI) and Stress Susceptibility Index (SSI) to evaluate the genotypic performance under stress and low-stress conditions and of Common Bean. The results indicated the possibility to identify superior genotypes for heat tolerance based on their stress indices. Heat tolerance indices, STI and GM, although correlated, were found to be effective stress indices for the selection of genotypes with good yield potential under stress and low-stress conditions.

Khattak *et al*. (2006) conducted studies on heat tolerance in mungbean (*Vigna radiata* L. wilczek) where 14 commercial mungbean varieties and 24 advanced genotypes developed through hybridization were evaluated for maximum flowers retention capability under high temperature (above 40°C). They reported that almost all of the commercial varieties and advanced genotypes showed moderate tolerance to flowers shedding under high temperature except NM 92 which showed susceptibility to flowers shedding under high temperature. The mutants derived from NM92 and recombinants selected from the three crosses showed moderate tolerance to flowers’ shedding under high temperature.

Chauhan *et al.* (2009) studied heat stress effects on morpho-physiological characters of Indian mustard (*Brassica juncea* L.) to analyze the effects of high temperature on seed yield, its components and growth parameters and also characterize genotypes for high temperature tolerance to identify suitable donors for utilization in the breeding program. They identified four terminal high temperature tolerant genotypes as indicated by their low heat susceptibility index for seed yield were BPR 538-10 (0.33), NRCDR 2 (0.44), RH 0216 (0.57) and NPJ 112 (0.58).

Singh *et al*. (2011) studied the effect of high temperature on yield attributing traits in bread wheat. Experiment was conducted on a set of 10 diverse genotypes, their 45 $F_{1s}$ and $F_{2s}$ for identification of high temperature stress genotype. The experiment was conducted under normal and late sown condition and results showed there were highly significant differences among all the characters and genotypes in all the sowing environments indicating the influence of sowing condition on genotypes and traits. Also concluded that heat stress intensity indicated grain yield pant$^{-1}$, biological yield plant$^{-1}$ and grain yield spike$^{-1}$ suffered adversely under late sown conditions.

Khodarahmpour *et al*. (2011) determined heat stress tolerance indices for 15 maize (*Zea mays* L.) hybrids and inbred lines. Five stress tolerance indices, including mean productivity (MP), stress tolerance (TOL), stress susceptibility (SSI), stress tolerance index (STI) and geometric mean productivity (GMP) were used. Data analysis revealed that the SSI, STI and GMP indices were the more accurate criteria for selection of heat tolerant and high yielding genotypes. GMP showed high positive correlations with grain yield in both stressed and non-stressed environments and exhibited efficient in inbred line selection.

Hamidou *et al*. (2013) studied the combined impact of heat and drought stress on groundnut yield. 268 groundnut genotypes were evaluated in four trials under both intermittent drought and fully irrigated conditions. Out of four, two trials were exposed to moderate temperature while the other two to high temperature. Strong effects of water treatment (Trt), genotype (G) and genotype-by-treatment (GxTrt) interaction were observed for pod yield (Py), haulm yield (Hy) and harvest index (HI). The decrease in pod yield caused by drought stress was 72 % at high temperature and 55 % at moderate temperature. They also observed considerable decrease in haulm yield upon exposure to high temperatures.

# Chapter III

# MATERIALS & METHODS

## Chapter-III

# MATERIALS AND METHODS

The present study was planned to screen groundnut genotypes tolerant to heat stress and the chapter includes the materials used and methods employed during the experiment under following heads-

### 3.1 Experimental site:

The present investigation was carried out during spring season 2013 at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Patancheru, Hyderabad, which is geographically located at17.53$^{0}$ N latitude and 78.27$^{0}$ E longitudes at an altitude of 545.0 meters above Mean Sea Level. The experiment was conducted on precision field with leveled topography and good drainage system.

### 3.2 Climate and weather conditions:

Hyderabad falls under semi-arid region where, annual mean temperature is 26$^{0}$C; with hot dry summers (March–June) and heavy rain from the south-west monsoon between June and September. Temperatures during morning and evening hours are generally cooler because of the city's moderate elevation. The maximum and minimum temperatures during crop growing period ranged from 23.6 to 43.2$^{0}$C and 11 to 28.2$^{0}$C respectively. May was recorded as the hottest month with an average maximum temperature of 40.2$^{o}$C. Towards the end of cropping season weather was mostly cloudy with June being the cloudiest month and precipitation was observed mostly in July (https://weatherspark.com/history/33947/2013/Hyderabad).

The weather data during the experimental period was obtained from the meteorological observatory of the institute. The weekly meteorological data regarding distribution of rainfall, evaporation, maximum and minimum temperature, relative humidity and bright sunshine hours are presented in Table 3.1.

**Table 3.1.** Weather Data recorded at ICRISAT Patancheru, during Jan-July, 2013.

| Year | Std Week | Rain (mm) | Evaporation (mm) | Max Temp (°C) | Min Temp (°C) | Relative Humidity1 at 07:17 (%) | Relative Humidity2 at 14:17 (%) | Bright Sunshine (Hrs) |
|---|---|---|---|---|---|---|---|---|
| 1st -7th Jan | 1 | 0 | 27 | 32.3 | 18.0 | 93.0 | 45.4 | 7.4 |
| 8th -14th Jan | 2 | 0 | 29.5 | 30.0 | 12.6 | 88.1 | 36.4 | 8.5 |
| 15th -21st Jan | 3 | 0 | 33.2 | 30.7 | 13.1 | 94.1 | 31.1 | 9.7 |
| 22nd - 28th Jan | 4 | 0 | 33.5 | 29.9 | 17.3 | 91.9 | 40.1 | 7.9 |
| 29thjan -4thFeb. | 5 | 1 | 33.3 | 29.2 | 15.3 | 90.4 | 38.4 | 7 |
| 5th - 11th Feb. | 6 | 3 | 41.9 | 30.8 | 18 | 89.1 | 36.9 | 8.3 |
| 12th - 18th Feb. | 7 | 7 | 45.2 | 30.9 | 17.1 | 79 | 34.7 | 8.7 |
| 19th - 25th Feb. | 8 | 0 | 40.2 | 31.7 | 15.4 | 89.1 | 32.4 | 9.5 |
| 26thFeb-4thmarch | 9 | 0 | 54.7 | 33.7 | 14.1 | 76.4 | 22 | 10.1 |
| 5th -11th March | 10 | 0 | 54.7 | 34.3 | 17 | 81.1 | 24.4 | 9.7 |
| 12th-18th March | 11 | 0 | 67.1 | 35.3 | 19.1 | 65.7 | 30 | 7.5 |
| 19th -25th March | 12 | 0 | 62.4 | 36.4 | 20.8 | 72.3 | 27 | 7.6 |
| 26th March-1st April | 13 | 0 | 66.7 | 37.9 | 23.1 | 69.6 | 33.7 | 9.5 |
| 2nd - 8th April | 14 | 60 | 64.7 | 36.9 | 21.6 | 82 | 44.6 | 9 |
| 9th -15th April | 15 | 0 | 69.1 | 37.9 | 23.2 | 76.9 | 28.6 | 9.4 |
| 16th - 22nd April | 16 | 0 | 73.4 | 37.7 | 21.5 | 62.3 | 27.1 | 10.2 |
| 23rd - 29th April | 17 | 0 | 52 | 37 | 23.3 | 72.9 | 34.3 | 8 |
| 30th april-6th May | 18 | 0 | 77.2 | 40.4 | 25 | 59.1 | 24.1 | 10 |
| 7th - 13th May | 19 | 0 | 83.9 | 40.6 | 26.3 | 63.4 | 28.3 | 9.2 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 14th - 20th May | 20 | 0 | 75.9 | 40.2 | 26.4 | 62 | 32.6 | 6.7 |
| 21st - 27th May | 21 | 0 | 101.6 | 41.3 | 26.9 | 51.7 | 26.4 | 9.3 |
| 28th May-3 rd June | 22 | 5 | 60.1 | 37 | 23.5 | 74.1 | 39.4 | 6.1 |
| 4th-10th June | 23 | 7 | 50.1 | 35 | 23.1 | 80.9 | 44.7 | 5.4 |
| 11th - 17th June | 24 | 40 | 32.8 | 30.2 | 21.8 | 85 | 62.4 | 1.2 |
| 18th - 24th June | 25 | 24 | 49.1 | 33.4 | 22.5 | 80.6 | 50.6 | 5 |
| 25th June – 1st July | 26 | 29 | 39.7 | 30.8 | 21.9 | 85.6 | 62.7 | 5.2 |
| 2nd - 8th July | 27 | 12 | 35.5 | 31.3 | 21.7 | 86.4 | 59 | 3.8 |
| 9th -15th July | 28 | 97 | 23.8 | 27.9 | 21.3 | 90.6 | 75.3 | 2.5 |
| 16th - 22nd July | 29 | 52.4 | 17.5 | 26.6 | 21 | 91.3 | 78 | 1.2 |
| 23rd -29th July | 30 | 57 | 25.2 | 27.85 | 21.44 | 88.28 | 73.7 | 2.39 |

## 3.3 Experimental details:

The experiment was laid out in Alpha lattice design with block size of seven plots and nine columns in two replications. The genotypes were evaluated under four different environments (E1, E2, E3, and E4) created by four sowing dates *viz*., (1) 25th January (2) 6th February (3) 18th Feb and (4) 2nd March, 2013. Each genotype was sown in four rows of 2m length with a spacing of 30cm between rows and 10cm between plants. Sowing was done on red precision soils at ICRISAT in broad-bed and furrow system and recommended package of practices were adopted for optimum crop growth and protective measures were applied to control insects and diseases.

Sixty-three genotypes were taken for the conduct of the experiment. Based on previous studies five heat susceptible (Chico, ICGS 11, J 11, GPBD4 and K 6) and five heat tolerant (ICGV 99001, ICGV 01232, ICGV 02266, ICGV 02271and 55-437) genotypes were included as checks in the present study. The genotypes include advanced breeding lines, released cultivars and germplasm lines. Due to poor viability of seeds ICGV 91112 was not considered for the observations. The pedigree of the test material is given in Table 3.2.

**Table 3.2.** Pedigree of the genotypes used in the experiment.

| Genotypes | Pedigree |
|---|---|
| ICGV 00298 | [{ (Shulamit x Chico) x PI 337409} x V75] x {(MH 2 x NC Ac 2731) x Chico}] |
| ICGV 00308 | [(Ah 2105 x Chico) x {JL 24 x (Dh. 3-20 x Robut 33-1) F8} x {(FSB 7-2 x G 201) x (F 334 A-B-14 x NC Ac 2214)}] |
| ICGV 00350 | {(FESR 13 x Chico) x (CS 9 x ICGS 5)} |
| ICGV 00351 | {(FESR 13x Chico) x (CS 9 x ICGS 5)} |
| ICGV 03042 | [{(F 334 A-B-14 x NC Ac 2214) x ICG 2241) x (ICGMS 42 x Kadiri 3)} x {(ICGMS 28 x (F 334 A-B-14 x NC Ac 2214) x (LI x ICGS 44)}] |
| ICGV 03057 | [{(F 334 A-B-14 x NC Ac 2214) x ICG 2241) x (ICGMS 42 x Kadiri 3)} x {(FESR 13x Chico) x (CS 9 x ICGS 5)}] |
| ICGV 03109 | [{(F 334 A-B-14 x NC Ac 2214) x ICG 2241) x (ICGMS 42 x Kadiri 3)} x {(FESR 13x Chico) x (CS 9 x ICGS 5)} |
| ICGV 05032 | [{(CS 39 x (Dh. 3-20 x Robut 33-1)} x {(FSB 7-2 x G 201) x (Ah 65 x Robut 33-1} x {ICGS 30 x (TMV 10 x Chico)} x CS 29/1-B2-B1}] |
| ICGV 05155 | [{(F 334 A-B-14 x NC Ac 2214) x ICG 2241) x (ICGMS 42 x Kadiri 3)} x {(FESR 13x Chico) x (CS 9 x ICGS 5)}] |
| ICGV 07456 | {(TMV 10 x Chico) x CSMG 84-1} |
| ICGV 06039 | [{(ICGS 35 x NC Ac 1705) x CS 16-B2-B2} x {(NC Ac 343 x (Dh. 3-20 x Robut 33-1)} x {(NC Ac 343 x (Dh. 3-20 x Robut 33-1)}] |
| ICGV 06040 | [{(ICGS 35 x NC Ac 1705) x CS 16-B2-B2} x {(NC Ac 343 x (Dh. 3-20 x Robut 33-1)} x {(NC Ac 343 x (Dh. 3-20 x Robut 33-1)}] |
| ICGV 06099 | [{(ICGS 35 x NC Ac 1705) x CS 16-B2-B2} x {(NC Ac 343 x (Dh. 3-20 x Robut 33-1)} x {(NC Ac 343 x (Dh. 3-20 x Robut 33-1)}] |
| ICGV 06175 | [{((ICGS 44 x TG 2E) x CS 29/1-B2-B1) x (JL 24 x CG 2187)} x {(ICGS 44 x TG 2E) x CS 29/1-B2-B1)} x {ICGS 30 x (TMV 10 x Chico)}] |
| ICGV 06420 | [{(CS 9 x ICGS 5)} x {(FESR 13 x Chico) X (CS 9 x ICGS 5)}] |
| ICGV 06424 | [{(F 334 A-B-14 x NC Ac 2214) x ICG 2241) x (ICGMS 42 x Kadiri 3)} x {(FESR 13x Chico) X (CS 9 x ICGS 5)} x {(Shulamit x Chico) x PI 337409}] |

| | |
|---|---|
| ICGV 07012 | [{(FSB-7-2 x NC Ac 2232) x (B4 x(ICGS 13 x ICGS 44)} x {(JL 24 x (TMV 10 x Chico) x JL 24} x {(FSB-7-2 x NC Ac 2232) x (B4 x (ICGS 13 x ICGS 44)} x {(JL 24 x ICG (FDRS) 4) x JL 24}] |
| ICGV 07013 | [{(FSB-7-2 x NC Ac 2232) x (B4 x (ICGS 13 x ICGS 44)} x {(JL 24 x (TMV 10 x Chico) x JL 24} x {(FSB-7-2 x NC Ac 2232) x (B4 x (ICGS 13 x ICGS 44)} x {(JL 24 x ICG (FDRS) 4) x JL 24}] |
| ICGV 07038 | [JL 24 X ({(J 11 x CS 52) x (ICGS 44 x TG 2E) x(ICGS 44 x TG 2E)}] |
| ICGV 05200 | [{(ICGS 30 x (CS 9 x ICGS 5)  x USA 40) x LY) x U4-7-5} x {(F 334 A-B-14 x NC Ac 2214) x (NC 17 x NC Ac 343) x JL 24}] |
| ICGV 07148 | [{(Robut 33-1 x L.No. 95-A) x (Manfredi x M 13) x Kadiri 134)} x {(J 11 x (Faizpur 1-5 x UF 71513-1)}] |
| ICGV 07211 | [{(ICGV 98191)} x {(M 13 x NC Ac 2214) x (F 334 A-B-14 x NC Ac 2214) x (*A. hypogaea* x *A. cardenasii*) CS 9)}] |
| ICGV 07213 | [{((ICGS 30 x (TMV 10 x Chico) F6) x  (Shulamit x Chico) x PI 337409) x (CS 29/1-B2-B1x (ICGS 44 x TG 2E))}] x {((J 11 x CS 52) x (ICGS 44 x TG 2E)) x (ICGV 93427))}] |
| ICGV 07217 | [{(JL 24 x (Dh. 3-20 x Robut 33-1) x ICG(FDRS) 10) x TAG 24)} x {(75-21 x (ICG 6327 x JL 24 x (Chico x EC 76445)}] |
| ICGV 07246 | [{(ICGS 35 x NC Ac 1705) x (CS 16-B2-B2) x (NC Ac 343 x (Dh. 3-20 x Robut 33-1) SIL 4 x (ICGS 44 x (TMV 10 x Chico)}] |
| ICGV 07268 | {(TMV 10 x Chico)  x TCGS 647} |
| ICGV 07273 | [{(ICGS 35 x NC Ac 1705) x (CS 16-B2-B2) x (NC Ac 343 x(Dh. 3-20 x Robut 33-1)} x {(CS 9 x ICGS 5)}] |
| ICGV 07356 | {ICGS 44 x (TMV 10 x Chico )} |
| ICGV 86325 | (ICGS 20 x G 201) |
| ICGV 87128 (ICGS 44) | Selection from Robut 33-1 |
| ICGV 87141 | (TMV 10 x Chico) |
| ICGV 87846 | (CS 9 x ICGS 5) |

| | |
|---|---|
| ICGV 89280 | {(Manfredi 68 x NC Ac 343) x(Ah 65 x NC Ac 17090)} |
| ICGV 91112 | (RSHY 5 x DH 8) |
| ICGV 91114 | {(72-R x Chico) x (ICGS 36 x NC Ac 1705)} |
| ICGV 92035 | {(F 334 A-B-14 x NC Ac 2214) x (ICG 2241)} |
| ICGV 92195 | {(72-R x Chico) x (Ah 65 x NC Ac 17090)} |
| ICGV 93468 | [(ICGS 44 x TG 2E) x {ICGS 30 x (TMV 10 x Chico)}] |
| ICGV 95390 | {(Dh. 3-20 x Robut 33-1) x (Robut 33-1 x PI 414331)} |
| ICGV 96346 | (TG 2E x ICGMS 2) |
| ICGV 97182 | {(Dh. 3-20 x Robut 33-1) x (Robut 33-1 x PI 414331)} |
| ICGV 97183 | {(Dh. 3-20 x Robut 33-1) x (Robut 33-1 x NC Ac 316)} |
| ICGV 98294 | [{(72-R x Chico) x (Ah 65 x NC Ac 17090)} x {(CS 29/1-B2-B1) x (ICGS 44 x TG 2E)}] |
| TAG 24 | (TMS 1x TGE 1) |
| TCGS 1043 | (VRI 2 x TCGP 6) |
| TG 37 | (TG 25 x TG 26) |
| TMV 2 | Mass selection from Gudhiantham Bunch |
| TPG 41 | (TG 25 x TG 26) |
| VRI 6 | (ALR2 x VG9513) |
| Abhaya | (K 134 x TAG 24) |
| Chico | Collected from United States of America (USA) |
| GJG 31 | (GG 2 x PBS 21065) |
| ICGS 11 | Selection from Robut 33-1 |
| ICGV 99001 | (Robut X Villosa) |
| ICGV 01232 | [{91176 x (Florigiant x Spancross)-der) x Chico} x {(91176)} x {JL 24 x (SM 5 x NC Ac 17500) F4}] |
| ICGV 02266 | [{(Dh. 3-20 x Robut 33-1) x (Robut 33-1 x CS 9)} X {((ICGS 30 x (Ah 65 x NC Ac 17090)) x (JL 24 x ICG 5728)}] |
| ICGV 02271 | {(TAG 24 x (F 334 A-B-14 x NC Ac 2214)} |

| | |
|---|---|
| GG 20 | (GAUG 10 x Robut 33-1) |
| J 11 | (Ah 4218 x AL 4354) |
| GPBD 4 | {KRG-1 x (A. hypogaea x A. cardenasii)} |
| JL 24 | Selection from EC 94943 |
| K 6 | (JL24 x Ah 316/s) |
| 55-437 | Selection from a population of South American origin in Senegal (West Africa) |

### 3.4 Observations to be recorded:

#### 3.4.1 Days to 50 percent seedling emergence

Number of days counted from the date of sowing (irrigation) to the date when 50 percent of the seedling emergence was observed in the plot.

#### 3.4.2 Days to 75 percent flowering

Number of days counted from the date of sowing (irrigation) to the date when 75 percent of flowering was observed in the plot.

#### 3.4.3 Days to maturity

This was determined by examining the foliage, internal pericarp colour, and colour of pods. The pods of the groundnut from several plants in the field were picked randomly and cracked or cut open to determine maturity. The percentage of pods with tan to brown color inside the hull and pink to dark pink seed coats was worked out. Harvesting is recommended when mature pods range from 75 to 85 %, depending on the variety, presence of dormancy, and environmental factors.

#### 3.4.4 Pod yield per plot (g)

From the plot, mature pods were stripped, dried, cleaned and then pod yield was recorded in grams which were further converted to Kg ha$^{-1}$.

#### 3.4.5 Shelling percentage

As given in the equation below, shelling percentage is measured by shelling known weight of pods and weighing the kernels obtained after shelling.

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

#### 3.4.6 Kernel yield (Kg ha$^{-1}$)

Kernel yield was calculated by using the following formula:

$$\text{Kernel yield (Kg ha}^{-1}) = \text{Pod yield (Kg ha}^{-1}) \text{ x Shelling (\%)}$$

### 3.4.7 Sound mature kernel percentage

Mature, sound and healthy kernels were selected, weighed and recorded as sound mature kernel percentage according to the formula;

$$\text{Sound mature kernel \%} = \frac{\text{Weight of fully mature kernel (g)}}{\text{Total weight of kernels (g)}} \times 100$$

### 3.4.8 Hundred kernel weight (g)

A random sample of 100 kernels was taken from the harvested bulk and weighed.

### 3.4.9 Dry haulm weight per plot (g)

The total produce of each plot was allowed to dry in the field and also in driers (during cloudy days) and after drying biological produce was kept into cloth bags and weighed.

### 3.4.10 Harvest index (%)

The harvest index was determined as the ratio of adjusted pod yield to total biomass and expressed in percentage.

$$\text{Harvest index (H.I)} = \frac{1.65 \times \text{Pod yield per plot (g)}}{\text{Total biomass per plot (g)}} \times 100$$

Where,

Total biomass = Hy + (Py X 1.65)

Hy = Haulm yield per plot (g $m^{-2}$)

Py = Pod yield per plot (g $m^{-2}$)

Here the pod weight was multiplied with a correction factor of 1.65 (Duncan *et al*. 1978) to adjust the differences in the energy requirement for producing pod dry matter compared with vegetative part.

### 3.4.11 Crop Growth Rate (g $m^{-2}day^{-1}$)

For each plot CGR was estimated following a modified procedure from Williams and Saxena (1991):

$$CGR = [\{Hwt + (Pwt \text{ X } 1.65)\} / T_2]$$

Where,

Hwt = Haulm weight (g $m^{-2}$)

Pwt = Pod weight (g $m^{-2}$)

$T_2$ = No. of days from sowing to harvest

### 3.4.12 Pod Growth Rate (g $m^{-2}day^{-1}$)

For each plot PGR was estimated following a modified procedure from Williams and Saxena (1991):

$$PGR = \frac{(Pwt \times 1.65)}{T_2 - T_1 - 15}$$

Where,

Pwt = Pod weight (g $m^{-2}$)

$T_1$= No. of days from sowing to flowering

$T_2$ = No. of days from sowing to harvest

15= No. of days between the beginning of flowering and the start of pod expansion

### 3.4.13 Partitioning factor

It is the proportion of dry matter partition into pods estimated by a modified procedure from Williams and Saxena (1991):

$$\text{Partitioning factor} = \frac{\text{Pod Growth Rate}}{\text{Crop Growth Rate}}$$

### 3.4.14 Oil content (%)

The oil content of the kernels was estimated by scanning the samples on NIR (Near-Infra Red reflectance) system model XDS-RCA (Rapid content$^{TM}$ Analyser) manufactured by FOSS analytical AB Sweden, Denmark.

### 3.4.15 Oil yield (kg ha$^{-1}$)

Oil yield was calculated by using the formula:

$$\text{Oil yield (kg ha}^{-1}\text{)} = \text{Kernel yield (Kg ha}^{-1}\text{)} \times \text{Oil content (\%)}.$$

### 3.4.16 Air and soil temperatures

Air temperature data was obtained from meteorology department at ICRISAT for entire period of experiment. Soil temperatures were measured during pod formation stage. It was measured with the help of Tinytag Radio Temperature Logger for Thermistor Probe (-40 to 125°C).

## 3.5 Statistical analysis:

Field experiment was evaluated for four different dates of sowing with sixty three genotypes laid in an alpha lattice design with block size of seven plots in two replications at International Crops Research Institute Semi-Arid Tropics Patancheru, Hyderabad, India. Each date of sowing was considered as an environment. Data obtained from each environment was analyzed separately by analysis of variance procedure and further data were pooled across four dates to perform combined analysis of variance. All statistical computations and estimations were carried out using GENSTAT software, 15$^{th}$ edition for windows.

### 3.5.1 Analysis of variance (ANOVA)

Analysis of variance (ANOVA) for an alpha-lattice design (Patterson & Williams, 1976) was used to test genotypic significance at individual environment. The significant difference among the genotypes was tested by F-test. Best linear unbiased estimates (BLUE) of genotypes and their pair wise contrasts were also computed. Further, to study the performance of genotypes across different environments, combined analysis of variance was done to assess variation attributed to different sources for which mixed model procedure was used to model individual environment error variance.

**Table 3.3.** Analysis of variance for alpha-lattice design

| **Source of variation** | **Degrees of freedom (d.f)** | **Mean sum of squares** | **F ratio** |
|---|---|---|---|
| Replication | r-1 | $MS_r$ | MSr/MSe |
| Blocks (within replicates) | r(b-1) | $MS_b$ | $MS_b / MS_e$ |
| Treatments(adjusted for blocks) | t-1 | $MS_t$ | $MS_t / MS_e$ |
| Error | r(t-b)-(t-1) | $MS_e$ | |
| Total | tr-1 | | |

Where,

r = number of replications

b= number of blocks

t = number of treatments

$MS_e$ = mean sum of squares due to error

$MS_t$= mean sum of squares due to treatments

$MS_b$= mean sum of squares due to blocks

**Standard Error of Difference between two means (S.E.D)**

S.E.D was calculated with the help of error mean square from ANOVA table.

$$\text{SED} = \sqrt{\frac{2\ \text{MSe}}{\text{r}}}$$

Where,

r = Number of replication

MSe = Mean sum of square due to error.

**Critical Difference (C.D)**

Critical Difference (C.D.) was calculated to judge whether the differences between two treatments were significant or not.

$$\text{C. D. at 1\% or 5\% probalities level} = \sqrt{\frac{2\ \text{MSe}}{\text{r}}} \times \text{t}^{*}$$

* t at 1% or 5% level (for error of probability level).

### 3.5.2 Site regression (GGE) using Biplot

A standard biplot is the scatter plot that graphically displays both the row factor and column factors of a two-way table data. A biplot graphically displays a matrix with application to principal component analysis (Kroonenberg, 1995). For generating a biplot, a two-way table representing two factors was subjected to singular value decomposition. The singular value decomposition of a matrix X= $(x_{ij})_{vxs}$ is given by:

$$x_{ij} = \sum_{k=1}^{r} u_{ik} \lambda_k v_{kj}$$

Where,

$(u_{ik})$ is the element of the matrix $U_{vxs}$ characterizing rows

$\lambda_k$'s are the singular values of a diagonal matrix $L_{sxs}$

$v_{kj}$ is the element of the matrix $V_{sxs}$ characterizing the columns and *r* represents the rank of matrix X≤ min (v,s).

Principal component scores for row and column factors were calculated after singular value partitioning of $(x_{ij})_{vxs}$ (Yan *et al.*, 2002) and biplot was obtained using first two components and percentage of variation. The fixed effect two-way model for analyzing multi-environments genotype trials is as follow:

$$E(Y_{ij}) = \mu + g_i + e_j + (ge)_{ij}$$

Where,

$\mu$ is the grand mean

$g_i$ and $e_j$ are the genotype and environmental main effects respectively,

$(ge)_{ij}$ is the G*E effect.

The sites regression model is given by (Crossa and Cornelius, 1997; Yan and Kang, 2003):

$$E(Y_{ij}) = \mu + e_j + \sum_{n=1}^{r} \xi_{in}^{*} \eta_{jn}^{*}$$

$r$ = number of principal components (PCs) required to approximate the original data.

$\xi_{in}^{*}$ and $\eta_{jn}^{*}$ are the $i^{th}$ genotype and the $j^{th}$ environmental scores for PCn, respectively. In the site regression method, PCA is applied on residuals of an additive model with environments as the only main effects. Therefore, the residual term $\sum_{n=1}^{r} \xi_{in}^{*} \eta_{jn}^{*}$ contains the variation due to G and G*E.

A two dimensional biplot (Gabriel, 1971) derived from above 2-way table of residuals is called GGE biplot (G plus G*E) (Yan *et al.*, 2000). A GGE biplot graphically depicts the genotypic main effect (G) and the G*E effect contained in the multi-environment trials. GGE biplot have been found very useful in understanding G*E, mega environment identification and genotype recommendation.

In biplot, the line that passes through the biplot origin and the average environment with a single arrow is called average environment coordinate-abscissa (AEC abscissa) or average-environment axis (AEA) which is defined by the average PC1 (principal component) and PC2 scores over all environments. The direction of the arrow on the AEA indicates higher values for the variables measured. A line perpendicular to AEA and passes the biplot origin is known as AEC ordinate, which points to greater variability in either direction. Hence greater the distance of a genotype from AEA, the less stable it is.

The vector length, *i.e.*, the absolute distance between the marker of an environment and the plot origin, is a measure its discriminating ability: the longer the distance the more discriminating the environment while the distance between the marker of an environment and AEC ordinate is a measure of its representativeness: the longer the projection, the less representative the environment.

### 3.5.3 Estimation of parameters of genetic variability

**<u>Phenotypic and Genotypic coefficient of variation (PCV and GCV)</u>**

The estimation of phenotypic and genotypic coefficients of variation was calculated as given by Burton, 1952-

Phenotypic coefficient of variation (PCV) = $\frac{\sigma_p}{\text{Mean}} \times 100$

Genotypic coefficient of variation (GCV) = $\frac{\sigma_g}{\text{Mean}} \times 100$

Where,

$\sigma_{p,}$ and $\sigma_{g,}$ are phenotypic and genotypic standard deviations respectively. PCV and GCV are classified as low, moderate or high by Sivasubramanian and Menon (1973) as shown below:

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

### 3.5.4 Heritability

The heritability in broad sense was estimated by applying formula given by Allard (1960):

$$h^2_{bs} = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,

$h^2_{bs}$ = Heritability in broad sense

$\sigma^2_g$ = Genotypic variance

$\sigma^2_p$ = Phenotypic variance = $\sigma^2_g + \sigma^2_e$

As suggested by Johnson *et al*. (1955a), heritability values are categorized as follows:

Low : Less than 30%

Moderate : 30 – 60 %

High : More than60 %

### 3.5.5 Genetic Advance (GA)

Genetic advance was computed by using the formula elucidated by Johnson *et al*. (1955a)

Genetic Advance = K x $h^2_{bs}$ x $\sigma_p$

Where,

$h^2_{bs}$= Heritability in broad sense

$\sigma_p$ = Phenotypic standard deviation

K = Selection differential in standard units which is 2.06 at 5% selection intensity.

**Genetic advance as percentage of mean was calculated by the following formula:**

$$\text{Genetic Advance as Percentage of Mean} = \left(\frac{GA}{\overline{\overline{X}}}\right) \times 100$$

Where,

GA = Expected genetic advance

$\overline{X}$ = General mean of the character in the population

The range of GA as per cent of mean was classified according to Johnson *et al*. (1955a):

Low : Less than 10%

Moderate : 10-20%

High : More than 20%

**3.5.6 Correlations**

Genotypic and phenotypic correlation coefficients between characters x and y were computed utilizing respective components of variance and co-variance by following formula.

$$r_{g(xy)} = \frac{\sigma_{g(xy)}}{\sqrt{\sigma^2_{g(x)}\,\sigma^2_{g(y)}}}$$

Where,

$r_{g(xy)}$ = Genotypic correlation coefficient between character x and y

$\sigma_{g(xy)}$ = Genotypic Co-variance of character x and y

$\sigma^2_{g(x)}$ = Genotypic Variance of character x

$\sigma^2_{g(y)}$ = Genotypic Variance of character y

$$r_{p\,(xy)} = \frac{\sigma_{p(xy)}}{\sqrt{\sigma^2_{p(x)}\,\sigma^2_{p(y)}}}$$

Where,

$r_{p(xy)}$ = Phenotypic correlation coefficient between character x and y

$\sigma_{p(xy)}$ = Phenotypic Co-variance of character x and y

$\sigma^2_{p(x)}$ = Phenotypic Variance of character x

$\sigma^2_{p(y)}$ = Phenotypic Variance of character y

To test the significance of correlation coefficients, the estimated values were compared with the tabulated values of Fisher and Yates (1938) at (t-2) d.f. at two levels of probability, *viz.*, 5% and 1%.

### 3.5.7 Determination of Stress tolerance indices

Stress tolerance indices were calculated using the following formula:

$$\mathrm{SSI} = \frac{1-\frac{\mathrm{Y_s}}{\mathrm{Y_p}}}{\mathrm{SI}} \qquad \text{(Fischer and Maurer, 1978)}$$

$$\mathrm{SI} = 1 - \frac{\overline{\mathrm{Y_s}}}{\overline{\mathrm{Y_p}}}$$

$$STI = \frac{Y_s \times Y_p}{(\overline{Y_p})^2} \qquad \text{(Fernandez, 1992)}$$

Where,

SSI = Stress Susceptibility Index

SI = Susceptibility Index

SST = Stress Tolerance Index

$Y_s$ and $Y_p$ = yields of genotypes evaluated under stress and non- stress conditions

$\overline{Ys}$ and $\overline{Yp}$ = mean yield over all genotypes evaluated under stress and non- stress conditions.

# Chapter IV

# EXPERIMENTAL FINDINGS

## Chapter-IV

# EXPERIMENTAL FINDINGS

The present investigation was carried out with the objectives to study the variation for agronomic parameters and their association for agronomic and quality parameters of groundnut genotypes under heat stress conditions. The data were recorded on 14 different traits *viz*., days to 75 percent flowering, days to maturity, haulm weight, pod yield per plot, kernel yield, shelling percentage, sound mature kernel, hundred kernel weight, oil content, oil yield, harvest index, crop growth rate, pod growth rate and partioning factor. The data for each trait was analyzed separately and the results obtained are presented under the following heads-

4.1 Analysis of Variance

4.2 Estimation of parameters of genetic variability.

4.3 Determination of association between traits

4.4 Screening of heat tolerant genotypes

### 4.1 Analysis of Variance

Analysis of variance showed that the mean sum of square exhibited highly significant differences ($p \leq 0.01$) among the genotypes for all the traits in all the four environments with an exception of non significant result for sound mature kernel in E2 which has been presented in Table 4.1.

Pooled analysis of variance of 14 traits for four different environments was performed. The results revealed highly significant ($p \leq 0.01$) differences among the genotypes for all the characters studied (Table 4.2). The differences due to genotype × environment interaction were found to be significantly high for six characters *viz.,* days to 75 % flowering, days to maturity, dry haulm weight (Kg $ha^{-1}$), sound mature kernel (%), hundred kernel weight (g) and crop growth rate (CGR, g $m^{-2}$ $day^{-1}$). The characters which were found significant for G × E interactions were subjected to stability analysis by GGE biplot.

**Table 4.1.** Analysis of variance for 14 traits evaluated in each of the four environments (E1, E2, E3 and E4).

| Traits | Sources of variation | d.f | | | | Mean Square | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | E1 | E2 | E3 | E4 | E1 | E2 | E3 | E4 |
| Days to 75% flowering (days) | Replication | 1 | 1 | 1 | 1 | 3.17 | 16.07 | 0.01 | 3.17 |
| | Block(Rep) | 12 | 12 | 12 | 12 | 1.91 | 1.83 | 0.60 | 1.98 |
| | Genotypes | 62 | 62 | 62 | 62 | 20.24** | 4.72** | 4.05** | 4.06** |
| | Error | 50 | 50 | 50 | 50 | 1.86 | 0.77 | 0.43 | 0.66 |
| | Corr. Total | 125 | 125 | 125 | 125 | | | | |
| Days to maturity (days) | Replication | 1 | 1 | 1 | 1 | 11.36 | 58.13 | 20.25 | 102.09 |
| | Block(Rep) | 12 | 12 | 12 | 12 | 4.17 | 14.76 | 18.74 | 14.91 |
| | Genotypes | 60 | 61 | 61 | 61 | 61.07** | 82.45** | 211.20** | 266.92** |
| | Error | 47 | 49 | 48 | 49 | 4.57 | 5.45 | 20.84 | 11.88 |
| | Corr. Total | 120 | 123 | 122 | 123 | | | | |
| Haulm weight (Kg ha$^{-1}$) | Replication | 1 | 1 | 1 | 1 | 7920653 | 8211579 | 294509 | 806082 |
| | Block(Rep) | 12 | 12 | 12 | 12 | 1072211 | 990981 | 1764161 | 1515460 |
| | Genotypes | 61 | 61 | 61 | 61 | 4931271** | 5889470** | 5434427** | 5655593** |
| | Error | 45 | 46 | 45 | 44 | 489319 | 432090 | 1051781 | 1113206 |
| | Corr. Total | 119 | 120 | 119 | 118 | | | | |
| Pod Yield (Kg ha$^{-1}$) | Replication | 1 | 1 | 1 | 1 | 4927416 | 76463 | 1483608 | 1657943 |
| | Block(Rep) | 12 | 12 | 12 | 12 | 1092997 | 471307 | 807221 | 468116 |
| | Genotypes | 60 | 61 | 61 | 61 | 2169388** | 1911466** | 2300859** | 2124942** |
| | Error | 47 | 49 | 48 | 49 | 471467 | 263400 | 439057 | 573739 |
| | Corr. Total | 120 | 123 | 122 | 123 | | | | |
| Kernel yield (Kg ha$^{-1}$) | Replication | 1 | 1 | 1 | 1 | 3498880 | 89 | 1844411 | 578308 |
| | Block(Rep) | 12 | 12 | 12 | 12 | 720743 | 126998 | 289472 | 177444 |
| | Genotypes | 60 | 61 | 61 | 61 | 990698** | 831817** | 856036** | 934526** |
| | Error | 47 | 49 | 47 | 49 | 315633 | 153690 | 214369 | 304869 |
| | Corr. Total | 120 | 123 | 121 | 123 | | | | |
| Shelling percentage (%) | Replication | 1 | 1 | 1 | 1 | 164.03 | 3.87 | 230.79 | 0.04 |
| | Block(Rep) | 12 | 12 | 12 | 12 | 53.98 | 22.00 | 21.25 | 40.04 |
| | Genotypes | 60 | 61 | 61 | 61 | 57.18** | 63.32** | 54.85** | 86.25** |
| | Error | 47 | 49 | 47 | 49 | 25.04 | 21.80 | 16.41 | 25.88 |
| | Corr. Total | 120 | 123 | 121 | 123 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sound Mature Kernel (%) | Replication | 1 | 1 | 1 | 1 | 259.84 | 54.15 | 1067.51 | 85.21 |
| | Block(Rep) | 12 | 12 | 12 | 12 | 20.58 | 21.46 | 35.70 | 32.19 |
| | Genotypes | 60 | 61 | 61 | 61 | 23.72** | 14.49 | 51.21** | 43.19** |
| | Error | 47 | 49 | 47 | 49 | 11.50 | 24.45 | 23.16 | 22.86 |
| | Corr. Total | 120 | 123 | 121 | 123 | | | | |
| Hundred Kernel Weight (g) | Replication | 1 | 1 | 1 | 1 | 70.09 | 8.74 | 134.12 | 164.87 |
| | Block(Rep) | 12 | 12 | 12 | 12 | 47.77 | 5.84 | 5.69 | 34.83 |
| | Genotypes | 60 | 61 | 61 | 61 | 95.59** | 52.71** | 52.88** | 94.81** |
| | Error | 47 | 49 | 47 | 49 | 18.45 | 4.99 | 9.47 | 13.97 |
| | Corr. Total | 120 | 123 | 121 | 123 | | | | |
| Oil Content (%) | Replication | 1 | 1 | 1 | 1 | 21.29 | 10.58 | 44.99 | 4.00 |
| | Block(Rep) | 12 | 12 | 12 | 12 | 1.60 | 1.44 | 1.83 | 5.53 |
| | Genotypes | 60 | 61 | 61 | 61 | 11.23** | 10.02** | 11.82** | 15.18** |
| | Error | 47 | 49 | 47 | 49 | 2.04 | 1.79 | 2.44 | 2.16 |
| | Corr. Total | 120 | 123 | 121 | 123 | | | | |
| Oil Yield (Kg $ha^{-1}$) | Replication | 1 | 1 | 1 | 1 | 754070 | 3920 | 840304 | 261710 |
| | Block(Rep) | 12 | 12 | 12 | 12 | 203389 | 40816 | 83397 | 75782 |
| | Genotypes | 60 | 61 | 61 | 61 | 316884** | 270664** | 294130** | 312333** |
| | Error | 47 | 49 | 47 | 49 | 88560 | 49631 | 70236 | 96083 |
| | Corr. Total | 120 | 123 | 121 | 123 | | | | |
| Harvest Index (%) | Replication | 1 | 1 | 1 | 1 | 624.99 | 62.66 | 32.31 | 18.13 |
| | Block(Rep) | 12 | 12 | 12 | 12 | 24.77 | 14.36 | 18.28 | 16.96 |
| | Genotypes | 60 | 61 | 61 | 61 | 87.32** | 85.68** | 102.64** | 109.08** |
| | Error | 44 | 46 | 45 | 44 | 20.13 | 11.75 | 31.63 | 22.75 |
| | Corr. Total | 117 | 120 | 119 | 118 | | | | |
| Crop Growth Rate ($gm^{-2}day^{-1}$) | Replication | 1 | 1 | 1 | 1 | 0.38 | 4.39 | 0.45 | 7.02 |
| | Block (Rep) | 12 | 12 | 12 | 12 | 2.73 | 1.88 | 4.62 | 2.69 |
| | Genotypes | 61 | 61 | 61 | 61 | 6.91** | 5.82** | 4.96** | 5.49** |
| | Error | 45 | 46 | 45 | 44 | 1.07 | 0.82 | 2.14 | 2.22 |
| | Corr. Total | 119 | 120 | 119 | 118 | | | | |
| Pod Growth Rate ($gm^{-2}day^{-1}$) | Replication | 1 | 1 | 1 | 1 | 20.59 | 0.55 | 4.32 | 17.72 |
| | Block (Rep) | 12 | 12 | 12 | 12 | 5.11 | 3.14 | 3.55 | 1.58 |
| | Genotypes | 60 | 61 | 61 | 61 | 7.96** | 6.92** | 5.91** | 8.27** |
| | Error | 47 | 49 | 48 | 49 | 2.32 | 1.28 | 1.80 | 2.36 |
| | Corr. Total | 120 | 123 | 122 | 123 | | | | |
| Partitioning Factor | Replication | 1 | 1 | 1 | 1 | 0.18 | 0.18 | 0.00 | 0.01 |
| | Block (Rep) | 12 | 12 | 12 | 12 | 0.01 | 0.01 | 0.00 | 0.00 |
| | Genotypes | 60 | 61 | 61 | 61 | 0.03** | 0.03** | 0.02** | 0.03** |
| | Error | 45 | 46 | 44 | 44 | 0.01 | 0.01 | 0.00 | 0.00 |
| | Corr. Total | 118 | 120 | 118 | 118 | | | | |

** Significant at 0.01 probability level
Corr. Total = corrected total; Rep = replication

**Table 4.2.** Pooled analysis of variance for 14 traits across the four environments.

| Traits | Fixed term | Wald statistic | d.f | F statistic | F probability | SED / LSD |
|---|---|---|---|---|---|---|
| Days to 75% flowering (days) | Season | 2111.21 | 3 | 701.5 | <0.001** | 0.50 |
| | Season (Replication) | 10.14 | 4 | 2.52 | 0.067 | |
| | Entry | 1545.9 | 62 | 24.93 | <0.001** | 0.98 |
| | Season *Entry | 542.11 | 186 | 2.88 | <0.001** | |
| Days to maturity (days) | Season | 649.78 | 3 | 214.06 | <0.001** | 1.68 |
| | Season (Replication) | 14.96 | 4 | 3.67 | 0.027 | |
| | Entry | 2982.18 | 61 | 48.85 | <0.001** | 3.30 |
| | Season *Entry | 759.2 | 182 | 4.12 | <0.001** | |
| Haulm weight (Kg ha$^{-1}$) | Season | 19.53 | 3 | 6.49 | 0.002** | 474.40 |
| | Season (Replication) | 12.64 | 4 | 3.15 | 0.032 | |
| | Entry | 1781.71 | 61 | 29.2 | <0.001** | 929.82 |
| | Season *Entry | 289.57 | 183 | 1.56 | 0.006** | |
| Pod Yield (Kg ha$^{-1}$) | Season | 22.89 | 3 | 7.61 | 0.001** | 344.30 |
| | Season (Replication) | 8.38 | 4 | 2.09 | 0.116 | |
| | Entry | 1122.37 | 61 | 18.4 | <0.001** | 678.27 |
| | Season *Entry | 168.65 | 182 | 0.92 | 0.706 | |
| Kernel yield (Kg ha$^{-1}$) | Season | 44.97 | 3 | 14.86 | <0.001** | 256.90 |
| | Season (Replication) | 16.52 | 4 | 4.08 | 0.018 | |
| | Entry | 821.52 | 61 | 13.46 | <0.001** | 506.09 |
| | Season *Entry | 178.68 | 182 | 0.97 | 0.581 | |
| Shelling percentage (%) | Season | 58.66 | 3 | 19.48 | <0.001** | 2.47 |
| | Season (Replication) | 10.84 | 4 | 2.69 | 0.064 | |
| | Entry | 481.81 | 61 | 7.9 | <0.001** | 4.87 |
| | Season *Entry | 236.61 | 182 | 1.28 | 0.069 | |
| Sound Mature Kernel (%) | Season | 14.47 | 3 | 4.8 | 0.013* | 2.35 |
| | Season (Replication) | 45.89 | 4 | 11.38 | <0.001 | |
| | Entry | 139.76 | 61 | 2.29 | <0.001** | 4.63 |
| | Season *Entry | 254.08 | 182 | 1.38 | 0.028* | |
| Hundred Kernel Weight (g) | Season | 124.24 | 3 | 40.89 | <0.001** | 1.86 |
| | Season (Replication) | 21.03 | 4 | 5.16 | 0.008 | |
| | Entry | 1437.44 | 61 | 23.55 | <0.001** | 3.67 |
| | Season *Entry | 254.75 | 182 | 1.38 | 0.03* | |

Table 4.2 (Cont.).

| | | | | | | |
|---|---|---|---|---|---|---|
| Oil Content (%) | Season | 22.58 | 3 | 7.42 | 0.007** | 0.75 |
| | Season (Replication) | 44.21 | 4 | 10.83 | 0.001 | |
| | Entry | 1240.05 | 61 | 20.28 | <0.001** | 1.47 |
| | Season *Entry | 188.22 | 182 | 1.02 | 0.465 | |
| Oil Yield (Kg ha$^{-1}$) | Season | 42.22 | 3 | 13.97 | <0.001** | 142.30 |
| | Season (Replication) | 17.21 | 4 | 4.25 | 0.015 | |
| | Entry | 877.82 | 61 | 14.38 | <0.001** | 280.33 |
| | Season *Entry | 177.08 | 182 | 0.96 | 0.602 | |
| Harvest Index (%) | Season | 100.87 | 3 | 33.1 | <0.001** | 2.37 |
| | Season (Replication) | 38.01 | 4 | 9.24 | 0.002 | |
| | Entry | 1019.87 | 61 | 16.66 | <0.001** | 4.66 |
| | Season *Entry | 203.29 | 182 | 1.1 | 0.294 | |
| Crop Growth Rate (g m$^{-2}$day$^{-1}$) | Season | 13.97 | 3 | 4.65 | 0.009** | 0.67 |
| | Season (Replication) | 3.43 | 4 | 0.86 | 0.502 | |
| | Entry | 912.59 | 61 | 14.96 | <0.001** | 1.31 |
| | Season*Entry | 268.54 | 183 | 1.45 | 0.02* | |
| Pod Growth Rate (g m$^{-2}$day$^{-1}$) | Season | 22.47 | 3 | 4.08 | 0.017* | 0.71 |
| | Season (Replication) | 9.98 | 4 | 1.62 | 0.2 | |
| | Entry | 829.62 | 61 | 13.01 | <0.001** | 1.40 |
| | Season *Entry | 217.07 | 182 | 1.14 | 0.216 | |
| Partitioning Factor | Season | 162 | 3 | 53.34 | <0.001** | 0.04 |
| | Season (Replication) | 37.27 | 4 | 9.16 | 0.002 | |
| | Entry | 1212.22 | 60 | 20.17 | <0.001** | 0.07 |
| | Season *Entry | 224.4 | 180 | 1.23 | 0.119 | |

** and * Significant at 0.01 and 0.05 probability level.

Pair-wise contrast estimation of genotypes was performed for different traits to identify significance between different environments *viz*., E1 vs. E2; E1 vs. E3; E1 vs. E4; E2 vs. E3; E2 vs. E4 and E3 vs. E4 respectively are presented in Table 4.3. Significant differences were observed for almost all the traits in most of the six combinations of environments. This depicted the effect of heat on performances of varieties under different environments. However, highly significant difference ($p \leq 0.001$) was exhibited by the traits - days to 75% flowering and days to maturity. Beside, significant difference ($p \leq 0.05$) was also exhibited by kernel yield, oil yield, harvest index, and partioning factor except in contrast E2 vs. E3. Shelling percentage and crop growth rate showed non-significant difference for E3 vs. E4.

**Table 4.3.** Pair-wise contrast estimates of genotypes between different environments for 14 traits.

| **Days to 75% flowering (days)** | | | | | **Days to maturity (days)** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** | **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** |
| Con1Vs2 | 3.659 | 0.143 | 25.42 | <0.001** | Con1Vs2 | 5.873 | 0.301 | 18.26 | <0.001** |
| Con1Vs3 | 6.294 | 0.132 | 25.42 | <0.001** | Con1Vs3 | 7.798 | 0.456 | 18.26 | <0.001** |
| Con1Vs4 | 8.778 | 0.141 | 25.42 | <0.001** | Con1Vs4 | 9.967 | 0.37 | 18.26 | <0.001** |
| Con2Vs3 | 2.6349 | 0.0976 | 25.42 | <0.001** | Con2Vs3 | 1.925 | 0.475 | 18.26 | <0.001** |
| Con2Vs4 | 5.119 | 0.109 | 25.42 | <0.001** | Con2Vs4 | 4.094 | 0.394 | 18.26 | <0.001** |
| Con3Vs4 | 2.4841 | 0.0944 | 25.42 | <0.001** | Con3Vs4 | 2.169 | 0.522 | 18.26 | <0.001** |
| **Haulm weight (Kg ha$^{-1}$)** | | | | | **Pod Yield (Kg ha$^{-1}$)** | | | | |
| **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** | **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** |
| Con1Vs2 | -374.96 | 89.07 | 24.92 | <0.001** | Con1Vs2 | 327.34 | 79.51 | 23.27 | <0.001** |
| Con1Vs3 | -583.8 | 115.1 | 24.92 | <0.001** | Con1Vs3 | 96.64 | 89.04 | 23.27 | 0.289 |
| Con1Vs4 | -828.5 | 118.6 | 24.92 | <0.001** | Con1Vs4 | 532.68 | 93.02 | 23.27 | <0.001** |
| Con2Vs3 | -208.8 | 113.1 | 24.92 | 0.077 | Con2Vs3 | -230.7 | 76.94 | 23.27 | 0.006** |
| Con2Vs4 | -453.5 | 116.7 | 24.92 | <0.001** | Con2Vs4 | 205.33 | 81.51 | 23.27 | 0.019* |
| **Kernel yield (Kg ha$^{-1}$)** | | | | | **Shelling percentage (%)** | | | | |
| **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** | **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** |
| Con1Vs2 | 326.88 | 65.66 | 17.1 | <0.001** | Con1Vs2 | 2.835 | 0.639 | 16.97 | <0.001** |
| Con1Vs3 | 322.12 | 70.55 | 17.1 | <0.001** | Con1Vs3 | 5.73 | 0.619 | 16.97 | <0.001** |
| Con1Vs4 | 514.73 | 73.59 | 17.1 | <0.001** | Con1Vs4 | 4.929 | 0.676 | 16.97 | <0.001** |
| Con2Vs3 | -4.76 | 55.39 | 17.1 | 0.932 | Con2Vs3 | 2.895 | 0.561 | 16.97 | <0.001** |
| Con2Vs4 | 187.85 | 59.21 | 17.1 | 0.006** | Con2Vs4 | 2.094 | 0.622 | 16.97 | 0.004** |
| Con3Vs4 | 192.62 | 64.58 | 17.1 | 0.008** | Con3Vs4 | -0.801 | 0.602 | 16.97 | 0.201 |
| **Sound Mature Kernel (%)** | | | | | **Hundred Kernel Weight (g)** | | | | |
| **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** | **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** |
| Con1Vs2 | 1.724 | 0.538 | 17.44 | 0.005** | Con1Vs2 | 5.248 | 0.479 | 17.71 | <0.001** |
| Con1Vs3 | 2.702 | 0.565 | 17.44 | <0.001** | Con1Vs3 | 6.087 | 0.513 | 17.71 | <0.001** |
| Con1Vs4 | 1.65 | 0.529 | 17.44 | 0.006** | Con1Vs4 | 4.369 | 0.572 | 17.71 | <0.001** |
| Con2Vs3 | 0.977 | 0.631 | 17.44 | 0.139 | Con2Vs3 | 0.839 | 0.339 | 17.71 | 0.024* |
| Con2Vs4 | -0.075 | 0.599 | 17.44 | 0.902 | Con2Vs4 | -0.88 | 0.423 | 17.71 | 0.052 |
| Con3Vs4 | -1.052 | 0.624 | 17.44 | 0.109 | Con3Vs4 | -1.718 | 0.461 | 17.71 | 0.002** |

Table 4.3 (Cont.).

| Oil Content (%) | | | | | Oil Yield (Kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** | **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** |
| Con1Vs2 | -0.06 | 0.175 | 129.77 | 0.734 | Con1Vs2 | 167.18 | 35.37 | 17.04 | <0.001** |
| Con1Vs3 | 0.666 | 0.19 | 129.77 | <0.001** | Con1Vs3 | 177.28 | 38.21 | 17.04 | <0.001** |
| Con1Vs4 | 0.248 | 0.2 | 129.77 | 0.216 | Con1Vs4 | 276.48 | 40.13 | 17.04 | <0.001** |
| Con2Vs3 | 0.725 | 0.184 | 129.77 | <0.001** | Con2Vs3 | 10.1 | 31.4 | 17.04 | 0.752 |
| Con2Vs4 | 0.308 | 0.194 | 129.77 | 0.116 | Con2Vs4 | 109.3 | 33.71 | 17.04 | 0.005** |
| Con3Vs4 | -0.418 | 0.208 | 129.77 | 0.046* | Con3Vs4 | 99.2 | 36.67 | 17.04 | 0.015* |
| **Harvest Index (%)** | | | | | **Crop Growth Rate (gm$^{-2}$day$^{-1}$)** | | | | |
| **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** | **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** |
| Con1Vs2 | 2.767 | 0.541 | 121.55 | <0.001** | Con1Vs2 | -0.308 | 0.127 | 27.77 | 0.022* |
| Con1Vs3 | 1.918 | 0.666 | 121.55 | 0.005** | Con1Vs3 | -0.886 | 0.162 | 27.77 | <0.001** |
| Con1Vs4 | 5.457 | 0.618 | 121.55 | <0.001** | Con1Vs4 | -0.778 | 0.172 | 27.77 | <0.001** |
| Con2Vs3 | -0.849 | 0.598 | 121.55 | 0.158 | Con2Vs3 | -0.578 | 0.154 | 27.77 | <0.001** |
| Con2Vs4 | 2.689 | 0.544 | 121.55 | <0.001** | Con2Vs4 | -0.47 | 0.164 | 27.77 | 0.008** |
| Con3Vs4 | 3.539 | 0.668 | 121.55 | <0.001** | Con3Vs4 | 0.108 | 0.193 | 27.77 | 0.58 |
| **Pod Growth Rate (gm$^{-2}$day$^{-1}$)** | | | | | **Partitioning Factor** | | | | |
| **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** | **Contrast** | **estimate** | **S.E.** | **d.f.** | **pr.** |
| Con1Vs2 | 0.325 | 0.172 | 25.63 | 0.07 | Con1Vs2 | 0.04865 | 0.00957 | 11.05 | <0.001** |
| Con1Vs3 | -0.108 | 0.185 | 25.63 | 0.565 | Con1Vs3 | 0.05193 | 0.00992 | 11.05 | <0.001** |
| Con1Vs4 | 0.771 | 0.193 | 25.63 | <0.001** | Con1Vs4 | 0.11975 | 0.00992 | 11.05 | <0.001** |
| Con2Vs3 | -0.433 | 0.157 | 25.63 | 0.011* | Con2Vs3 | 0.00328 | 0.00832 | 11.05 | 0.701 |
| Con2Vs4 | 0.446 | 0.166 | 25.63 | 0.012* | Con2Vs4 | 0.0711 | 0.00832 | 11.05 | <0.001** |
| Con3Vs4 | 0.879 | 0.18 | 25.63 | <0.001** | Con3Vs4 | 0.06783 | 0.00872 | 11.05 | <0.001** |

**and*significant at 1% and 5% probability level

Pod yield exhibited significant difference when compared between different environments with an exception to environment E1 vs. E3. Hundred kernel weight exhibited significant difference for five combinations (except E2 vs. E4) while haulm weight showed significance for four combinations (except E2 vs. E3 and E3 vs. E4). Moreover, pod growth rate estimates exhibited significant difference for E1 vs. E4; E2 vs. E3; E2 vs. E4 and E3 vs. E4. Sound mature kernel showed significance when compared E1 with E2, E3 and E4 while oil content % exhibited non significant results for E1 vs. E2, E1 vs. E4 and E2 vs. E4.

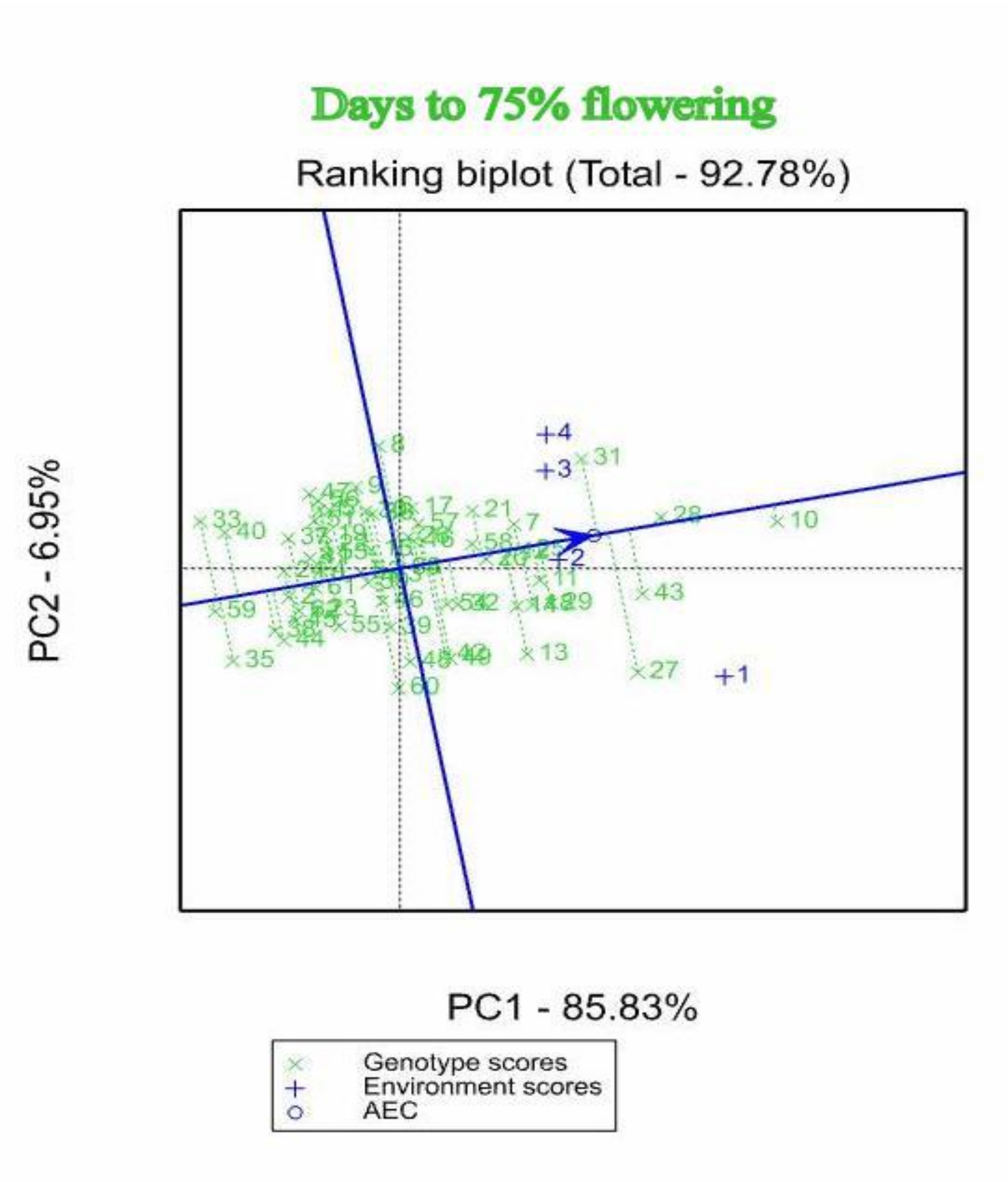


**Figure 4.1** GGE biplot ranking of genotypes for stability and mean performance of days to 75% flowering evaluated across four environments. Environments E1, E2, E3, and E4 are marked as +1, +2, +3 and +4 while genotypes are denoted as 1, 2, 3...62.

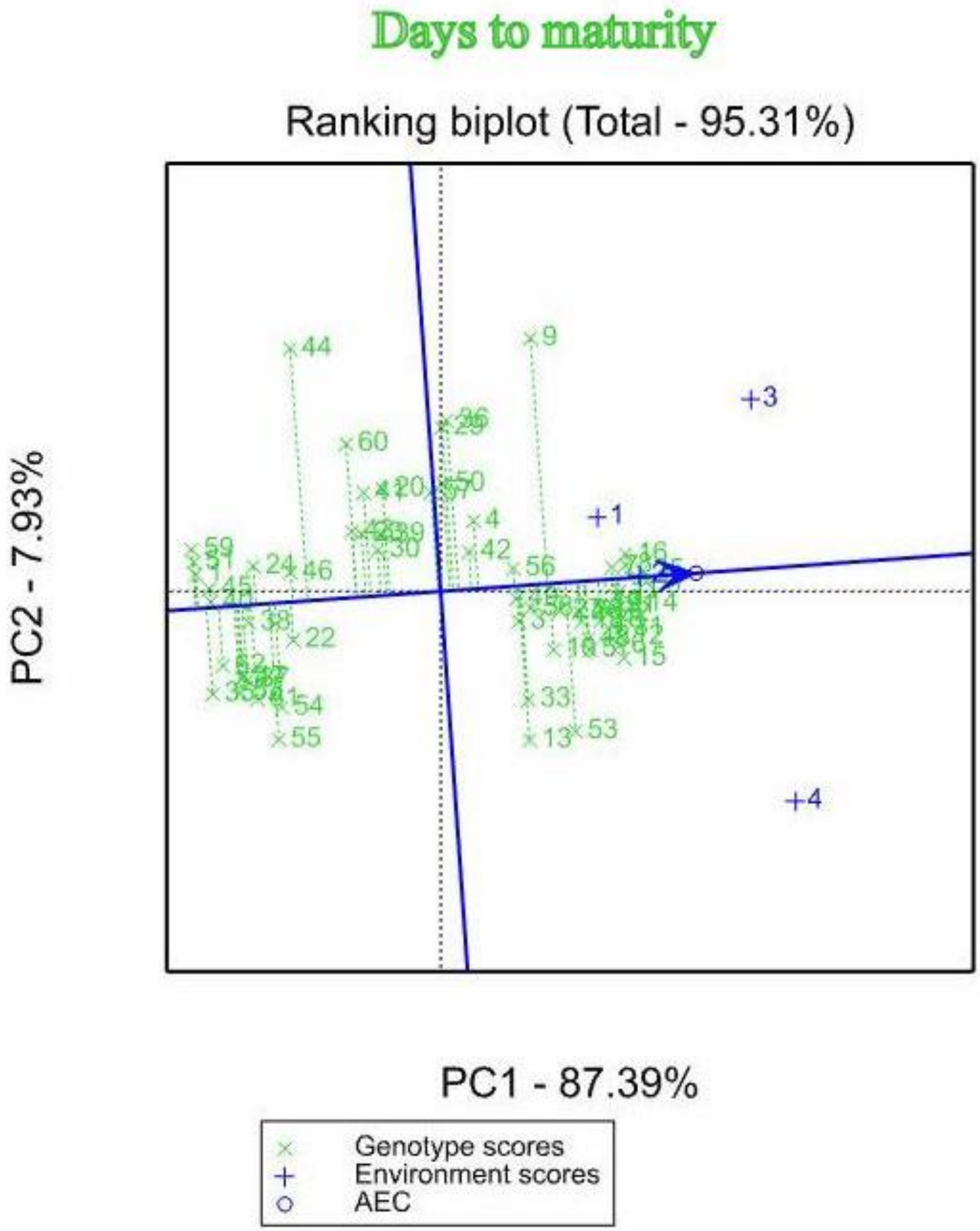


**Figure 4.2** GGE biplot ranking of genotypes for stability and mean performance of days to maturity evaluated across four environments. Environments E1, E2, E3, and E4 are marked as +1, +2, +3 and +4 while genotypes are denoted as 1, 2, 3...62.

## Genotype and Genotype by Environment interactions (GGE)

GGE Biplot is a graphical analysis tool that produces a two-dimensional biplot based upon genotype (G) and genotype X environment (G x E) information; therefore, only variables (traits) found significant for G or GE at $p \leq 0.05$ were suitable for analysis in GGE Biplot. The variables (traits) that were significant for G x E were subjected to biplot analysis indicating that analysis in GGE Biplot was appropriate for these variables which were enlisted in Table 4.2. In this study, days to 75% flowering, days to maturity, dry haulm weight (Kg $ha^{-1}$), sound mature kernel (%), hundred kernel weight (g) and crop growth rate (g $m^{-2}$ $day^{-1}$) were analyzed.

### 4.2.1 Days to 75 % flowering (DF)

The principal components of the GGE biplot for days to 75 % flowering explained 93.55 % (82.64 % and 10.91 % by PC1 and PC2 respectively) of total variation of the environment centered G by E data (Table 4.2). For the trait moving along the line in the direction of the arrow indicates late flowering (Fig. 4.1). The dotted lines were unit-less measures and exist only to rank or evaluate the cultivars for mean performance. Therefore for days to flowering genotype J 11 (59) showed early flowering followed by ICGV 91114 (35) and ICGV 89280 (33) whereas, genotype ICGV 07456 (10) recorded for maximum number of days followed by ICGV 07356 (28) and ICGV 98294 (43) across the four environments.

Among all the environments, E2 was most representative (as it had a near zero projection on the AEC ordinate) and also highly discriminating (as it had a large projection onto the AEA) while E1 was discriminating (far away from the origin) but not representative of the average environment (large projection onto the AEC ordinate). E3 and E4 were neither discriminating (small distance from origin) nor representative (large projection onto the AEC ordinate).

### 4.2.2 Day s to maturity

In the biplot, PCs explained 95.31 % (PC1=87.39 % and PC2 =7.93 %) of the total GGE variation (Fig 4.2). Both the PC1 (87.39 %) and PC2 (7.93 %) observed to be

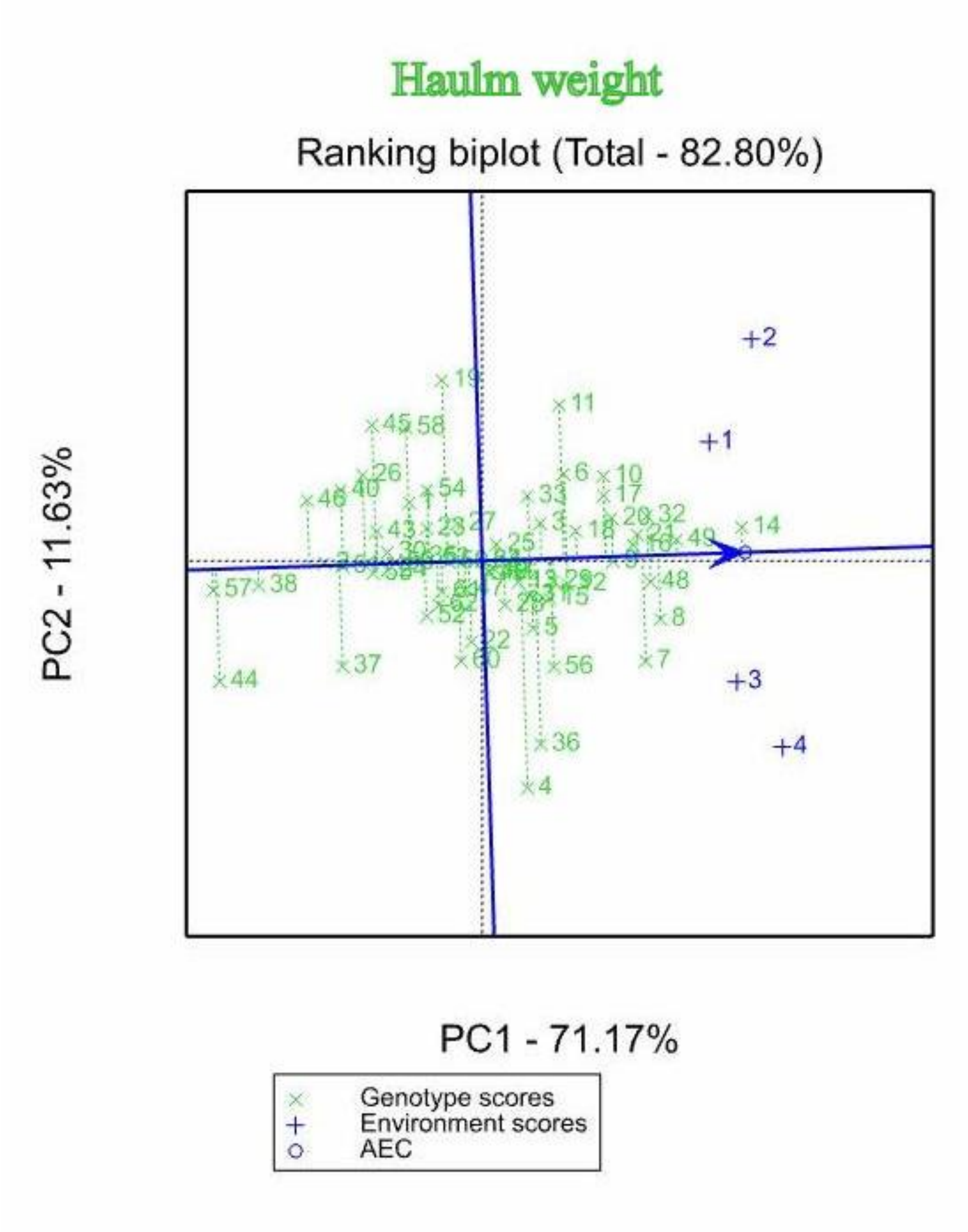


**Figure 4.3** GGE biplot ranking of genotypes for stability and mean performance of haulm weight evaluated across four environments. Environments E1, E2, E3, and E4 are marked as +1, +2, +3 and +4 while genotypes are denoted as 1, 2, 3...62.

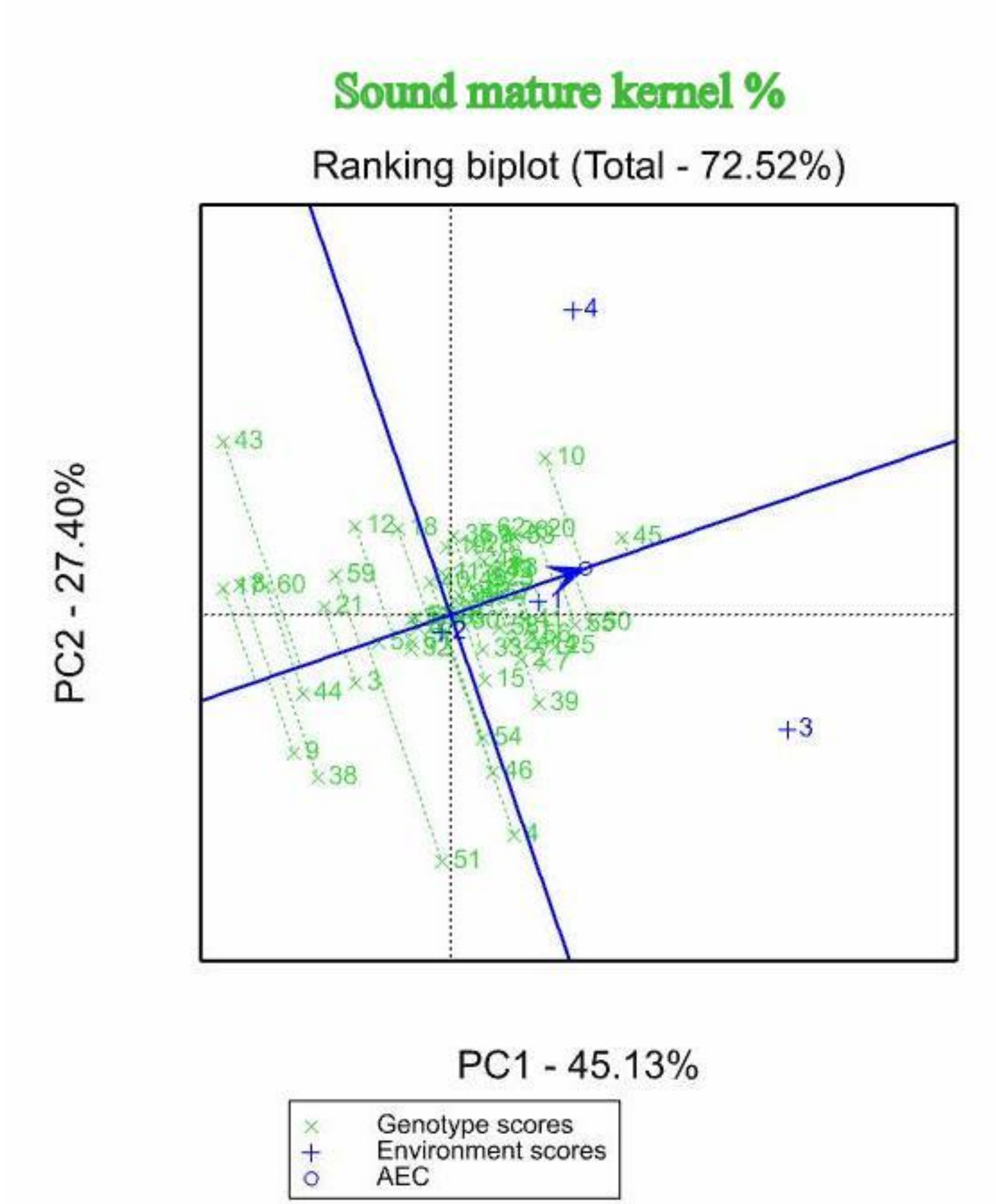


**Figure 4.4** GGE biplot ranking of genotypes for stability and mean performance of sound mature kernel evaluated across four environments. Environments E1, E2, E3, and E4 are marked as +1, +2, +3 and +4 while genotypes are denoted as 1, 2, 3...62.

significant for days to maturity. Stability analysis for days to maturity using biplot technique represented that genotypes J 11 (59) took minimum number of days *i.e*. it matured early followed by ICGV 91114 (35) and Chico (51) while, genotypes ICGV 07012 (17), ICGV 07246 (25) and ICGV 06175 (14) being farthest from the origin to right were late maturing and stable (zero projection onto AEC ordinate) across the environments. All the other genotypes with shorter projections onto AEC ordinate were also stable over the environments.

Environment E2 was most representative and also discriminating where as E4 being far away from the origin was discriminating *i.e.* this environment had maximum discriminating ability among the genotypes for days to maturity (101-139 days).

### 4.2.3 Haulm weight

In the biplot (Fig. 4.3) the four test environments were divided into two mega environments *i.e.* E1 and E2 as one environment while E3 and E4 as another. The first two principal components of the GGE biplot for haulm weight explained 90.58 % (82.87 % and 7.71 % by PC1 and PC2 respectively) of total variation. The biplot analysis for haulm weight revealed that both PC1 and PC2 were observed significant for haulm weight with highest weight being recorded by genotype ICGV 06175 (14) followed by VRI 6 (49) and TPG 41 (48) over different environment. Genotypes such as ICGV 92035 (36) and ICGV 00351 (4) also performed better but were unstable (large projections onto AEC ordinate). Low haulm weight was recorded for ICGV02271 (57) as it was being farthest to the left of the biplot origin followed by TAG 24 (44) and ICGV 93468 (38).

### 4.2.4 Sound mature kernel percentage (SMK %)

Analysis of SMK % using biplot (Fig. 4.4) showed that environment E1 and E2 fall on AEA which indicates that these environments were most representative but had low discriminating ability between the genotypes when compared to environment E3 and E4 which have high discriminating ability.

PCs in the biplot (Fig. 4.4) explained 72.52 % (PC1=45.13 % and PC2 =27.40 %) of the total GGE variation. Both the PC1 (45.13 %) and PC2 (27.40 %) were observed

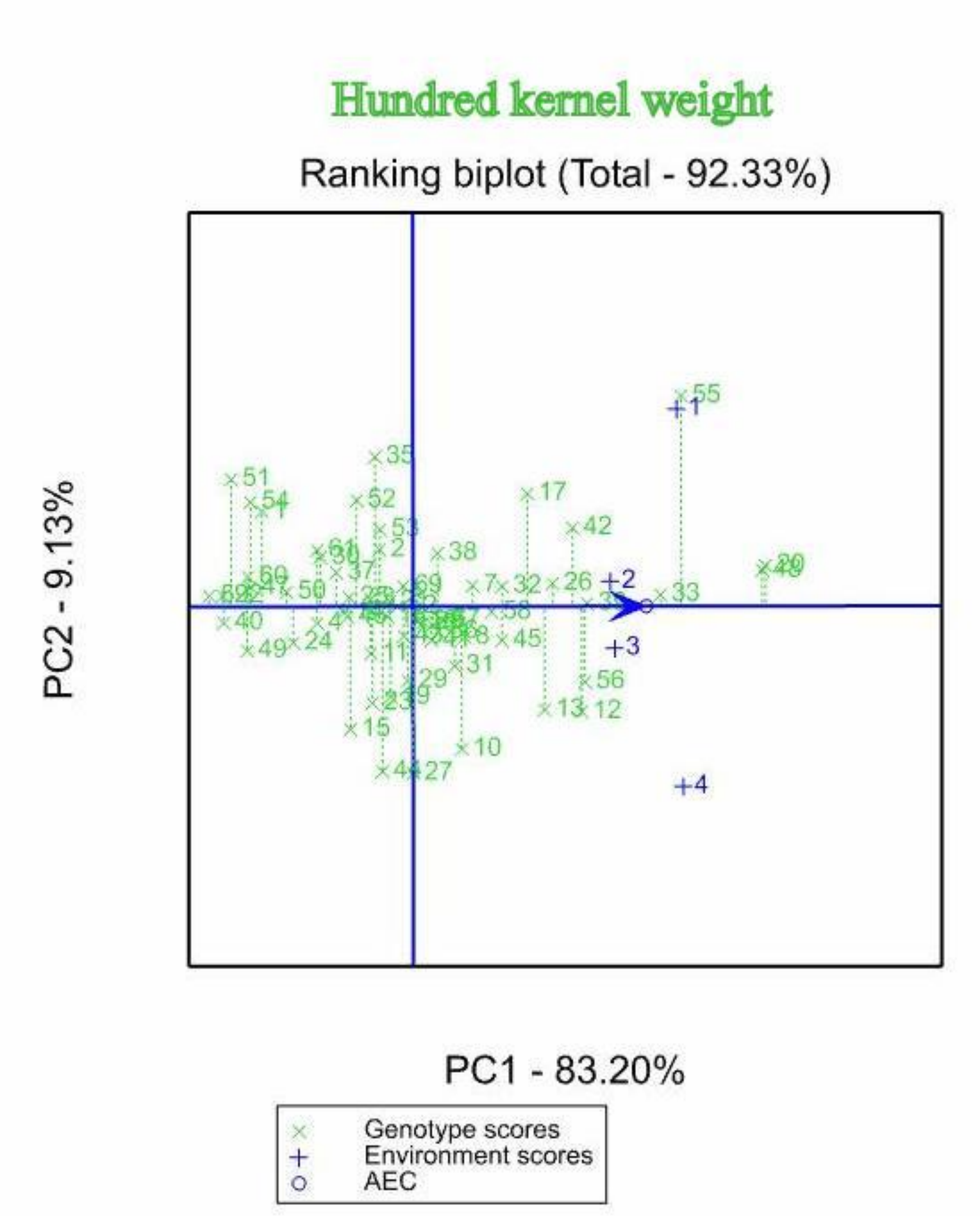


**Figure 4.5** GGE biplot ranking of genotypes for stability and mean performance of hundred kernel weight evaluated across four environments. Environments E1, E2, E3, and E4 are marked as +1, +2, +3 and +4 while genotypes are denoted as 1, 2, 3...62.

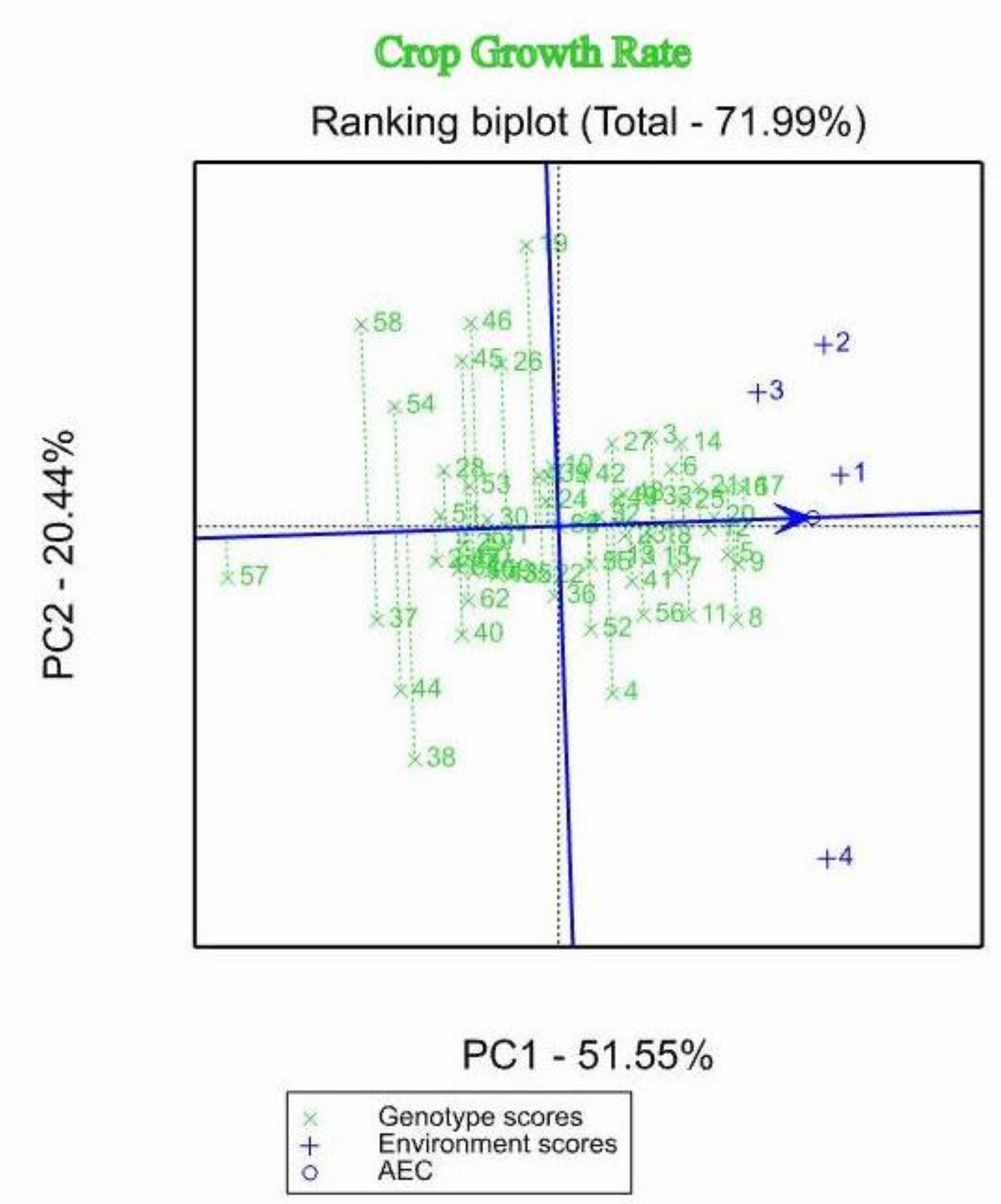


**Figure 4.6** GGE biplot ranking of genotypes for stability and mean performance of crop growth rate evaluated across four environments. Environments E1, E2, E3, and E4 are marked as +1, +2, +3 and +4 while genotypes are denoted as 1, 2, 3...62.

significant for SMK percentage. Biplot for SMK percentage exhibited that genotypes TCGS 1043 (45), ICGV 07456 (10), Abhaya (50) being farthest to right from the biplot origin showed high percentage of sound mature kernels, while genotypes pictured to the left of biplot origin represented lowest mean values of SMK percentage. All the genotypes that lie on ATC x-axis with zero projections on AEC ordinate were stable for the trait.

#### 4.2.5 Hundred Kernel Weight (HKW)

The biplot for hundred kernel weight showed that the PC's explained 92.33 % (PC1=83.20 % and PC2 =9.13 %) of the total GGE variation (Fig. 4.5). Both PC1 (83.20 %) and PC2 (9.13 %) were observed significant for hundred seed weight. Genotypes ICGV 05200 (20) and TPG 41 (48) were recorded for highest mean value and were stable for the trait followed by ICGV 01232 (55) which was unstable due to larger projection onto AEC ordinate while genotypes J 11 (59), ICGV 07211 (22) and ICGV 96346 (40) showed low values for HKW but were consistent across the environments. In this biplot environment E1 and E4 represent most discriminating environments (due to large distance from the origin).

#### 4.2.6 Crop Growth Rate (CGR)

The principal components of the GGE biplot for Crop Growth Rate explained 85.76 % (73.77 % and 12.00 % by PC1 and PC2 respectively) of total variation of the environment centered G by E data. The GGE biplot analysis for CGR revealed that both PC1 and PC2 were observed significant, with stable and highest growth rate being recorded by genotypes ICGV 06039 (11) followed by ICGV 07012 (17) and ICGV 05032 (8) across the environments.

Genotypes such as GJG 31 (52) and ICGV 92035 (36) also performed better but were unstable. Low Crop Growth Rate was recorded for ICGV02271 (57) as it was being farthest to the left of the biplot origin followed by ICGV 99001 (54) and Chico (51). According to the biplot (Fig4.6) E4 was most discriminating whereas E1, E2 and E3 all were grouped into one environment.

**Table 4.4.** Estimates of genetic parameters in groundnut genotypes for 14 traits across four environments.

| Traits | Genotypic coefficient of variation (%) | | | | Phenotypic coefficient of variation (%) | | | | Heritability (%) | | | | Genetic Advance as percent of Mean | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E1 | E2 | E3 | E4 | E1 | E2 | E3 | E4 | E1 | E2 | E3 | E4 | E1 | E2 | E3 | E4 |
| Days to 75% flowering (days) | 7.8 | 4.1 | 4.1 | 4.0 | 8.4 | 4.7 | 4.6 | 4.9 | 92.5 | 85.7 | 89.9 | 80.5 | 15.9 | 8.2 | 8.4 | 8.1 |
| Days to maturity (days) | 4.1 | 5.1 | 8.3 | 9.5 | 4.4 | 5.5 | 9.0 | 10.0 | 92.9 | 92.9 | 91.0 | 95.6 | 8.5 | 10.5 | 16.9 | 19.6 |
| Haulm weight (Kg $ha^{-1}$) | 21.1 | 21.5 | 18.2 | 19.2 | 23.1 | 23.1 | 22.5 | 23.1 | 90.0 | 91.9 | 78.7 | 80.0 | 42.7 | 43.6 | 36.3 | 38.0 |
| Pod Yield (Kg $ha^{-1}$) | 21.2 | 23.0 | 22.5 | 24.0 | 26.3 | 26.2 | 27.4 | 30.5 | 77.6 | 86.2 | 80.0 | 76.5 | 42.0 | 46.5 | 45.0 | 48.0 |
| Kernel yield (Kg $ha^{-1}$) | 21.4 | 26.2 | 24.4 | 27.1 | 30.3 | 30.8 | 31.1 | 36.2 | 65.9 | 84.1 | 74.8 | 71.8 | 41.0 | 53.2 | 47.9 | 53.5 |
| Shelling percentage | 6.0 | 8.5 | 8.5 | 9.6 | 10.7 | 11.7 | 11.2 | 13.7 | 48.0 | 68.8 | 70.6 | 66.9 | 10.6 | 16.5 | 16.2 | 18.8 |
| Sound Mature Kernel (%) | 2.5 | 0.1 | 4.2 | 3.5 | 4.6 | 4.8 | 7.0 | 6.4 | 45.4 | 0.1 | 51.2 | 44.7 | 4.3 | 0.1 | 7.4 | 5.9 |
| Hundred Kernel Weight (g) | 17.8 | 16.0 | 16.9 | 20.6 | 21.3 | 17.6 | 19.6 | 23.9 | 79.8 | 90.5 | 85.1 | 84.5 | 34.9 | 32.8 | 34.2 | 41.5 |
| Oil Content (%) | 4.4 | 4.0 | 4.4 | 4.9 | 5.1 | 4.7 | 5.3 | 5.7 | 84.4 | 83.9 | 81.6 | 84.3 | 8.9 | 8.2 | 8.9 | 9.9 |
| Oil Yield (Kg $ha^{-1}$) | 23.9 | 28.2 | 27.8 | 30.0 | 32.2 | 33.1 | 34.8 | 39.9 | 70.5 | 84.2 | 76.6 | 72.4 | 46.7 | 57.3 | 54.8 | 59.4 |
| Harvest Index (%) | 12.1 | 13.7 | 13.4 | 15.9 | 15.3 | 15.7 | 17.6 | 19.2 | 76.0 | 86.2 | 71.9 | 80.2 | 23.9 | 27.8 | 26.1 | 31.6 |
| Crop Growth Rate (g $m^{-2}day^{-1}$) | 17.0 | 14.2 | 9.3 | 11.7 | 19.3 | 16.2 | 15.6 | 16.9 | 85.3 | 85.1 | 51.1 | 61.6 | 33.9 | 28.3 | 16.4 | 21.4 |
| Pod Growth Rate (g $m^{-2}day^{-1}$) | 18.4 | 19.2 | 15.4 | 21.7 | 24.7 | 23.2 | 21.2 | 27.8 | 69.7 | 80.4 | 67.9 | 75.8 | 35.4 | 38.4 | 29.6 | 43.3 |
| Partitioning Factor | 12.2 | 13.0 | 13.0 | 14.3 | 17.2 | 13.0 | 13.0 | 14.3 | 73.6 | 85.9 | 82.0 | 86.0 | 26.1 | 22.9 | 21.9 | 25.3 |

## 4.3 Estimation of parameters of genetic variability.

Estimates of genetic parameters namely, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance as percent of mean (GAM) were worked out for all the traits which are presented in Table 4.4.

### Phenotypic and Genotypic coefficient of variation (PCV and GCV)

**Environment 1:**

A perusal of data concerning phenotypic co-efficient of variation revealed higher magnitudes for oil yield (32.2%) followed by kernel yield (30.3%), pod yield (24.0%), pod growth rate (24.7%), haulm weight (23.1%) and hundred kernel weight (21.3%). However, moderate estimates were observed for crop growth rate (19.3%), partitioning factor (17.2%), harvest index (15.3%), and shelling percentage (10.7%) while low estimates were noticed for days to 75% flowering (8.4%), oil content (5.1%), sound mature kernel (4.6%) and days to maturity (4.4%).

In E1 higher magnitudes of GCV was recorded for oil yield (23.9%), kernel yield (21.4%), pod yield (21.2%) and haulm weight (21.1%). Five traits *viz*., pod growth rate (18.4%), hundred kernel weight (17.8%), crop growth rate (17.0%), partitioning factor (12.2%) and harvest index (12.1%) showed moderate magnitudes while days to 75% flowering (7.8%), shelling percentage (6.0%), oil content (4.4%), days to maturity (4.1%) and sound mature kernel (2.5%) obtained low estimates of GCV.

**Environment 2:**

Higher estimates of PCV were observed for oil yield (33.1%), kernel yield (30.8%), pod yield (26.2%), pod growth rate (23.2%) and haulm weight (23.1%) while moderate estimates for hundred kernel weight (17.6%), crop growth rate (16.2%), harvest index (15.7%), partitioning factor (13.0%) and shelling percentage (11.7%) were recorded in the second environment. Also lower magnitudes were obtained for days to maturity (5.5%), sound mature kernel (4.8%), days to 75% flowering (4.7%), and oil content (4.7%).

Higher estimates of genotypic coefficient of variation was recorded for oil yield (28.2%), kernel yield (26.2%), pod yield (23.0%) and haulm weight (21.5%) along with moderate magnitudes for pod growth rate (19.2%), hundred kernel weight (16.0%), crop growth rate (14.2%), harvest index (13.7%), and partitioning factor (13.0%). Besides these, low GCV was observed for shelling percentage (8.5%), days to maturity (5.1%), days to 75% flowering (4.1%) and oil content (4.0%) in E2.

**Environment 3:**

Phenotypic coefficient of variation estimates showed higher magnitude for oil yield (34.8%), kernel yield (31.1%), pod yield (27.4%), pod growth rate (21.2%) and haulm weight (22.5%). Additionally, moderate values were obtained for hundred kernel weight (19.6%), crop growth rate (15.6%), harvest index (17.6%), partitioning factor (13.0%) and shelling percentage (11.2%). Low estimates were recorded for days to maturity (9.0%), sound mature kernel (7.0%), oil content (5.3%) and days to 75% flowering (4.6%).

A perusal of data revealed higher estimates of GCV for oil yield (27.8%), kernel yield (24.4%) and pod yield (22.5%). However, haulm weight (18.2%), pod growth rate (15.4%), hundred kernel weight (16.9%), harvest index (13.4%) and partitioning factor (13.0%) were recorded for moderate estimates. The remaining traits *viz.*, crop growth rate (9.3%), shelling percentage (8.5%), days to maturity (8.3%), oil content (4.4%), sound mature kernel (4.2%), and days to 75% flowering (4.1%) showed lower magnitudes for GCV.

**Environment 4:**

An estimate of phenotypic coefficient of variation revealed higher magnitudes for oil yield (39.9%), kernel yield (36.2%), pod yield (30.5%), pod growth rate (27.8%) and haulm weight (23.1%). However, moderate estimates were observed for and hundred kernel weight (23.9%), crop growth rate (16.9%), harvest index (19.2%) partitioning factor (14.3%) and shelling percentage (13.7%) along with lower magnitude for days to maturity (10.0%), sound mature kernel (6.4%), oil content (5.7%) and days to 75% flowering (4.9%).

Higher magnitude of GCV was recorded for oil yield (30.0%), pod yield (24.0%), pod growth rate (21.7%), kernel yield (27.1%), and hundred kernel weight (20.6%) along with Moderate values for haulm weight (19.2%), harvest index (15.9%), partitioning factor (14.3%) and crop growth rate (11.7%) respectively. The remaining traits *viz.*, shelling percentage (9.6%), days to maturity (9.5%), oil content (4.9%), days to 75% flowering (4.0%) and sound mature kernel (3.5%) exhibited low genotypic coefficient of variation.

Higher estimates of GCV for kernel yield, oil yield and pod yield and high to moderate GCV for haulm weight over all the environments reflects the genetic differences among the genotypes for these traits and effectiveness of selection.

**Heritability and Genetic advance as percent of mean (GAM)**

**Environment 1:**

The estimates of heritability for 14 traits revealed that the majority of the these traits were highly heritable in nature and the highest estimate were observed for days to maturity (92.9%) closely followed by days to 75% flowering (92.5%), haulm weight (90.0%), crop growth rate (85.3%), oil content (84.4%), hundred kernel weight (79.8%),pod yield (77.6%), harvest index (76.0%), partitioning factor (73.6%), oil yield (70.5%), pod growth rate (69.7%), and kernel yield (65.9%). Further, shelling percentage (48.0%) and sound mature kernel (45.4%) had moderate value of heritability.

High genetic advance as percent of mean was observed for traits *viz.*, oil yield (46.7%), haulm weight (42.7%), pod yield (42.0%), kernel yield (41.0%), pod growth rate (35.4%), hundred kernel weight (34.9%), crop growth rate (33.9%), partitioning factor (26.1%) and harvest index (23.9%) whereas, days to 75% flowering (15.9%) and shelling percentage (10.6%) exhibited moderate estimates of GAM.

Lower estimates were observed for oil content (8.9%), days to maturity (8.5%) and sound mature kernel (4.3%) respectively.

**Environment 2:**

In E2, high heritability was observed for traits *viz.*, days to maturity (92.9%), haulm weight (91.9%), hundred kernel weight (90.5%), pod yield (86.2%), harvest index (86.2%), partitioning factor (85.9%), days to 75% flowering (85.7%), crop growth rate (85.1%), oil yield (84.2%), kernel yield (84.1%), oil content (83.9%), pod growth rate (80.4%) and shelling percentage (68.8%).

Genetic advance as percent of mean in E2 showed higher estimates for traits *viz*., oil yield (57.3%), kernel yield (53.2%), pod yield (46.5%), haulm weight (43.6%), pod growth rate (38.4%), hundred kernel weight (32.8%), crop growth rate (28.3%), harvest index (27.8%) and partitioning factor (22.9%) while moderate estimates were observed for shelling percentage (16.5%) and days to maturity (10.5%). However, days to 75% flowering (8.2%) and oil content (8.2%) exhibited low GAM.

**Environment 3:**

Broad sense heritability estimates in E3 was higher for traits *viz*., days to maturity (91.0%), days to 75% flowering (89.9%), hundred kernel weight (85.1%), partitioning factor (82.0%), oil content (81.6%), pod yield (80.0%), haulm weight (78.7%), oil yield (76.6%), kernel yield (74.8%), harvest index (71.9%), shelling percentage (70.6%), and pod growth rate (67.9%) whereas sound mature kernel (51.2%), crop growth rate (51.1%) had moderate values of heritability.

The values pertaining to genetic advance as percent of mean revealed higher estimates for oil yield (54.8%), kernel yield (47.9%), pod yield (45.0%), haulm weight (36.3%), hundred kernel weight (34.2%), pod growth rate (29.6%), harvest index (26.1%) and partitioning factor (21.9%). Among the remaining traits days to maturity (16.9%), crop growth rate (16.4%) and shelling percentage (16.2%) showed moderate values while oil content (8.9%), days to 75% flowering (8.4%) and sound mature kernel (7.4%) were noted with lower estimates.

**Environment 4:**

A perusal of the data showed that traits such as days to maturity (95.6%), partitioning factor (86.0%), hundred kernel weight (84.5%), oil content (84.3%), days to 75% flowering (80.5%), harvest index (80.2%), haulm weight (80.0%), pod yield (76.5%), pod growth rate (75.8%), oil yield (72.4%), kernel yield (71.8%), shelling percentage (66.9%), and crop growth rate (61.6%) exhibited high heritability whereas only sound mature kernel (44.7%) showed moderate estimates of heritability.

The genetic advance as percent of mean estimates were high for traits *viz*., oil yield (59.4%), kernel yield (53.5%), pod yield (48.0%), pod growth rate (43.3%), hundred kernel weight (41.5%), haulm weight (38.0%), harvest index (31.6%), partitioning factor (25.3%) and CGR (21.4%). However, days to maturity (19.6%) and shelling percentage (18.8%) showed moderate values for GAM while oil content (9.9%), days to 75% flowering (8.1%) and sound mature kernel percentage (5.9%) were classified as low.

Higher estimates of heritability and higher genetic advance as percent of mean was found for the traits *viz.*, pod yield, kernel yield, oil yield, haulm weight, hundred kernel weight, harvest index, pod growth rate and partioning factor across four environments. Higher estimates of heritability and genetic advance as percent of mean for above mentioned traits showed the genetic potential of genotypes in the present study for these traits. Whereas, low heritability along with low to moderate genetic advance as percent of mean for days to 75 % flowering, days to maturity, shelling percentage, sound mature kernel, oil content and crop growth rate reflect less chances for improvement through selection for these traits.

## 4.4 Determination of association between traits

Grain yield is a complex character and is dependent on several contributing traits. Hence, traits associations were studied in the present investigation, to assess the relationships among yield, its components for enhancing the usefulness of selection.

**Table 4.5.** Genotypic (G) and phenotypic (P) correlation coefficients among 14 traits of groundnut genotypes across four environments.

**Environment 1**

| TRAITS | | DM | SP | KY | OC | OY | SMK% | HKW | HI | CGR | PGR | PF | H-wt | PY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days to 75% flowering (DF) | **G** | 0.65 ** | -0.08 NS | 0 NS | 0.14 NS | 0.02 NS | -0.04 NS | 0.07 NS | -0.28 ** | -0.2 * | -0.07 NS | -0.19 * | 0.08 NS | 0 NS |
| | **P** | 0.56 ** | 0.03 NS | 0.08 NS | 0.13 NS | 0.1 NS | 0.05 NS | 0.11 NS | -0.13 NS | -0.11 NS | 0.06 NS | -0.03 NS | 0.06 NS | 0.07 NS |
| Days to maturity (DM) | **G** | | -0.04 NS | 0.53 ** | 0.48 ** | 0.57 ** | -0.16 NS | 0.06 NS | -0.06 NS | 0.7 ** | 0.34 ** | -0.17 NS | 0.76 ** | 0.54 ** |
| | **P** | | -0.02 NS | 0.31 ** | 0.37 ** | 0.36 ** | -0.1 NS | 0.01 NS | -0.08 NS | 0.5 ** | 0.16 NS | -0.17 NS | 0.56 ** | 0.36 ** |
| Shelling percentage (SP) | **G** | | | 0.21 * | 0.21 * | 0.24 ** | 0.37 ** | -0.44 ** | 0.18 * | -0.17 NS | 0.03 NS | 0.16 NS | -0.25 ** | -0.03 NS |
| | **P** | | | 0.55 ** | 0.09 NS | 0.54 ** | 0.03 NS | 0.08 NS | 0.33 ** | 0.08 NS | 0.26 ** | 0.34 ** | -0.14 NS | 0.23 ** |
| Kernel yield (KY) | **G** | | | | 0.43 ** | 0.98 ** | -0.16 NS | -0.02 NS | 0.71 ** | 0.78 ** | 0.95 ** | 0.54 ** | 0.31 ** | 0.97 ** |
| | **P** | | | | 0.21 * | 0.99 ** | 0.01 NS | 0.24 ** | 0.7 ** | 0.68 ** | 0.91 ** | 0.65 ** | 0.22 * | 0.93 ** |
| Oil Content (OC) | **G** | | | | | 0.62 ** | -0.01 NS | -0.39 ** | 0.12 NS | 0.22 * | 0.23 ** | 0.04 NS | 0.15 NS | 0.38 ** |
| | **P** | | | | | 0.36 ** | -0.02 NS | -0.24 ** | 0.06 NS | 0.08 NS | 0.08 NS | 0.01 NS | 0.06 NS | 0.19 * |
| Oil Yield (OY) | **G** | | | | | | -0.15 NS | -0.09 NS | 0.61 ** | 0.83 ** | 0.9 ** | 0.49 ** | 0.33 ** | 0.94 ** |
| | **P** | | | | | | 0 NS | 0.19 * | 0.67 ** | 0.78 ** | 0.88 ** | 0.62 ** | 0.24 ** | 0.92 ** |
| Sound Mature Kernel (SMK%) | **G** | | | | | | | -0.02 NS | -0.05 NS | -0.28 ** | -0.3 ** | -0.04 NS | -0.18 * | -0.28 ** |
| | **P** | | | | | | | 0 NS | 0.14 NS | -0.09 NS | 0.03 NS | 0.16 NS | -0.16 NS | 0.01 NS |
| Hundred Kernel Weight (HKW) | **G** | | | | | | | | -0.04 NS | 0.28 ** | 0.15 NS | -0.05 NS | 0.21 * | 0.1 NS |
| | **P** | | | | | | | | 0.14 NS | 0.27 ** | 0.28 ** | 0.15 NS | 0.12 NS | 0.24 ** |
| Harvest Index (HI) | **G** | | | | | | | | | 0.28 ** | 0.76 ** | 0.98 ** | -0.51 ** | 0.63 ** |
| | **P** | | | | | | | | | 0.33 ** | 0.76 ** | 0.98 ** | -0.47 ** | 0.71 ** |
| Crop Growth Rate (CGR) | **G** | | | | | | | | | | 0.83 ** | 0.15 NS | 0.71 ** | 0.87 ** |
| | **P** | | | | | | | | | | 0.83 ** | 0.26 ** | 0.74 ** | 0.77 ** |
| Pod Growth Rate (PGR) | **G** | | | | | | | | | | | 0.67 ** | 0.18 * | 0.96 ** |
| | **P** | | | | | | | | | | | 0.74 ** | 0.18 * | 0.96 ** |
| Partitioning Factor (PF) | **G** | | | | | | | | | | | | -0.57 ** | 0.51 ** |
| | **P** | | | | | | | | | | | | -0.51 ** | 0.64 ** |
| Haulm weight (H-wt) | **G** | | | | | | | | | | | | | 0.37 ** |
| | **P** | | | | | | | | | | | | | 0.32 ** |

** and * Significant at 1% and 5% probability level; PY= pod yield

**Table 4.5 (Cont.).**
**Environment 2**

| TRAITS | | DM | SP | KY | OC | OY | SMK% | HKW | HI | CGR | PGR | PF | H-wt | PY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days to 75% flowering (DF) | **G** | 0.52 ** | -0.29 ** | 0.01 NS | -0.07 NS | 0 NS | -0.66 ** | 0.32 ** | -0.38 ** | 0.36 ** | -0.01 NS | -0.38 ** | 0.55 ** | 0.12 NS |
| | **P** | 0.35 ** | -0.18 * | 0.04 NS | -0.07 NS | 0.02 NS | -0.05 NS | 0.25 ** | -0.23 ** | 0.26 ** | 0.07 NS | -0.2 * | 0.39 ** | 0.12 NS |
| Days to maturity (DM) | **G** | | -0.17 NS | 0.45 ** | 0.37 ** | 0.48 ** | 0.09 NS | 0.33 ** | -0.15 NS | 0.72 ** | 0.3 ** | -0.32 ** | 0.82 ** | 0.58 ** |
| | **P** | | -0.14 NS | 0.36 ** | 0.29 ** | 0.38 ** | -0.02 NS | 0.26 ** | -0.13 NS | 0.57 ** | 0.18 * | -0.3 ** | 0.73 ** | 0.49 ** |
| Shelling percentage (SP) | **G** | | | 0.56 ** | 0.14 NS | 0.54 ** | 0.46 ** | -0.03 NS | 0.44 ** | 0.01 NS | 0.32 ** | 0.4 ** | -0.26 ** | 0.23 ** |
| | **P** | | | 0.54 ** | 0.14 NS | 0.52 ** | 0.25 ** | 0.07 NS | 0.31 ** | 0.02 NS | 0.25 ** | 0.29 ** | -0.17 NS | 0.18 * |
| Kernel yield (KY) | **G** | | | | 0.41 ** | 0.99 ** | 0.53 ** | 0.31 ** | 0.64 ** | 0.71 ** | 0.91 ** | 0.52 ** | 0.24 ** | 0.93 ** |
| | **P** | | | | 0.39 ** | 0.99 ** | 0.24 ** | 0.3 ** | 0.66 ** | 0.72 ** | 0.89 ** | 0.57 ** | 0.23 ** | 0.92 ** |
| Oil Content (OC) | **G** | | | | | 0.53 ** | 0.71 ** | -0.12 NS | 0.21 * | 0.35 ** | 0.32 ** | 0.11 NS | 0.23 ** | 0.41 ** |
| | **P** | | | | | 0.52 ** | 0.11 NS | -0.07 NS | 0.23 ** | 0.31 ** | 0.31 ** | 0.16 NS | 0.16 NS | 0.39 ** |
| Oil Yield (OY) | **G** | | | | | | 0.58 ** | 0.26 ** | 0.61 ** | 0.72 ** | 0.89 ** | 0.49 ** | 0.26 ** | 0.93 ** |
| | **P** | | | | | | 0.24 ** | 0.27 ** | 0.64 ** | 0.71 ** | 0.87 ** | 0.55 ** | 0.24 ** | 0.91 ** |
| Sound Mature Kernel (SMK%) | **G** | | | | | | | -0.04 NS | 0.59 ** | 0.2 * | 0.52 ** | 0.48 ** | -0.13 NS | 0.44 ** |
| | **P** | | | | | | | 0.06 NS | 0.21 * | 0.1 NS | 0.2 * | 0.21 * | -0.03 NS | 0.18 * |
| Hundred Kernel Weight (HKW) | **G** | | | | | | | | 0.11 NS | 0.46 ** | 0.37 ** | 0.07 NS | 0.35 ** | 0.38 ** |
| | **P** | | | | | | | | 0.12 NS | 0.39 ** | 0.32 ** | 0.1 NS | 0.3 ** | 0.34 ** |
| Harvest Index (HI) | **G** | | | | | | | | | 0.05 NS | 0.76 ** | 0.98 ** | -0.5 ** | 0.62 ** |
| | **P** | | | | | | | | | 0.13 NS | 0.76 ** | 0.98 ** | -0.47 ** | 0.64 ** |
| Crop Growth Rate (CGR) | **G** | | | | | | | | | | 0.68 ** | -0.07 NS | 0.79 ** | 0.83 ** |
| | **P** | | | | | | | | | | 0.7 ** | 0.04 NS | 0.77 ** | 0.84 ** |
| Pod Growth Rate (PGR) | **G** | | | | | | | | | | | 0.67 ** | 0.12 NS | 0.95 ** |
| | **P** | | | | | | | | | | | 0.71 ** | 0.13 NS | 0.93 ** |
| Partitioning Factor (PF) | **G** | | | | | | | | | | | | -0.61 ** | 0.44 ** |
| | **P** | | | | | | | | | | | | -0.56 ** | 0.51 ** |
| Haulm weight (H-wt) | **G** | | | | | | | | | | | | | 0.39 ** |
| | **P** | | | | | | | | | | | | | 0.36 ** |

** and * Significant at 1% and 5% probability level; PY= pod yield

**Table 4.5 (Cont.).**
**Environment 3**

| TRAITS | | DM | SP | KY | OC | OY | SMK% | HKW | HI | CGR | PGR | PF | H-wt | PY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days to 75% flowering (DF) | **G** | 0.67 ** | -0.07 NS | 0.31 ** | 0.2 * | 0.31 ** | -0.2 * | 0.25 ** | 0.1 NS | 0.21 * | 0.1 NS | -0.09 NS | 0.38 ** | 0.39 ** |
| | **P** | 0.56 ** | -0.01 NS | 0.17 NS | 0.16 NS | 0.18 * | -0.08 NS | 0.19 * | 0.02 NS | 0.03 NS | -0.03 NS | -0.09 NS | 0.25 ** | 0.2 * |
| Days to maturity (DM) | **G** | | 0.05 NS | 0.69 ** | 0.61 ** | 0.7 ** | -0.31 ** | 0.51 ** | 0.36 ** | 0.63 ** | 0.29 ** | -0.12 NS | 0.65 ** | 0.76 ** |
| | **P** | | -0.01 NS | 0.53 ** | 0.51 ** | 0.55 ** | -0.15 NS | 0.39 ** | 0.31 ** | 0.31 ** | 0.16 NS | -0.12 NS | 0.5 ** | 0.61 ** |
| Shelling percentage (SP) | **G** | | | 0.39 ** | 0.05 NS | 0.35 ** | 0.62 ** | -0.07 NS | 0.15 NS | -0.43 ** | -0.03 NS | 0.26 ** | -0.35 ** | 0.01 NS |
| | **P** | | | 0.49 ** | 0.12 NS | 0.46 ** | 0.33 ** | 0.07 NS | 0.22 * | -0.03 NS | 0.2 * | 0.31 ** | -0.21 * | 0.14 NS |
| Kernel yield (KY) | **G** | | | | 0.68 ** | 0.99 ** | -0.04 NS | 0.33 ** | 0.82 ** | 0.46 ** | 0.78 ** | 0.56 ** | 0.09 NS | 0.92 ** |
| | **P** | | | | 0.56 ** | 0.99 ** | 0.05 NS | 0.34 ** | 0.67 ** | 0.58 ** | 0.82 ** | 0.52 ** | 0.19 * | 0.93 ** |
| Oil Content (OC) | **G** | | | | | 0.77 ** | -0.14 NS | 0.14 NS | 0.43 ** | 0.75 ** | 0.49 ** | 0.09 NS | 0.47 ** | 0.73 ** |
| | **P** | | | | | 0.66 ** | -0.1 NS | 0.17 NS | 0.27 ** | 0.42 ** | 0.37 ** | 0.09 NS | 0.34 ** | 0.57 ** |
| Oil Yield (OY) | **G** | | | | | | -0.07 NS | 0.31 ** | 0.78 ** | 0.53 ** | 0.76 ** | 0.5 ** | 0.17 NS | 0.93 ** |
| | **P** | | | | | | 0.03 NS | 0.33 ** | 0.64 ** | 0.59 ** | 0.79 ** | 0.48 ** | 0.23 ** | 0.93 ** |
| Sound Mature Kernel (SMK%) | **G** | | | | | | | 0.08 NS | -0.21 * | -0.36 ** | -0.21 * | 0.03 NS | -0.22 * | -0.33 ** |
| | **P** | | | | | | | 0.06 NS | -0.04 NS | -0.02 NS | -0.01 NS | 0.02 NS | -0.06 NS | -0.09 NS |
| Hundred Kernel Weight (HKW) | **G** | | | | | | | | 0.29 ** | 0.15 NS | 0.19 * | 0.02 NS | 0.3 ** | 0.4 ** |
| | **P** | | | | | | | | 0.28 ** | 0.17 NS | 0.22 * | 0.1 NS | 0.17 NS | 0.37 ** |
| Harvest Index (HI) | **G** | | | | | | | | | 0.14 NS | 0.9 ** | 0.9 ** | -0.37 ** | 0.83 ** |
| | **P** | | | | | | | | | 0.1 NS | 0.65 ** | 0.79 ** | -0.33 ** | 0.68 ** |
| Crop Growth Rate (CGR) | **G** | | | | | | | | | | 0.47 ** | -0.12 NS | 0.79 ** | 0.65 ** |
| | **P** | | | | | | | | | | 0.67 ** | -0.08 NS | 0.7 ** | 0.68 ** |
| Pod Growth Rate (PGR) | **G** | | | | | | | | | | | 0.8 ** | -0.16 NS | 0.84 ** |
| | **P** | | | | | | | | | | | 0.67 ** | 0.07 NS | 0.85 ** |
| Partitioning Factor (PF) | **G** | | | | | | | | | | | | -0.69 ** | 0.5 ** |
| | **P** | | | | | | | | | | | | -0.65 ** | 0.47 ** |
| Haulm weight (H-wt) | **G** | | | | | | | | | | | | | 0.24 ** |
| | **P** | | | | | | | | | | | | | 0.31 ** |

** and * Significant at 1% and 5% probability level; PY= pod yield

**Table 4.5 (Cont.).**

**Environment 4**

| TRAITS | | DM | SP | KY | OC | OY | SMK% | HKW | HI | CGR | PGR | PF | H-wt | PY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days to 75% flowering (DF) | G | 0.67 ** | 0.27 ** | 0.14 NS | 0.18 * | 0.14 NS | 0.34 ** | 0.35 ** | -0.29 ** | 0.05 NS | -0.32 ** | -0.41 ** | 0.54 ** | 0.08 NS |
| | P | 0.51 ** | 0.17 NS | 0.06 NS | 0.16 NS | 0.05 NS | 0.23 ** | 0.23 ** | -0.2 * | -0.07 NS | -0.22 * | -0.27 ** | 0.29 ** | 0.01 NS |
| Days to maturity (DM) | G | | 0.24 ** | 0.47 ** | 0.38 ** | 0.46 ** | 0.54 ** | 0.56 ** | -0.14 NS | 0.34 ** | -0.16 NS | -0.42 ** | 0.77 ** | 0.46 ** |
| | P | | 0.24 ** | 0.43 ** | 0.3 ** | 0.43 ** | 0.24 ** | 0.48 ** | -0.02 NS | 0.22 * | -0.08 NS | -0.29 ** | 0.61 ** | 0.42 ** |
| Shelling percentage (SP) | G | | | 0.59 ** | 0.27 ** | 0.56 ** | 0.64 ** | 0.06 NS | 0.34 ** | 0.07 NS | 0.2 * | 0.26 ** | -0.02 NS | 0.28 ** |
| | P | | | 0.62 ** | 0.23 ** | 0.6 ** | 0.19 * | 0.25 ** | 0.34 ** | 0.08 NS | 0.24 ** | 0.28 ** | -0.01 NS | 0.31 ** |
| Kernel yield (KY) | G | | | | 0.61 ** | 0.98 ** | 0.3 ** | 0.4 ** | 0.7 ** | 0.74 ** | 0.73 ** | 0.52 ** | 0.25 ** | 0.94 ** |
| | P | | | | 0.43 ** | 0.98 ** | 0.08 NS | 0.43 ** | 0.7 ** | 0.66 ** | 0.78 ** | 0.55 ** | 0.29 ** | 0.93 ** |
| Oil Content (OC) | G | | | | | 0.74 ** | -0.31 ** | 0.07 NS | 0.22 * | 0.49 ** | 0.33 ** | 0.08 NS | 0.38 ** | 0.55 ** |
| | P | | | | | 0.55 ** | -0.01 NS | 0.17 NS | 0.2 * | 0.26 ** | 0.23 ** | 0.11 NS | 0.22 * | 0.39 ** |
| Oil Yield (OY) | G | | | | | | 0.22 * | 0.36 ** | 0.66 ** | 0.74 ** | 0.71 ** | 0.49 ** | 0.29 ** | 0.92 ** |
| | P | | | | | | 0.05 NS | 0.41 ** | 0.69 ** | 0.65 ** | 0.75 ** | 0.53 ** | 0.29 ** | 0.91 ** |
| Sound Mature Kernel (SMK%) | G | | | | | | | 0.58 ** | -0.05 NS | -0.11 NS | -0.22 * | -0.23 ** | 0.26 ** | 0.09 NS |
| | P | | | | | | | 0.29 ** | -0.06 NS | 0.02 NS | -0.1 NS | -0.11 NS | 0.13 NS | 0.02 NS |
| Hundred Kernel Weight (HKW) | G | | | | | | | | 0.18 * | 0.42 ** | 0.18 * | 0.01 NS | 0.45 ** | 0.46 ** |
| | P | | | | | | | | 0.2 * | 0.31 ** | 0.22 * | 0.07 NS | 0.33 ** | 0.42 ** |
| Harvest Index (HI) | G | | | | | | | | | 0.38 ** | 0.89 ** | 0.96 ** | -0.42 ** | 0.71 ** |
| | P | | | | | | | | | 0.27 ** | 0.79 ** | 0.95 ** | -0.37 ** | 0.7 ** |
| Crop Growth Rate (CGR) | G | | | | | | | | | | 0.72 ** | 0.28 ** | 0.6 ** | 0.84 ** |
| | P | | | | | | | | | | 0.75 ** | 0.19 * | 0.69 ** | 0.78 ** |
| Pod Growth Rate (PGR) | G | | | | | | | | | | | 0.88 ** | -0.17 NS | 0.8 ** |
| | P | | | | | | | | | | | 0.78 ** | 0.08 NS | 0.86 ** |
| Partitioning Factor (PF) | G | | | | | | | | | | | | -0.59 ** | 0.52 ** |
| | P | | | | | | | | | | | | -0.52 ** | 0.55 ** |
| Haulm weight (H-wt) | G | | | | | | | | | | | | | 0.31 ** |
| | P | | | | | | | | | | | | | 0.37 ** |

** and * Significant at 1% and 5% probability level; PY= pod yield

The result pertaining to genotypic and phenotypic correlations has been presented in Table 4.5 for each of the four environments. In the following description pertaining genotypic correlation has been described.

**Environment 1:**

The data revealed that PY expressed highly significant and positive association with days to maturity, kernel yield, oil yield, oil content, crop growth rate, harvest index, pod growth rate, partitioning factor and haulm weight while highly significant and negative association was found with sound mature kernel percentage.

Days to 75 % flowering were highly significant and positively associated with days to maturity whereas negative and significant association with harvest index, crop growth rate and partitioning factor. However, days to maturity found to be positively and significantly associated with kernel yield, oil content, oil yield, crop growth rate, pod growth rate and haulm weight.

Shelling percentage was highly significantly and positively associated with oil yield, sound mature kernel percentage and significantly associated with kernel yield, oil content, and harvest index while negative and significant association was found for hundred kernel weight and haulm weight. Sound mature kernel percentage exhibited highly significant and negative association with crop growth rate and pod growth rate.

Kernel yield and oil yield both showed positive and highly significant correlation with pod growth rate, harvest index, crop growth rate, partitioning factor, haulm weight and oil content.

Oil content showed highly significant and negative association with hundred kernel weight and highly significant and positive association with pod growth rate.

Hundred kernel weight showed positive and highly significant correlations with crop growth rate while harvest index exhibited highly positive significant correlation with crop growth rate, pod growth rate and partioning factor but exhibited negative significant associations with haulm weight.

Crop growth rate showed positive and highly significant association with pod growth rate and haulm weight. Pod growth rate exhibited high positive significant association with partitioning factor while partitioning factor exhibited negative and highly significant correlation with haulm weight.

**Environment 2:**

A perusal of correlation co-efficient in E2 revealed that pod yield expressed highly significant and positive association with days to maturity, shelling percentage, kernel yield, oil content, oil yield, sound mature kernel percentage, hundred kernel weight, harvest index, crop growth rate, pod growth rate, partitioning factor and haulm weight.

Days to 75 % flowering recorded positive and highly significant association with days to maturity, hundred kernel weight, crop growth rate and haulm weight while negative and significant correlation with shelling percentage, sound mature kernel percentage and partitioning factor.

Days to maturity exhibited highly significant and positive correlation coefficients with kernel yield, oil content, oil yield, hundred kernel weight, crop growth rate, pod growth rate and haulm weight. However, negative significant correlation was expressed for partitioning factor.

Shelling percentage was found to have positive and highly significant correlation with kernel yield, oil yield, sound mature kernel percentage, pod growth rate, partitioning factor, and harvest index while negative and significant association was found for haulm weight. Sound mature kernel exhibited highly significant and positive association with harvest index, pod growth rate and partitioning factor.

However, kernel yield and oil yield showed highly significant and positive association with oil content, sound mature kernel percentage, harvest index, crop growth rate, pod growth rate, partitioning factor, haulm weight and hundred kernel weight.

Oil content expressed highly significant and positive association with sound mature kernel percentage, pod growth rate, crop growth rate.

Hundred kernel weight was found to have positive and highly significant correlation with crop growth rate, pod growth rate and haulm weight. Moreover, harvest index showed positive and highly significant association with pod growth rate and partitioning factor while negative highly significant association for haulm weight.

Crop growth rate exhibited highly significant and positive association with pod growth rate and haulm weight. Pod growth rate showed highly significant and positive association with partitioning factor. Further, partitioning factor showed negative and highly significant correlation with haulm weight.

**Environment 3:**

The correlation coefficient analysis in E3 showed that pod yield exhibits highly significant and positive association with days to 75 % flowering, days to maturity, kernel yield, oil content, oil yield, hundred kernel weight, harvest index, pod growth rate, partitioning factor, haulm weight and crop growth rate. Sound mature kernel showed highly significant but negative association.

Days to 75 % flowering expressed highly significant and positive association to traits days to maturity, kernel yield, oil yield, hundred kernel weight and haulm weight. However, days to maturity showed positive and highly significant correlation with kernel yield, oil content, oil yield, hundred kernel weight, crop growth rate, pod growth rate, haulm weight and harvest index. Both DF and DM showed negative significant association with sound mature kernel percentage.

Shelling percentage was highly correlated with sound mature kernel, kernel yield and partitioning factor in positive direction while negative and highly significant association was recorded for crop growth rate. Sound mature kernel exhibited highly significant and significant negative association with crop growth rate, harvest index, pod growth rate and haulm weight.

Kernel yield and oil yield was observed to have highly significant and positive association with oil content, harvest index, crop growth rate, pod growth rate, partitioning factor and hundred kernel weight.

Oil content showed highly significant and positive association with harvest index, haulm weight, crop growth rate and pod growth rate.

Moreover, hundred kernel weight was highly significant and positively associated with harvest index and haulm weight. Further, harvest index expressed positive and highly significant association with pod growth rate and partitioning factor in contrary non-significant association with haulm weight.

Crop growth rate was highly significant and positively associated with haulm weight and pod growth rate. Moreover, pod growth rate showed highly significant and positive association with partitioning factor and partitioning factor is negatively and highly significantly correlated with haulm weight.

**Environment 4:**

The data revealed that pod yield expressed highly significant and positive association with days to maturity, kernel yield, oil content, oil yield, shelling percentage, harvest index, hundred kernel weight, crop growth rate, pod growth rate, partitioning factor and haulm weight.

Days to 75 % flowering were highly significant and positively associated with days to maturity, shelling percentage, sound mature kernel percentage, hundred kernel weight and haulm weight and negative but highly significant association with harvest index, pod growth rate and partitioning factor. Other than the above associations days to maturity registered positive and highly significant correlation with kernel yield, oil content, oil yield and crop growth rate while negative but highly significant association with partitioning factor.

Shelling percentage expressed highly significant and positive association with kernel yield, oil content, sound mature kernel percentage, harvest index, partitioning factor and oil yield. However, sound mature kernel showed highly significant and positive association with hundred kernel weight and haulm weight while negative significant correlation with pod growth rate and partitioning factor.

For kernel and oil yield positive and highly significant correlation was recorded for oil content, sound mature kernel percentage, hundred kernel weight, harvest index, crop growth rate, pod growth rate, partitioning factor and haulm weight.

Oil content was significantly and positively associated with pod growth rate, crop growth rate and haulm weight and negative highly significant correlation with sound mature kernel percentage.

Hundred kernel weight showed positive and highly significant correlations with haulm weight and crop growth rate. Further, harvest index exhibited highly positive significant correlation with crop growth rate, pod growth rate and partioning factor but exhibited highly significant negative associations for haulm weight.

Crop growth rate showed positive and highly significant association with pod growth rate and haulm weight. Pod growth rate exhibited high positive significant association with partitioning factor and partitioning factor showed negative and highly significant association with haulm weight.

## 4.4 Screening of heat tolerant genotypes

The mean performance of genotypes for all the characters under study has been presented in Table 4.6, 4.7 and 4.8. In general a wide range of mean values within the genotypes were found for the respective characters. The mean performances of the genotypes have been characterized based on the overall of each trait in respective environment.

### 4.4.1 Days to 75% flowering (DF 75%)

In E1 Significant difference was observed for days to 75% flowering among the genotypes in the present study. Twenty genotypes were found significantly earlier than overall mean of the environment. The earliest flowering genotypes were ICGV 89280 and ICGV 96346 (35days). Moreover, nine genotypes were found delayed flowering wherein maximum of 50 days was observed for ICGV 07456.

**Table 4.6** Mean performance for days to 75% flowering, days to maturity, haulm weight and pod yield studied in groundnut genotypes across four environments (E1, E2, E3 and E4).

| S.No. | Genotypes | Days to 75% flowering | | | | Days to maturity | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | E1 | E2 | E3 | E4 | E1 | E2 | E3 | E4 |
| 1 | ICGV 00298 | 38 | 35 | 34 | 32 | 123 | 119 | 109 | 103 |
| 2 | ICGV 00308 | 38 | 36 | 33 | 30 | 124 | 118 | 108 | 111 |
| 3 | ICGV 00350 | 40 | 37 | 34 | 32 | 138 | 129 | 127 | 129 |
| 4 | ICGV 00351 | 38 | 37 | 33 | 31 | 137 | 124 | 129 | 122 |
| 5 | ICGV 03042 | 38 | 35 | 34 | 32 | 135 | 130 | 133 | 136 |
| 6 | ICGV 03057 | 40 | 36 | 35 | 33 | 135 | 135 | 134 | 137 |
| 7 | ICGV 03109 | 42 | 39 | 37 | 33 | 138 | 133 | 137 | 134 |
| 8 | ICGV 05032 | 38 | 37 | 35 | 33 | 139 | 136 | 136 | 134 |
| 9 | ICGV 05155 | 39 | 35 | 35 | 33 | 139 | 138 | 137 | 116 |
| 10 | ICGV 07456 | 50 | 40 | 39 | 37 | 138 | 128 | 129 | 134 |
| 11 | ICGV 06039 | 44 | 39 | 36 | 33 | 138 | 138 | 134 | 134 |
| 12 | ICGV 06040 | 43 | 37 | 35 | 34 | 137 | 132 | 135 | 138 |
| 13 | ICGV 06099 | 44 | 38 | 35 | 32 | 133 | 132 | 123 | 134 |
| 14 | ICGV 06175 | 43 | 40 | 35 | 33 | 136 | 137 | 136 | 136 |
| 15 | ICGV 06420 | 40 | 36 | 34 | 32 | 138 | 136 | 132 | 138 |
| 16 | ICGV 06424 | 41 | 37 | 34 | 33 | 139 | 137 | 137 | 133 |
| 17 | ICGV 07012 | 40 | 38 | 35 | 32 | 139 | 136 | 137 | 136 |
| 18 | ICGV 07013 | 44 | 39 | 34 | 34 | 137 | 129 | 133 | 134 |
| 19 | ICGV 07038 | 38 | 36 | 34 | 31 | 135 | 134 | 134 | 134 |
| 20 | ICGV 05200 | 42 | 39 | 35 | 33 | 131 | 120 | 127 | 115 |
| 21 | ICGV 07148 | 41 | 38 | 35 | 34 | 138 | 127 | 137 | 137 |
| 22 | ICGV 07211 | 38 | 36 | 34 | 31 | 124 | 119 | 115 | 114 |
| 23 | ICGV 07213 | 39 | 36 | 34 | 30 | 131 | 125 | 121 | 113 |
| 24 | ICGV 07217 | 38 | 35 | 33 | 31 | 131 | 117 | 112 | 108 |
| 25 | ICGV 07246 | 43 | 39 | 37 | 32 | 138 | 134 | 139 | 136 |
| 26 | ICGV 07268 | 40 | 38 | 35 | 32 | 134 | 129 | 134 | 134 |
| 27 | ICGV 07273 | 47 | 40 | 36 | 33 | 138 | 126 | 132 | 133 |
| 28 | ICGV 07356 | 47 | 40 | 37 | 36 | 137 | 136 | 132 | 134 |
| 29 | ICGV 86325 | 44 | 40 | 36 | 33 | 138 | 125 | 130 | 115 |
| 30 | ICGV 87128 | 39 | 36 | 35 | 32 | 130 | 118 | 124 | 117 |
| 31 | ICGV 87141 | 44 | 39 | 38 | 35 | 138 | 133 | 134 | 137 |
| 32 | ICGV 87846 | 42 | 38 | 34 | 32 | 135 | 136 | 134 | 135 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 33 | ICGV 89280 | 35 | 35 | 33 | 30 | 130 | 126 | 128 | 134 |
| 35 | ICGV 91114 | 37 | 35 | 31 | 29 | 125 | 117 | 105 | 110 |
| 36 | ICGV 92035 | 39 | 37 | 35 | 32 | 132 | 125 | 134 | 116 |
| 37 | ICGV 92195 | 37 | 36 | 34 | 31 | 123 | 118 | 109 | 112 |
| 38 | ICGV 93468 | 38 | 35 | 32 | 30 | 123 | 119 | 112 | 109 |
| 39 | ICGV 95390 | 41 | 37 | 34 | 30 | 135 | 121 | 122 | 116 |
| 40 | ICGV 96346 | 35 | 36 | 32 | 31 | 125 | 117 | 109 | 106 |
| 41 | ICGV 97182 | 38 | 36 | 33 | 31 | 131 | 122 | 124 | 113 |
| 42 | ICGV 97183 | 43 | 37 | 34 | 32 | 131 | 125 | 130 | 123 |
| 43 | ICGV 98294 | 47 | 39 | 38 | 34 | 131 | 120 | 122 | 114 |
| 44 | TAG 24 | 38 | 35 | 33 | 29 | 123 | 120 | 128 | 101 |
| 45 | TCGS 1043 | 39 | 35 | 33 | 30 | 124 | 121 | 109 | 104 |
| 46 | TG 37 | 41 | 36 | 34 | 31 | 124 | 120 | 117 | 111 |
| 47 | TMV 2 | 37 | 36 | 34 | 31 | 123 | 118 | 109 | 112 |
| 48 | TPG 41 | 41 | 38 | 33 | 31 | 138 | 137 | 129 | 134 |
| 49 | VRI 6 | 43 | 37 | 34 | 31 | 134 | 132 | 128 | 128 |
| 50 | Abhaya | 40 | 35 | 34 | 31 | 139 | 130 | 125 | 117 |
| 51 | Chico | 38 | 35 | 33 | 32 | 125 | 118 | 109 | 102 |
| 52 | GJG 31 | 39 | 37 | 34 | 31 | 124 | 118 | 107 | 112 |
| 53 | ICGS 11 | 39 | 35 | 35 | 31 | 132 | 130 | 129 | 139 |
| 54 | ICGV 99001 | 42 | 37 | 34 | 32 | 131 | 122 | 106 | 115 |
| 55 | ICGV 01232 | 39 | 36 | 33 | 31 | 124 | 118 | 109 | 117 |
| 56 | ICGV 02266 | 38 | 36 | 33 | 33 | 134 | 124 | 132 | 128 |
| 57 | ICGV 02271 | 40 | 39 | 35 | 32 | 136 | 130 | 125 | 116 |
| 58 | GG 20 | 41 | 39 | 35 | 33 | 134 | 132 | 129 | 129 |
| 59 | J 11 | 36 | 36 | 31 | 29 | 125 | 117 | 109 | 102 |
| 60 | GPBD 4 | 42 | 36 | 33 | 31 | 135 | 121 | 123 | 109 |
| 61 | JL 24 | 38 | 37 | 33 | 30 | 123 | 118 | 109 | 114 |
| 62 | K 6 | 39 | 35 | 32 | 31 | 125 | 121 | 106 | 109 |
| 63 | 55-437 | NA | 38 | 34 | 31 | NA | 119 | 108 | 110 |
| Co-efficient of Variation | | 3 | 2 | 2 | 3 | 2 | 2 | 4 | 3 |
| Mean | | 41 | 37 | 34 | 32 | 132 | 126 | 124 | 122 |
| Least Significant Difference | | 2 | 1 | 1 | 1 | 4 | 5 | 10 | 7 |
| R-Square | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Range | MINIMUM | 35 | 35 | 31 | 29 | 123 | 117 | 105 | 101 |
| | MAXIMUM | 50 | 40 | 39 | 37 | 139 | 138 | 139 | 139 |

Table 4.6 (Cont.).

| S.No. | Genotypes | Haulm weight (Kg ha$^{-1}$) | | | | Pod yield (Kg ha$^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | E1 | E2 | E3 | E4 | E1 | E2 | E3 | E4 |
| 1 | ICGV 00298 | 7480 | 7542 | 7016 | 6105 | 3582 | 4235 | 3634 | 3274 |
| 2 | ICGV 00308 | 5731 | 5482 | 4966 | 6221 | 4501 | 3312 | 3336 | 3435 |
| 3 | ICGV 00350 | 8507 | 8963 | 10016 | 7472 | 4737 | 5497 | 5428 | 4818 |
| 4 | ICGV 00351 | 9158 | 7891 | 11345 | 9969 | 5544 | 4473 | 5492 | 4838 |
| 5 | ICGV 03042 | 8168 | 7833 | 8830 | 9643 | 5662 | 5841 | 6192 | 6180 |
| 6 | ICGV 03057 | 8181 | 10496 | 8199 | 9023 | 4692 | 5742 | 5844 | 5271 |
| 7 | ICGV 03109 | 8063 | 9192 | 10552 | 12038 | 5429 | 4362 | 5246 | 3747 |
| 8 | ICGV 05032 | 9688 | 9859 | 9891 | 12214 | 6188 | 4568 | 5482 | 5635 |
| 9 | ICGV 05155 | 8489 | 10415 | 9505 | 10479 | 6219 | 5733 | 5817 | 4250 |
| 10 | ICGV 07456 | 9141 | 10567 | 9966 | 8360 | 2855 | 2947 | 3299 | 2769 |
| 11 | ICGV 06039 | 10032 | 10494 | 8889 | 10063 | 6041 | 6536 | 5308 | 5605 |
| 12 | ICGV 06040 | 9545 | 8367 | 8973 | 9636 | 5884 | 4881 | 6767 | 5606 |
| 13 | ICGV 06099 | 8402 | 7907 | 8620 | 8568 | 6080 | 4816 | 4840 | 5410 |
| 14 | ICGV 06175 | 10310 | 12179 | 11799 | 11721 | 4462 | 3962 | 3888 | 2892 |
| 15 | ICGV 06420 | 7866 | 8232 | 8200 | 10303 | 5089 | 5188 | 5198 | 5131 |
| 16 | ICGV 06424 | 9315 | 10119 | 10035 | 10387 | 6586 | 4996 | 6597 | 4496 |
| 17 | ICGV 07012 | 9021 | 10763 | 8505 | 10353 | 6761 | 5947 | 6072 | 5237 |
| 18 | ICGV 07013 | 8496 | 9866 | 7901 | 10324 | 5250 | 4696 | 4717 | 4664 |
| 19 | ICGV 07038 | 7790 | 9448 | 8153 | 8549 | 5206 | 5267 | 6521 | 5678 |
| 20 | ICGV 05200 | 10083 | 9831 | 10349 | 9178 | 4482 | 4211 | 5154 | 4152 |
| 21 | ICGV 07148 | 10166 | 10069 | 9845 | 10313 | 5714 | 4189 | 5815 | 4346 |
| 22 | ICGV 07211 | 7058 | 6396 | 8718 | 8436 | 4002 | 2648 | 3539 | 3370 |
| 23 | ICGV 07213 | 6802 | 7414 | 6655 | 7252 | 5360 | 5082 | 4483 | 4713 |
| 24 | ICGV 07217 | 5613 | 6526 | 7530 | 6094 | 4155 | 4513 | 4609 | 3740 |
| 25 | ICGV 07246 | 7315 | 8783 | 7142 | 8887 | 6416 | 6622 | 6761 | 5385 |
| 26 | ICGV 07268 | 6532 | 6692 | 6476 | 9648 | 6248 | 5609 | 5051 | 4922 |
| 27 | ICGV 07273 | 7469 | 7692 | 6889 | 7605 | 5379 | 5945 | 5212 | 4402 |
| 28 | ICGV 07356 | 8180 | 9915 | 9322 | 8824 | 4682 | 4388 | 3685 | 2661 |
| 29 | ICGV 86325 | 8092 | 8326 | 9863 | 8851 | 2205 | 2868 | 2854 | 1995 |
| 30 | ICGV 87128 | 6329 | 6512 | 6884 | 6534 | 3923 | 3798 | 3774 | 3925 |
| 31 | ICGV 87141 | 7300 | 8610 | 9010 | 9178 | 3511 | 3235 | 3705 | 3512 |
| 32 | ICGV 87846 | 10002 | 11018 | 10032 | 10368 | 3529 | 3164 | 4622 | 4045 |
| 33 | ICGV 89280 | 8992 | 9082 | 7758 | 8447 | 5246 | 4690 | 4648 | 4915 |
| 35 | ICGV 91114 | 7239 | 6664 | 6401 | 7594 | 4026 | 3309 | 2751 | 3302 |
| 36 | ICGV 92035 | 7305 | 8482 | 11349 | 10421 | 4066 | 4720 | 4941 | 3652 |
| 37 | ICGV 92195 | 6909 | 6502 | 6332 | 6724 | 3429 | 3094 | 3452 | 2892 |
| 38 | ICGV 93468 | 5165 | 4199 | 5380 | 6757 | 4220 | 3942 | 3954 | 5338 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 39 | ICGV 95390 | 7180 | 7933 | 9295 | 7752 | 3841 | 4182 | 4064 | 3204 |
| 40 | ICGV 96346 | 6062 | 6696 | 6567 | 6486 | 4062 | 3237 | 4259 | 3089 |
| 41 | ICGV 97182 | 7425 | 7780 | 8685 | 8021 | 4482 | 4017 | 4824 | 4643 |
| 42 | ICGV 97183 | 7494 | 7773 | 8976 | 7912 | 5393 | 4434 | 3761 | 3508 |
| 43 | ICGV 98294 | 6113 | 6831 | 5863 | 6365 | 4244 | 3851 | 3600 | 4180 |
| 44 | TAG 24 | 4252 | 3811 | 5497 | 4464 | 4603 | 4468 | 5149 | 4879 |
| 45 | TCGS 1043 | 7179 | 8118 | 7035 | 7608 | 3988 | 3811 | 4256 | 4337 |
| 46 | TG 37 | 5928 | 5596 | 6849 | 6648 | 4558 | 4397 | 5033 | 4494 |
| 47 | TMV 2 | 7825 | 6757 | 7516 | 8209 | 2523 | 2630 | 2253 | 2357 |
| 48 | TPG 41 | 10644 | 9275 | 10597 | 10765 | 4590 | 3846 | 3996 | 2941 |
| 49 | VRI 6 | 11058 | 10534 | 10676 | 10772 | 3735 | 3106 | 3726 | 2841 |
| 50 | Abhaya | 7681 | 7277 | 7029 | 7957 | 4715 | 3326 | 3302 | 3093 |
| 51 | Chico | 5403 | 6100 | 6011 | 5991 | 3265 | 3587 | 3769 | 2522 |
| 52 | GJG 31 | 6469 | 6345 | 6758 | 8412 | 3308 | 3942 | 3935 | 4895 |
| 53 | ICGS 11 | 7790 | 6610 | 7299 | 6973 | 4484 | 3371 | 3645 | 3454 |
| 54 | ICGV 99001 | 7428 | 7604 | 7061 | 6190 | 2225 | 2754 | 2034 | 1483 |
| 55 | ICGV 01232 | 5665 | 6286 | 5863 | 7213 | 5576 | 4692 | 4119 | 4603 |
| 56 | ICGV 02266 | 7419 | 7374 | 9011 | 10887 | 4982 | 4320 | 5399 | 4809 |
| 57 | ICGV 02271 | 3658 | 5115 | 4389 | 4027 | 2459 | 3669 | 3442 | 2722 |
| 58 | GG 20 | 7665 | 7773 | 8299 | 7883 | 2369 | 3104 | 3851 | 3607 |
| 59 | J 11 | 7020 | 6012 | 6469 | 6704 | 3612 | 3099 | 3136 | 2302 |
| 60 | GPBD 4 | 6644 | 5874 | 9326 | 7730 | 2954 | 3502 | 3396 | 2257 |
| 61 | JL 24 | 6496 | 7266 | 7664 | 7639 | 2895 | 2480 | 2460 | 3039 |
| 62 | K 6 | 6681 | 6935 | 7597 | 7527 | 3675 | 2235 | 2576 | 2435 |
| 63 | 55-437 | NA | 5693 | 7014 | 7139 | NA | 2402 | 2602 | 2427 |
| Co-efficient of Variation | | 9 | 8 | 13 | 13 | 15 | 12 | 15 | 19 |
| Mean | | 7642 | 7970 | 8178 | 8406 | 4531 | 4144 | 4373 | 3945 |
| Least Significant Difference | | 1409 | 1323 | 2066 | 2126 | 1454 | 1081 | 1389 | 1645 |
| R-Square | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Range | MINIMUM | 3658 | 3811 | 4389 | 4027 | 2205 | 2235 | 2034 | 1483 |
| | MAXIMUM | 11058 | 12179 | 11799 | 12214 | 6761 | 6622 | 6767 | 6180 |

The mean values for 13 genotypes in E2 were found significantly earlier than the overall mean of the environment for days to 75% flowering which were also the earliest flowering genotypes. Hence, the genotypes were ICGV 91114, ICGV 00298, ICGV 03042, ICGV 05155, ICGV 07217 ICGV 89280 ICGV 93468, TAG 24, TCGS 1043, Abhaya, Chico, ICGS 11 and K 6 respectively. Besides, these 14 genotypes were found delayed flowering which included genotypes ICGV 07273, ICGV 06175, ICGV 07456, ICGV 07356, and ICGV 86325 which took a maximum of 40 days to reach DF 75%.

In environment E3 five genotypes were found to flower significantly earlier than overall mean of the environment. Hence, the earliest flowering genotypes were ICGV 91114 and J 11, took 31 days for DF 75%. Furthermore, nine genotypes showed significantly delayed flowering. ICGV 07456 took 39 days which was recorded as most delayed one.

Ten genotypes in E4 were observed to reach 75% flowering significantly earlier than the overall mean of the environment. The genotypes TAG 24, ICGV 91114 and J 11 took 29 days to reach 75% flowering respectively. In addition, seven genotypes were found to be significantly late maturing. However in E4, ICGV 07456 showed delayed flowering with a maximum of 29 days.

A trend of gradual decrease in the number of days to reach days to 75% flowering was observed across the environments. Moreover, in all the four environments ICGV 07456 showed delayed flowering (37-50 days) while ICGV 91114 (29-35days) flowered early in all the environments with an exception in E1.

### 4.4.2 Days to maturity (DM)

The mean data pertaining to days to maturity in E1 showed that 17 genotypes were noticed to mature significantly earlier than the overall mean of the environment. The earliest maturing genotypes were TMV 2, ICGV 00298, ICGV 92195, ICGV 93468, TAG 24 and JL 24 (123 days). However, 20 genotypes were significantly late maturing. In E1, five genotypes *i.e*. ICGV 05032, ICGV 05155, ICGV 06424, ICGV 07102 and Abhaya were recorded for most delayed maturity (139 days).

For days to maturity, 20 genotypes in E2 were found significantly early maturing than the overall mean of the environment, which varied from 117 to 121 days. The genotypes recorded to reach earliest maturity were ICGV 07217, ICGV 91114, ICGV 96346 and J11 (117days). However, 19 genotypes were late maturing. Among all the genotypes under study ICGV 05155, ICGV 06039 took maximum number of days to reach maturity (138 days).

The mean values concerning days to maturity for E3 showed that 17 genotypes were found to be maturing significantly earlier than the overall mean of the environment which varied from 105-112 days. The genotype ICGV 91114 (105 days) showed earliest maturity. Moreover, nine genotypes were found for delayed maturity wherein maximum of 139 days was observed for ICGV 07246.

In the present study 22 genotypes were observed to reach maturity significantly earlier than the overall mean of the environment in E4. The genotypes TAG 24 (101 days) were found to mature the earliest. In addition to the above 24 genotypes were found to be significantly late maturing. However in E4, ICGS 11 showed delayed maturity with a maximum of 139 days.

It has also been observed that delayed sowing reduces the maturity of the genotypes. Among the entire environment most early maturing genotypes were recovered in E4 of which TAG 24 was identified as most early maturing.

### 4.4.3 Haulm weight

The mean values regarding haulm weight in E1 showed significant variation among the genotypes. Twelve genotypes were found to perform higher than the overall mean of the environment. Genotype VRI 6 (11058 Kg ha$^{-1}$) was recorded with maximum haulm weight. Ten genotypes were recorded to have significantly lower haulm weights where ICGV 02271 recorded for minimum (3658 Kg ha$^{-1}$) in E1.

In E2 15 genotypes showed significantly higher haulm weight with respect to overall mean of the environment among which ICGV 06175 (12179 Kg ha$^{-1}$) had maximum haulm weight. Besides, these 16 genotypes were found to have significantly lower haulm weights. However, TAG 24 was found to be the minimum yielder (3811 Kg ha$^{-1}$).

The mean values pertaining to haulm weight in E3 revealed that seven genotypes were found to be significantly higher than the overall mean of the environment. Genotype ICGV 06175 (11799 Kg ha$^{-1}$) was observed with maximum haulm weight. Moreover seven were found to be significantly lower and ICGV 02271 (4389 Kg ha$^{-1}$) was recorded to be the minimum yielder for haulm weight.

Significant difference was observed in E4 for haulm weight among the genotypes in the present study. In E4 six genotypes were found significantly high yielder than overall mean of the environment. The maximum yielding genotype recorded in E4 was ICGV 05032 (12214 Kg ha$^{-1}$). On the other hand seven genotypes were lower than the overall mean wherein ICGV 02271 with a yield of 4027 Kg ha$^{-1}$ was recorded as the minimum yielder.

Among all the genotypes under study, ICGV 02271 was recorded to be minimum haulm yielder in all the environments except E2.

### 4.4.4 Pod yield (PY)

The mean performance of pod yield in E1 showed significant difference among the genotypes leading to a wide range of variability. In E1, eight genotypes were significantly higher than the overall mean of the environment while seven genotypes were low yielder. Genotype ICGV 07012 (6761 Kg ha$^{-1}$) was identified with maximum yield while ICGV 86325 (2205 Kg ha$^{-1}$) was recorded with minimum yield.

Mean values concerning pod yield in E2 revealed that ten genotypes showed statistically higher yield than the overall mean of the environment. Hence, ICGV 07246 (6622 Kg ha$^{-1}$) was recorded with maximum yield. However, eight genotypes were low yielders wherein K 6 (2235 Kg ha$^{-1}$) was found to have minimum pod yield.

PY in E3 showed that nine genotypes were significantly higher than the overall mean of the environment and the genotype ICGV 06040 (6767 Kg ha$^{-1}$) had maximum pod yield. Other than the above, seven showed below average yield where ICGV 99001 (2034 Kg $ha^{-1}$) was observed as minimum pod yielder for E3.

In E4 five genotypes were identified to be significantly higher than the overall mean of the environment where ICGV 03042 (6180 Kg $ha^{-1}$) was noted with maximum yield. However, only three genotypes were found to be low yielders where ICGV 99001(1483 Kg $ha^{-1}$) was minimum.

### 4.4.5 Kernel yield (KY)

Mean values of KY in E1 observed significant differences among genotypes with respect to kernel yield. A clear perusal of the mean yield showed that four genotypes were significantly higher yielder than overall mean of the environment where ICGV 06424 (4456 Kg $ha^{-1}$) had maximum kernel yield. While six genotypes performed below overall mean of the environment. In E1 ICGV 99001 (1033 Kg $ha^{-1}$) was the minimum yielder for kernel yield.

The scrutiny of mean values revealed that in E2 nine genotypes yielded higher than the overall mean of the environment. The maximum yielding genotype was ICGV 06039 (4123 Kg $ha^{-1}$). Further, five were below average where K 6 (1053 Kg $ha^{-1}$) was identified as minimum yielder.

In E3, five genotypes were observed to yield significantly higher than the overall mean of the environment and ICGV 06040 (4123 Kg $ha^{-1}$) was found to be with maximum KY whereas six genotypes were significantly low yielder than the overall mean of the environment. ICGV 99001 (972 Kg $ha^{-1}$) was recorded with minimum yield.

Only five genotypes yielded significantly higher than overall mean of the E4 environment. The genotype recorded with maximum yield was ICGV 07038 (3659 Kg $ha^{-1}$) whereas only one *i.e.,* ICGV 99001 (603 Kg $ha^{-1}$) was significantly lowest yielder.

For kernel yield ICGV 99001 yielded minimum (603-1033 Kg $ha^{-1}$) in all the environments except in E2.

**Table 4.7.** Mean performance for kernel yield, shelling percentage, sound mature kernel and hundred kernel weight studied in genotypes across four environments (E1, E2, E3 and E4).

| S.No. | Genotypes | Kernel yield (Kg ha$^{-1}$) | | | | Shelling percentage (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | E1 | E2 | E3 | E4 | E1 | E2 | E3 | E4 |
| 1 | ICGV 00298 | 1941 | 2603 | 2115 | 1637 | 56 | 61 | 57 | 52 |
| 2 | ICGV 00308 | 3049 | 1960 | 2149 | 1774 | 68 | 59 | 62 | 53 |
| 3 | ICGV 00350 | 3144 | 2611 | 2880 | 2314 | 65 | 47 | 52 | 47 |
| 4 | ICGV 00351 | 3492 | 2806 | 3096 | 2575 | 63 | 62 | 56 | 54 |
| 5 | ICGV 03042 | 3187 | 3300 | 3619 | 3544 | 55 | 56 | 58 | 57 |
| 6 | ICGV 03057 | 3049 | 3400 | 2899 | 3148 | 65 | 59 | 50 | 60 |
| 7 | ICGV 03109 | 3863 | 2719 | 3164 | 2416 | 70 | 63 | 61 | 63 |
| 8 | ICGV 05032 | 3420 | 1984 | 2293 | 2475 | 56 | 44 | 41 | 43 |
| 9 | ICGV 05155 | 4293 | 3377 | 3257 | 2351 | 70 | 58 | 57 | 55 |
| 10 | ICGV 07456 | 1592 | 1758 | 1711 | 1941 | 57 | 59 | 51 | 67 |
| 11 | ICGV 06039 | 3953 | 4123 | 2844 | 3403 | 66 | 64 | 54 | 61 |
| 12 | ICGV 06040 | 3853 | 2867 | 4123 | 3477 | 64 | 60 | 62 | 63 |
| 13 | ICGV 06099 | 3921 | 2911 | 2819 | 3449 | 65 | 61 | 58 | 64 |
| 14 | ICGV 06175 | 2564 | 2281 | 2185 | 1277 | 58 | 57 | 55 | 46 |
| 15 | ICGV 06420 | 2944 | 3293 | 2921 | 3335 | 58 | 62 | 56 | 65 |
| 16 | ICGV 06424 | 4456 | 2772 | 3616 | 2576 | 68 | 55 | 55 | 56 |
| 17 | ICGV 07012 | 3812 | 2598 | 2722 | 2238 | 57 | 46 | 44 | 42 |
| 18 | ICGV 07013 | 3017 | 2583 | 2339 | 2843 | 58 | 54 | 50 | 60 |
| 19 | ICGV 07038 | 3060 | 3060 | 3915 | 3659 | 59 | 58 | 61 | 64 |
| 20 | ICGV 05200 | 2346 | 2336 | 2510 | 2197 | 52 | 55 | 48 | 52 |
| 21 | ICGV 07148 | 3094 | 1927 | 2715 | 2121 | 54 | 46 | 47 | 48 |
| 22 | ICGV 07211 | 2382 | 1666 | 1727 | 1874 | 61 | 60 | 49 | 55 |
| 23 | ICGV 07213 | 3002 | 3371 | 2613 | 2794 | 56 | 65 | 58 | 59 |
| 24 | ICGV 07217 | 2783 | 2900 | 2924 | 2299 | 62 | 65 | 63 | 61 |
| 25 | ICGV 07246 | 3816 | 4051 | 3876 | 3016 | 59 | 62 | 57 | 56 |
| 26 | ICGV 07268 | 4332 | 3850 | 3024 | 3316 | 70 | 69 | 60 | 68 |
| 27 | ICGV 07273 | 3160 | 3643 | 2926 | 2750 | 58 | 61 | 54 | 62 |
| 28 | ICGV 07356 | 2760 | 2494 | 2039 | 1580 | 59 | 56 | 55 | 58 |
| 29 | ICGV 86325 | 1231 | 1561 | 1623 | 1095 | 57 | 54 | 56 | 53 |
| 30 | ICGV 87128 | 2443 | 2564 | 2110 | 2367 | 63 | 66 | 55 | 60 |
| 31 | ICGV 87141 | 2315 | 2036 | 2089 | 2062 | 65 | 63 | 57 | 59 |
| 32 | ICGV 87846 | 2101 | 1659 | 2419 | 2305 | 59 | 52 | 53 | 57 |
| 33 | ICGV 89280 | 3080 | 2655 | 2766 | 2528 | 59 | 56 | 58 | 52 |
| 35 | ICGV 91114 | 2901 | 2047 | 1432 | 1527 | 71 | 62 | 49 | 48 |
| 36 | ICGV 92035 | 1826 | 2838 | 2611 | 2062 | 47 | 59 | 52 | 56 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 37 | ICGV 92195 | 2087 | 1730 | 1983 | 1572 | 63 | 55 | 58 | 52 |
| 38 | ICGV 93468 | 2564 | 2247 | 2171 | 2852 | 62 | 56 | 54 | 54 |
| 39 | ICGV 95390 | 2093 | 2414 | 2113 | 1398 | 53 | 59 | 52 | 43 |
| 40 | ICGV 96346 | 2325 | 1583 | 2217 | 1290 | 57 | 48 | 52 | 43 |
| 41 | ICGV 97182 | 2608 | 2199 | 2548 | 2732 | 57 | 56 | 54 | 57 |
| 42 | ICGV 97183 | 3249 | 2660 | 1941 | 1597 | 59 | 61 | 52 | 44 |
| 43 | ICGV 98294 | 2475 | 2121 | 2072 | 2243 | 57 | 56 | 56 | 54 |
| 44 | TAG 24 | 2262 | 3081 | 3282 | 3184 | 51 | 69 | 63 | 65 |
| 45 | TCGS 1043 | 2864 | 2417 | 2858 | 2890 | 73 | 64 | 68 | 67 |
| 46 | TG 37 | 2888 | 2665 | 2573 | 2490 | 63 | 61 | 51 | 57 |
| 47 | TMV 2 | 1401 | 1517 | 1147 | 1392 | 56 | 58 | 53 | 58 |
| 48 | TPG 41 | 2350 | 1695 | 1848 | 1451 | 51 | 44 | 47 | 50 |
| 49 | VRI 6 | 2100 | 1703 | 2070 | 1619 | 57 | 56 | 54 | 57 |
| 50 | Abhaya | 3064 | 2001 | 2025 | 2055 | 65 | 61 | 62 | 65 |
| 51 | Chico | 2181 | 2259 | 2234 | 1377 | 65 | 64 | 60 | 54 |
| 52 | GJG 31 | 1604 | 2081 | 1486 | 2318 | 49 | 53 | 38 | 47 |
| 53 | ICGS 11 | 3041 | 1778 | 2222 | 2059 | 68 | 54 | 59 | 60 |
| 54 | ICGV 99001 | 1033 | 1573 | 972 | 603 | 46 | 57 | 49 | 40 |
| 55 | ICGV 01232 | 3470 | 2711 | 2104 | 2224 | 61 | 58 | 50 | 48 |
| 56 | ICGV 02266 | 3253 | 2710 | 2947 | 2590 | 65 | 62 | 55 | 53 |
| 57 | ICGV 02271 | 1551 | 1674 | 2067 | 1827 | 62 | 46 | 60 | 64 |
| 58 | GG 20 | 1282 | 1499 | 2345 | 2112 | 55 | 49 | 60 | 59 |
| 59 | J 11 | 2291 | 1696 | 1665 | 1259 | 60 | 54 | 53 | 54 |
| 60 | GPBD 4 | 1911 | 2068 | 1775 | 1126 | 64 | 59 | 53 | 49 |
| 61 | JL 24 | 1496 | 1449 | 1280 | 1547 | 54 | 59 | 52 | 50 |
| 62 | K 6 | 2405 | 1053 | 1344 | 1455 | 65 | 48 | 52 | 57 |
| 63 | 55-437 | NA | 1313 | 1404 | 1024 | NA | 56 | 53 | 43 |
| Co-efficient of Variation | | 20 | 16 | 19 | 25 | 8 | 8 | 7 | 9 |
| Mean | | 2751 | 2392 | 2398 | 2203 | 60 | 57 | 55 | 55 |
| Least Significant Difference | | 1192 | 855 | 959 | 1199 | 11 | 9 | 9 | 11 |
| R-Square | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Range | MINIMUM | 1033 | 1053 | 972 | 603 | 46 | 44 | 38 | 40 |
| | MAXIMUM | 4456 | 4123 | 4123 | 3659 | 73 | 69 | 68 | 68 |

Table 4.7 (Cont.).

| S.No. | Genotypes | Sound Mature Kernel (%) | | | | Hundred kernel weight (g) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | E1 | E2 | E3 | E4 | E1 | E2 | E3 | E4 |
| 1 | ICGV 00298 | 91 | 95 | 90 | 96 | 32 | 27 | 23 | 21 |
| 2 | ICGV 00308 | 97 | 89 | 94 | 89 | 38 | 28 | 28 | 29 |
| 3 | ICGV 00350 | 96 | 89 | 84 | 83 | 35 | 28 | 28 | 30 |
| 4 | ICGV 00351 | 91 | 91 | 98 | 80 | 30 | 29 | 27 | 26 |
| 5 | ICGV 03042 | 91 | 91 | 85 | 87 | 37 | 31 | 31 | 34 |
| 6 | ICGV 03057 | 92 | 96 | 90 | 91 | 36 | 31 | 31 | 30 |
| 7 | ICGV 03109 | 90 | 90 | 97 | 90 | 40 | 36 | 30 | 35 |
| 8 | ICGV 05032 | 89 | 97 | 76 | 87 | 39 | 31 | 32 | 37 |
| 9 | ICGV 05155 | 89 | 92 | 83 | 79 | 37 | 33 | 29 | 32 |
| 10 | ICGV 07456 | 95 | 91 | 91 | 98 | 33 | 35 | 32 | 40 |
| 11 | ICGV 06039 | 91 | 86 | 88 | 92 | 32 | 32 | 27 | 32 |
| 12 | ICGV 06040 | 88 | 92 | 82 | 94 | 41 | 36 | 41 | 43 |
| 13 | ICGV 06099 | 91 | 87 | 92 | 94 | 37 | 36 | 44 | 39 |
| 14 | ICGV 06175 | 89 | 86 | 96 | 91 | 33 | 27 | 26 | 30 |
| 15 | ICGV 06420 | 92 | 93 | 93 | 88 | 29 | 27 | 27 | 34 |
| 16 | ICGV 06424 | 91 | 89 | 88 | 90 | 35 | 33 | 31 | 32 |
| 17 | ICGV 07012 | 84 | 90 | 76 | 87 | 46 | 37 | 35 | 33 |
| 18 | ICGV 07013 | 92 | 92 | 84 | 94 | 33 | 34 | 29 | 30 |
| 19 | ICGV 07038 | 84 | 88 | 89 | 95 | 31 | 31 | 30 | 34 |
| 20 | ICGV 05200 | 98 | 91 | 92 | 96 | 56 | 46 | 43 | 49 |
| 21 | ICGV 07148 | 89 | 84 | 81 | 88 | 35 | 28 | 32 | 30 |
| 22 | ICGV 07211 | 98 | 92 | 90 | 92 | 28 | 22 | 23 | 22 |
| 23 | ICGV 07213 | 97 | 93 | 90 | 93 | 30 | 31 | 29 | 33 |
| 24 | ICGV 07217 | 94 | 92 | 93 | 90 | 30 | 24 | 24 | 29 |
| 25 | ICGV 07246 | 98 | 89 | 95 | 90 | 31 | 32 | 31 | 26 |
| 26 | ICGV 07268 | 94 | 91 | 91 | 96 | 44 | 38 | 35 | 38 |
| 27 | ICGV 07273 | 91 | 90 | 89 | 90 | 30 | 31 | 29 | 39 |
| 28 | ICGV 07356 | 94 | 88 | 89 | 94 | 36 | 32 | 29 | 34 |
| 29 | ICGV 86325 | 83 | 86 | 91 | 92 | 33 | 32 | 30 | 34 |
| 30 | ICGV 87128 | 98 | 90 | 89 | 89 | 33 | 29 | 27 | 25 |
| 31 | ICGV 87141 | 94 | 88 | 91 | 93 | 36 | 33 | 33 | 36 |
| 32 | ICGV 87846 | 89 | 85 | 88 | 87 | 42 | 32 | 37 | 35 |
| 33 | ICGV 89280 | 93 | 85 | 92 | 89 | 50 | 39 | 43 | 44 |
| 35 | ICGV 91114 | 91 | 94 | 88 | 95 | 39 | 32 | 28 | 24 |
| 36 | ICGV 92035 | 92 | 93 | 89 | 91 | 37 | 31 | 31 | 35 |
| 37 | ICGV 92195 | 94 | 90 | 86 | 89 | 34 | 26 | 30 | 26 |
| 38 | ICGV 93468 | 87 | 92 | 85 | 79 | 40 | 31 | 31 | 32 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 39 | ICGV 95390 | 97 | 93 | 96 | 87 | 47 | 35 | 35 | 43 |
| 40 | ICGV 96346 | 87 | 88 | 88 | 92 | 27 | 19 | 26 | 23 |
| 41 | ICGV 97182 | 93 | 89 | 94 | 91 | 37 | 29 | 33 | 34 |
| 42 | ICGV 97183 | 93 | 94 | 91 | 94 | 45 | 44 | 36 | 36 |
| 43 | ICGV 98294 | 97 | 88 | 70 | 94 | 35 | 30 | 29 | 33 |
| 44 | TAG 24 | 96 | 93 | 80 | 82 | 27 | 34 | 28 | 36 |
| 45 | TCGS 1043 | 94 | 87 | 98 | 98 | 40 | 35 | 31 | 39 |
| 46 | TG 37 | 93 | 91 | 95 | 82 | 33 | 29 | 26 | 30 |
| 47 | TMV 2 | 93 | 91 | 87 | 89 | 30 | 22 | 24 | 23 |
| 48 | TPG 41 | 90 | 83 | 91 | 94 | 58 | 42 | 39 | 52 |
| 49 | VRI 6 | 95 | 94 | 89 | 92 | 27 | 25 | 21 | 26 |
| 50 | Abhaya | 93 | 92 | 98 | 93 | 31 | 25 | 27 | 24 |
| 51 | Chico | 91 | 90 | 94 | 76 | 31 | 25 | 24 | 17 |
| 52 | GJG 31 | 91 | 88 | 87 | 89 | 38 | 32 | 21 | 28 |
| 53 | ICGS 11 | 93 | 90 | 92 | 96 | 39 | 28 | 26 | 30 |
| 54 | ICGV 99001 | 91 | 89 | 94 | 84 | 30 | 28 | 24 | 18 |
| 55 | ICGV 01232 | 86 | 92 | 99 | 94 | 59 | 42 | 38 | 40 |
| 56 | ICGV 02266 | 96 | 92 | 94 | 91 | 42 | 36 | 40 | 43 |
| 57 | ICGV 02271 | 99 | 90 | 90 | 91 | 37 | 31 | 33 | 34 |
| 58 | GG 20 | 88 | 88 | 93 | 91 | 40 | 34 | 35 | 36 |
| 59 | J 11 | 85 | 89 | 82 | 90 | 28 | 20 | 21 | 22 |
| 60 | GPBD 4 | 83 | 89 | 78 | 88 | 28 | 26 | 25 | 21 |
| 61 | JL 24 | 92 | 88 | 87 | 88 | 32 | 30 | 27 | 24 |
| 62 | K 6 | 93 | 85 | 90 | 95 | 37 | 27 | 29 | 33 |
| 63 | 55-437 | NA | 88 | 91 | 82 | NA | 22 | 21 | 19 |
| Co-efficient of Variation | | 4 | 5 | 5 | 5 | 12 | 7 | 10 | 12 |
| Mean | | 92 | 90 | 89 | 90 | 36 | 31 | 30 | 32 |
| Least Significant Difference | | 7 | 11 | 10 | 10 | 9 | 5 | 7 | 8 |
| R-Square | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Range | MINIMUM | 83 | 83 | 70 | 76 | 27 | 19 | 21 | 17 |
| | MAXIMUM | 99 | 97 | 99 | 98 | 59 | 46 | 44 | 52 |

### 4.4.6 Shelling percentage (SP)

The perusal of data for shelling percentage in E1 revealed that only TCGS 1043 (73%) was found to have higher shelling percent than the overall mean of the environment while three genotypes were found to have lower SP of which ICGV 99001(46 %) was the least.

In E2, ICGV 07268 and TAG 24 with a SP of 69 % was recorded to be significantly higher than the overall mean of the environment. Among the genotypes under study six had lower percentage. TPG 41 and ICGV 05032 with 44% were observed to be the minimum.

The results pertaining to shelling percentage in E3 revealed that only one genotypes *viz.*, TCGS 1043 (68 %) was found to be significantly higher than the overall mean of the environment. Further, three genotypes had lower percent than overall mean where GJG 31 (38 %) was least.

In E4, three genotype *viz.*, ICGV 07268 (68 %), TCGS 1043 (67%) and ICGV 07456 (67%) were found to be significantly higher than the overall mean of the environment. However, seven genotypes had lower percent wherein ICGV 99001 (40 %) had the least shelling percentage.

### 4.4.7 Sound Mature Kernel Percentage (SMK %)

Across the four environments *viz.*, E1, E2, E3 and E4 none of the genotypes were found to have significantly higher SMK % with respect to overall mean of the environment.

However in E1 three genotypes had lower SMK percent than overall mean. Genotypes ICGV 86325 and GPBD 4 (83 %) were recorded as the lowest while ICGV 02271 with 99% sound mature kernels were recorded as the highest.

All the genotypes (62) in E2 were found to be at par with the overall mean of the environment wherein TPG 41 (83%) and ICGV 05032 (97%) had lowest and highest percentage of sound mature kernels.

In E3 four genotypes had lower SMK percent than overall mean. In this environment ICGV 98294 (69 %) and ICGV 01232 (99 %) had lowest and highest percent of sound mature kernels.

For E4 three genotypes had low SMK % than overall mean. Chico with SMK % of 76 was the lowest while TCGS 1043 and ICGV 07456 (98%) was observed as the highest.

### 4.4.8 Hundred Kernel Weight (HKW)

The mean performance of hundred kernel weight in E1 showed significant difference among the genotypes. In E1 five genotypes were significantly higher than the overall mean of the environment with ICGV 01232 (59 g) recorded for highest HKW, while 56 genotypes showed statistical parity. However, VRI 6 (27g) was recorded for lowest HKW.

The results concerning HKW in E2 revealed that seven genotypes showed statistically higher hundred kernel weight than the overall mean of the environment. Hence, genotype ICGV 05200 (46 g) was recorded with highest HKW. Besides these nine genotypes showed low HKW wherein IVCG 96346 (19g) was regarded as the lowest.

Eight genotypes had significantly higher weight than the overall mean in E3 and the genotype ICGV 06099 (44 g) had highest HKW. However, seven showed significantly lower hundred kernel weight where genotype 55-437 (21g) was observed to have lowest test weights.

For E4 six genotypes were identified to be significantly higher than the overall mean of the environment in which TPG 41 (52 g) had highest test weight. However, nine genotypes were found to below average yielders among which Chico (17g) was lowest.

### 4.4.9 Oil content (OC %)

The percent findings for oil content in E1 revealed that five genotypes have highest OC % than the overall mean of the environment where ICGV 06420 (59%) had the highest OC. Genotypes ICGV 89280, ICGV 05200, ICGV 92195, ICGV 96346, and TPG 41 has lowest OC (49 %) in E1.

In E2, five genotypes had significantly higher oil content than the overall mean of the environment. ICGV 06420 (59%) had the highest OC % while five genotypes identified with lowest OC of 49 % were ICGV 87141, ICGV 05200, ICGV 89280, TMV 2, and Chico (49 %) respectively.

The mean values pertaining to oil content in E3 revealed that seven genotypes were found to be significantly higher than the overall mean of the environment. ICGV 06040 with 58% oil content was highest. Further, three genotypes *viz*., ICGV 05200, ICGV 91114, and Chico were recorded to have lowest oil content (48%).

Oil content percentage in E4 showed that nine genotypes had significantly higher oil content than the overall mean of the environment with ICGV 06420 (61%) as highest. In addition to the above, only one genotype *i.e*., TMV 2 (48%) was observed to have significantly lower oil content.

However, ICGV 06420 had highest oil content across the environment except in E3 while ICGV 05200 had lowest oil content in all environments with an exception in E4.

### 4.4.10 Oil yield (OY)

The present findings for E1 revealed significant differences among genotypes with respect to oil yield. A clear perusal of the mean yield showed that seven genotypes were recorded significantly higher oil yielder than overall mean of the environment where ICGV 06424 (2495 Kg $ha^{-1}$) had maximum OY. In addition to above six genotypes

**Table 4.8.** Mean performance for oil content, oil yield, harvest index, crop growth rate, pod growth rate and partioning factor studied in genotypes across four environments (E1, E2, E3 and E4).

| S.No | Genotypes | Oil content (%) | | | | Oil yield (Kg/ha$^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | E1 | E2 | E3 | E4 | E1 | E2 | E3 | E4 |
| 1 | ICGV 00298 | 50 | 54 | 49 | 49 | 960 | 1407 | 1022 | 814 |
| 2 | ICGV 00308 | 50 | 52 | 50 | 49 | 1563 | 1005 | 1078 | 869 |
| 3 | ICGV 00350 | 56 | 55 | 52 | 54 | 1739 | 1422 | 1509 | 1245 |
| 4 | ICGV 00351 | 55 | 55 | 56 | 55 | 1918 | 1552 | 1727 | 1423 |
| 5 | ICGV 03042 | 53 | 55 | 55 | 54 | 1691 | 1829 | 1981 | 1892 |
| 6 | ICGV 03057 | 54 | 57 | 55 | 57 | 1652 | 1933 | 1589 | 1794 |
| 7 | ICGV 03109 | 55 | 57 | 56 | 57 | 2139 | 1552 | 1757 | 1373 |
| 8 | ICGV 05032 | 53 | 53 | 54 | 52 | 1823 | 1061 | 1229 | 1279 |
| 9 | ICGV 05155 | 58 | 58 | 58 | 59 | 2485 | 1943 | 1886 | 1388 |
| 10 | ICGV 07456 | 50 | 51 | 50 | 53 | 788 | 882 | 854 | 1022 |
| 11 | ICGV 06039 | 54 | 54 | 54 | 53 | 2152 | 2241 | 1546 | 1806 |
| 12 | ICGV 06040 | 57 | 55 | 58 | 55 | 2218 | 1586 | 2407 | 1911 |
| 13 | ICGV 06099 | 56 | 55 | 54 | 54 | 2185 | 1597 | 1536 | 1901 |
| 14 | ICGV 06175 | 54 | 55 | 53 | 54 | 1383 | 1247 | 1159 | 699 |
| 15 | ICGV 06420 | 59 | 59 | 57 | 61 | 1741 | 1948 | 1659 | 2041 |
| 16 | ICGV 06424 | 56 | 55 | 57 | 55 | 2495 | 1536 | 2040 | 1385 |
| 17 | ICGV 07012 | 50 | 51 | 51 | 51 | 1942 | 1328 | 1416 | 1147 |
| 18 | ICGV 07013 | 51 | 53 | 51 | 50 | 1529 | 1358 | 1201 | 1163 |
| 19 | ICGV 07038 | 54 | 54 | 54 | 57 | 1665 | 1649 | 2116 | 2107 |
| 20 | ICGV 05200 | 49 | 49 | 48 | 50 | 1156 | 1143 | 1205 | 1102 |
| 21 | ICGV 07148 | 52 | 52 | 53 | 51 | 1600 | 998 | 1446 | 1051 |
| 22 | ICGV 07211 | 55 | 54 | 55 | 56 | 1288 | 886 | 963 | 1051 |
| 23 | ICGV 07213 | 52 | 53 | 51 | 53 | 1549 | 1764 | 1344 | 1464 |
| 24 | ICGV 07217 | 56 | 54 | 53 | 55 | 1549 | 1585 | 1558 | 1257 |
| 25 | ICGV 07246 | 52 | 52 | 53 | 50 | 1990 | 2120 | 2039 | 1514 |
| 26 | ICGV 07268 | 52 | 51 | 51 | 50 | 2264 | 1973 | 1535 | 1681 |
| 27 | ICGV 07273 | 54 | 56 | 53 | 56 | 1721 | 2033 | 1566 | 1542 |
| 28 | ICGV 07356 | 50 | 50 | 49 | 49 | 1377 | 1244 | 1013 | 623 |
| 29 | ICGV 86325 | 50 | 51 | 50 | 49 | 605 | 802 | 814 | 539 |
| 30 | ICGV 87128 | 50 | 50 | 49 | 49 | 1199 | 1271 | 1025 | 1209 |
| 31 | ICGV 87141 | 51 | 49 | 50 | 50 | 1190 | 985 | 1043 | 1030 |
| 32 | ICGV 87846 | 52 | 52 | 52 | 52 | 1085 | 851 | 1260 | 1233 |
| 33 | ICGV 89280 | 49 | 49 | 49 | 50 | 1484 | 1303 | 1363 | 1242 |
| 35 | ICGV 91114 | 50 | 50 | 48 | 50 | 1474 | 1027 | 689 | 750 |
| 36 | ICGV 92035 | 51 | 51 | 51 | 52 | 930 | 1440 | 1327 | 1072 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 37 | ICGV 92195 | 49 | 50 | 49 | 49 | 1013 | 853 | 976 | 789 |
| 38 | ICGV 93468 | 52 | 51 | 49 | 51 | 1330 | 1135 | 1071 | 1468 |
| 39 | ICGV 95390 | 54 | 54 | 52 | 55 | 1133 | 1301 | 1104 | 761 |
| 40 | ICGV 96346 | 49 | 50 | 51 | 50 | 1135 | 781 | 1122 | 602 |
| 41 | ICGV 97182 | 56 | 55 | 56 | 57 | 1467 | 1206 | 1402 | 1560 |
| 42 | ICGV 97183 | 51 | 53 | 54 | 55 | 1661 | 1412 | 1054 | 889 |
| 43 | ICGV 98294 | 55 | 52 | 52 | 55 | 1378 | 1098 | 1084 | 1263 |
| 44 | TAG 24 | 51 | 55 | 52 | 52 | 1132 | 1697 | 1689 | 1650 |
| 45 | TCGS 1043 | 52 | 54 | 50 | 53 | 1500 | 1302 | 1437 | 1522 |
| 46 | TG 37 | 51 | 50 | 50 | 49 | 1458 | 1324 | 1283 | 1219 |
| 47 | TMV 2 | 50 | 49 | 51 | 48 | 683 | 750 | 567 | 694 |
| 48 | TPG 41 | 49 | 50 | 51 | 50 | 1136 | 835 | 945 | 724 |
| 49 | VRI 6 | 53 | 52 | 51 | 52 | 1096 | 881 | 1075 | 835 |
| 50 | Abhaya | 53 | 52 | 53 | 52 | 1624 | 1026 | 1066 | 1080 |
| 51 | Chico | 50 | 49 | 48 | 49 | 1079 | 1117 | 1098 | 663 |
| 52 | GJG 31 | 53 | 53 | 49 | 51 | 841 | 1085 | 729 | 1194 |
| 53 | ICGS 11 | 52 | 52 | 50 | 50 | 1569 | 921 | 1113 | 1042 |
| 54 | ICGV 99001 | 56 | 54 | 52 | 53 | 582 | 845 | 504 | 328 |
| 55 | ICGV 01232 | 50 | 51 | 50 | 49 | 1722 | 1392 | 1072 | 1089 |
| 56 | ICGV 02266 | 54 | 54 | 53 | 52 | 1740 | 1462 | 1584 | 1314 |
| 57 | ICGV 02271 | 57 | 54 | 53 | 56 | 865 | 910 | 1090 | 1021 |
| 58 | GG 20 | 53 | 54 | 53 | 53 | 673 | 830 | 1241 | 1132 |
| 59 | J 11 | 51 | 51 | 50 | 51 | 1146 | 874 | 835 | 635 |
| 60 | GPBD 4 | 57 | 57 | 53 | 52 | 1093 | 1169 | 938 | 577 |
| 61 | JL 24 | 52 | 50 | 49 | 50 | 760 | 727 | 620 | 797 |
| 62 | K 6 | 51 | 52 | 50 | 52 | 1236 | 540 | 681 | 748 |
| 63 | 55-437 | NA | 51 | 49 | 49 | NA | 672 | 696 | 502 |
| Co-efficient of Variation | | 3 | 3 | 3 | 3 | 21 | 18 | 21 | 27 |
| Mean | | 53 | 53 | 52 | 52 | 1451 | 1266 | 1257 | 1156 |
| Least Significant Difference | | 3 | 3 | 3 | 3 | 632 | 486 | 545 | 608 |
| R-Square | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Range | MINIMUM | 49 | 49 | 48 | 48 | 582 | 540 | 504 | 328 |
| | MAXIMUM | 59 | 59 | 58 | 61 | 2495 | 2241 | 2407 | 2107 |

**Table 4.8 (Cont.).**

| S.No. | Genotypes | Harvest index (%) | | | | Crop growth rate ($gm^{-2}day^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | E1 | E2 | E3 | E4 | E1 | E2 | E3 | E4 |
| 1 | ICGV 00298 | 44.6 | 47.0 | 47.1 | 46.4 | 11.0 | 12.0 | 12.5 | 10.9 |
| 2 | ICGV 00308 | 56.0 | 50.2 | 49.7 | 48.1 | 10.1 | 9.3 | 10.0 | 10.5 |
| 3 | ICGV 00350 | 48.0 | 49.9 | 46.5 | 53.4 | 11.8 | 13.7 | 15.1 | 11.8 |
| 4 | ICGV 00351 | 51.5 | 50.7 | 43.6 | 45.9 | 13.3 | 12.8 | 15.7 | 14.9 |
| 5 | ICGV 03042 | 52.5 | 55.0 | 59.6 | 52.0 | 13.1 | 13.5 | 14.5 | 14.7 |
| 6 | ICGV 03057 | 49.3 | 47.9 | 55.8 | 47.6 | 11.9 | 14.7 | 13.3 | 12.9 |
| 7 | ICGV 03109 | 52.3 | 44.6 | 46.4 | 35.2 | 12.4 | 12.1 | 14.3 | 14.0 |
| 8 | ICGV 05032 | 51.0 | 43.0 | 49.3 | 41.2 | 14.1 | 12.8 | 14.0 | 15.9 |
| 9 | ICGV 05155 | 54.4 | 46.8 | 48.4 | 40.6 | 13.6 | 14.3 | 13.8 | 14.6 |
| 10 | ICGV 07456 | 36.0 | 32.1 | 32.2 | 38.5 | 10.4 | 12.2 | 12.2 | 10.1 |
| 11 | ICGV 06039 | 50.3 | 51.0 | 45.7 | 49.5 | 14.4 | 15.6 | 12.8 | 14.5 |
| 12 | ICGV 06040 | 49.5 | 48.0 | 57.0 | 50.4 | 14.0 | 12.6 | 14.7 | 13.8 |
| 13 | ICGV 06099 | 54.3 | 50.2 | 48.7 | 51.2 | 13.6 | 12.1 | 10.0 | 12.7 |
| 14 | ICGV 06175 | 42.0 | 36.2 | 41.2 | 29.1 | 13.2 | 13.8 | 13.6 | 12.0 |
| 15 | ICGV 06420 | 51.8 | 50.8 | 51.7 | 46.4 | 11.7 | 12.4 | 12.9 | 13.7 |
| 16 | ICGV 06424 | 54.1 | 46.0 | 51.7 | 40.9 | 14.6 | 13.2 | 15.1 | 13.3 |
| 17 | ICGV 07012 | 55.0 | 47.7 | 56.9 | 44.2 | 14.3 | 15.3 | 13.4 | 14.0 |
| 18 | ICGV 07013 | 51.1 | 43.8 | 49.0 | 41.0 | 12.5 | 13.7 | 11.6 | 13.3 |
| 19 | ICGV 07038 | 53.0 | 48.2 | 56.3 | 45.1 | 12.1 | 13.5 | 13.7 | 11.9 |
| 20 | ICGV 05200 | 40.4 | 41.2 | 44.6 | 43.1 | 13.1 | 13.9 | 15.0 | 14.0 |
| 21 | ICGV 07148 | 48.1 | 40.3 | 59.8 | 41.4 | 14.0 | 13.5 | 13.9 | 12.8 |
| 22 | ICGV 07211 | 47.3 | 41.8 | 39.3 | 40.9 | 10.8 | 9.4 | 12.8 | 12.4 |
| 23 | ICGV 07213 | 56.1 | 53.0 | 50.6 | 51.6 | 12.0 | 12.6 | 11.6 | 13.1 |
| 24 | ICGV 07217 | 52.1 | 54.0 | 42.3 | 51.1 | 9.6 | 11.7 | 13.4 | 11.5 |
| 25 | ICGV 07246 | 60.4 | 55.0 | 59.9 | 51.7 | 13.0 | 14.6 | 13.3 | 13.1 |
| 26 | ICGV 07268 | 61.3 | 59.1 | 54.9 | 50.0 | 12.4 | 12.1 | 11.1 | 14.6 |
| 27 | ICGV 07273 | 53.6 | 57.1 | 57.3 | 48.3 | 11.9 | 13.7 | 12.1 | 11.3 |
| 28 | ICGV 07356 | 55.6 | 41.3 | 37.6 | 32.0 | 13.0 | 12.6 | 11.6 | 9.7 |
| 29 | ICGV 86325 | 33.7 | 35.7 | 31.7 | 29.7 | 8.8 | 10.3 | 11.1 | 10.5 |
| 30 | ICGV 87128 | 51.6 | 49.7 | 47.3 | 46.1 | 9.8 | 11.0 | 10.8 | 11.0 |
| 31 | ICGV 87141 | 44.5 | 37.3 | 40.6 | 39.1 | 9.5 | 10.6 | 11.0 | 10.9 |
| 32 | ICGV 87846 | 36.1 | 31.7 | 44.8 | 36.1 | 11.8 | 12.0 | 13.2 | 12.5 |
| 33 | ICGV 89280 | 50.5 | 45.3 | 50.0 | 49.7 | 13.6 | 13.2 | 12.3 | 12.4 |
| 35 | ICGV 91114 | 47.9 | 45.7 | 40.0 | 41.9 | 11.2 | 10.4 | 10.2 | 11.7 |
| 36 | ICGV 92035 | 48.1 | 48.2 | 40.6 | 36.3 | 10.5 | 13.0 | 14.7 | 14.3 |
| 37 | ICGV 92195 | 45.8 | 43.0 | 43.0 | 41.1 | 10.3 | 9.6 | 10.9 | 10.1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 38 | ICGV 93468 | 57.5 | 60.8 | 54.3 | 54.3 | 9.7 | 9.2 | 9.3 | 13.9 |
| 39 | ICGV 95390 | 46.5 | 46.5 | 47.3 | 40.1 | 10.1 | 12.2 | 13.1 | 11.0 |
| 40 | ICGV 96346 | 51.9 | 44.8 | 50.6 | 45.8 | 10.4 | 10.2 | 13.3 | 11.4 |
| 41 | ICGV 97182 | 50.7 | 45.8 | 46.1 | 52.6 | 11.7 | 11.7 | 13.1 | 13.6 |
| 42 | ICGV 97183 | 53.2 | 48.2 | 38.9 | 40.9 | 12.5 | 12.2 | 11.7 | 11.0 |
| 43 | ICGV 98294 | 53.1 | 48.2 | 45.3 | 51.7 | 10.1 | 10.9 | 9.7 | 11.5 |
| 44 | TAG 24 | 65.2 | 64.7 | 62.6 | 64.6 | 9.8 | 9.0 | 11.1 | 12.1 |
| 45 | TCGS 1043 | 47.3 | 42.3 | 49.7 | 47.6 | 10.8 | 11.8 | 12.7 | 14.1 |
| 46 | TG 37 | 55.1 | 56.2 | 55.5 | 51.0 | 11.1 | 11.0 | 12.8 | 12.6 |
| 47 | TMV 2 | 36.0 | 38.7 | 35.6 | 31.4 | 9.8 | 9.3 | 10.8 | 10.8 |
| 48 | TPG 41 | 41.5 | 40.9 | 37.3 | 30.1 | 13.4 | 11.4 | 13.1 | 11.7 |
| 49 | VRI 6 | 34.3 | 32.0 | 37.3 | 29.8 | 12.6 | 12.0 | 13.2 | 12.2 |
| 50 | Abhaya | 49.7 | 42.3 | 43.2 | 37.8 | 10.8 | 10.0 | 9.9 | 11.1 |
| 51 | Chico | 49.6 | 49.5 | 43.3 | 40.0 | 8.9 | 10.2 | 10.8 | 9.8 |
| 52 | GJG 31 | 45.6 | 51.7 | 49.0 | 48.4 | 9.6 | 11.1 | 12.7 | 14.6 |
| 53 | ICGS 11 | 48.5 | 45.3 | 48.7 | 45.8 | 11.6 | 9.5 | 10.6 | 9.0 |
| 54 | ICGV 99001 | 33.1 | 38.2 | 34.6 | 24.6 | 8.7 | 10.3 | 9.9 | 7.4 |
| 55 | ICGV 01232 | 61.9 | 55.5 | 53.7 | 51.7 | 12.2 | 11.6 | 11.5 | 12.7 |
| 56 | ICGV 02266 | 54.2 | 49.8 | 49.3 | 41.4 | 11.9 | 11.4 | 13.2 | 14.7 |
| 57 | ICGV 02271 | 54.8 | 53.7 | 59.3 | 55.0 | 5.7 | 8.4 | 8.4 | 8.1 |
| 58 | GG 20 | 34.9 | 39.7 | 49.7 | 41.1 | 8.8 | 9.8 | 11.5 | 10.2 |
| 59 | J 11 | 45.3 | 46.1 | 42.6 | 38.7 | 10.6 | 9.4 | 10.6 | 11.0 |
| 60 | GPBD 4 | 43.0 | 49.3 | 40.6 | 35.5 | 8.8 | 9.4 | 12.1 | 10.7 |
| 61 | JL 24 | 42.6 | 36.0 | 37.1 | 39.8 | 9.1 | 9.7 | 11.0 | 11.1 |
| 62 | K 6 | 45.7 | 33.7 | 35.8 | 38.0 | 9.8 | 8.8 | 11.2 | 11.2 |
| 63 | 55-437 | NA | 40.0 | 34.5 | 35.9 | NA | 8.1 | 10.4 | 9.9 |
| Co-efficient of Variation | | 9.1 | 7.4 | 12.0 | 11.0 | 9.1 | 7.7 | 11.9 | 12.3 |
| Mean | | 49.1 | 46.1 | 46.8 | 43.2 | 11.4 | 11.7 | 12.3 | 12.1 |
| Least Significant Difference | | 9.5 | 7.3 | 12.8 | 10.9 | 2.1 | 1.8 | 2.9 | 3.0 |
| R-Square | | 0.9 | 0.9 | 0.8 | 0.9 | 0.9 | 0.9 | 0.8 | 0.8 |
| Range | MINIMUM | 33.1 | 31.7 | 31.7 | 24.6 | 5.7 | 8.1 | 8.4 | 7.4 |
| | MAXIMUM | 65.2 | 64.7 | 62.6 | 64.6 | 14.6 | 15.6 | 15.7 | 15.9 |

**Table 4.8 (Cont.).**

| S.No. | Genotypes | Pod growth rate ($gm^{-2}day^{-1}$) | | | | Partitioning factor | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | E1 | E2 | E3 | E4 | E1 | E2 | E3 | E4 |
| 1 | ICGV 00298 | 8.6 | 9.5 | 10.5 | 8.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| 2 | ICGV 00308 | 8.9 | 8.0 | 9.5 | 8.3 | 0.9 | 0.9 | 1.0 | 0.8 |
| 3 | ICGV 00350 | 9.2 | 11.1 | 11.6 | 9.2 | 0.8 | 0.8 | 0.8 | 0.8 |
| 4 | ICGV 00351 | 10.8 | 9.9 | 10.7 | 10.5 | 0.8 | 0.8 | 0.7 | 0.7 |
| 5 | ICGV 03042 | 11.4 | 12.0 | 12.4 | 11.4 | 0.9 | 0.9 | 0.9 | 0.8 |
| 6 | ICGV 03057 | 9.6 | 11.1 | 11.3 | 9.4 | 0.8 | 0.7 | 0.8 | 0.7 |
| 7 | ICGV 03109 | 10.7 | 8.6 | 10.2 | 7.7 | 0.9 | 0.7 | 0.7 | 0.6 |
| 8 | ICGV 05032 | 11.2 | 8.8 | 10.3 | 10.5 | 0.8 | 0.7 | 0.7 | 0.7 |
| 9 | ICGV 05155 | 11.9 | 10.4 | 10.6 | 10.7 | 0.9 | 0.7 | 0.8 | 0.7 |
| 10 | ICGV 07456 | 6.8 | 6.8 | 7.3 | 6.1 | 0.7 | 0.6 | 0.6 | 0.6 |
| 11 | ICGV 06039 | 11.8 | 12.9 | 10.6 | 10.9 | 0.8 | 0.8 | 0.8 | 0.7 |
| 12 | ICGV 06040 | 11.6 | 10.3 | 12.8 | 10.3 | 0.8 | 0.8 | 0.9 | 0.7 |
| 13 | ICGV 06099 | 12.6 | 10.2 | 11.3 | 9.8 | 0.9 | 0.9 | 0.9 | 0.8 |
| 14 | ICGV 06175 | 9.6 | 8.0 | 7.6 | 5.1 | 0.7 | 0.6 | 0.6 | 0.4 |
| 15 | ICGV 06420 | 9.6 | 10.1 | 10.4 | 9.3 | 0.8 | 0.8 | 0.8 | 0.7 |
| 16 | ICGV 06424 | 12.7 | 9.1 | 12.0 | 8.5 | 0.9 | 0.7 | 0.8 | 0.6 |
| 17 | ICGV 07012 | 12.4 | 11.9 | 11.1 | 9.5 | 0.9 | 0.8 | 0.8 | 0.7 |
| 18 | ICGV 07013 | 10.6 | 10.3 | 9.0 | 8.7 | 0.9 | 0.8 | 0.8 | 0.6 |
| 19 | ICGV 07038 | 10.4 | 10.1 | 12.1 | 10.3 | 0.8 | 0.8 | 0.9 | 0.7 |
| 20 | ICGV 05200 | 9.2 | 10.1 | 10.9 | 10.1 | 0.7 | 0.7 | 0.7 | 0.7 |
| 21 | ICGV 07148 | 10.7 | 9.4 | 10.5 | 8.0 | 0.8 | 0.7 | 0.7 | 0.6 |
| 22 | ICGV 07211 | 8.8 | 7.1 | 8.9 | 8.3 | 0.8 | 0.8 | 0.7 | 0.7 |
| 23 | ICGV 07213 | 11.4 | 11.3 | 10.3 | 10.9 | 1.0 | 0.9 | 0.9 | 0.8 |
| 24 | ICGV 07217 | 8.5 | 10.3 | 11.7 | 9.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| 25 | ICGV 07246 | 12.7 | 12.8 | 12.6 | 9.9 | 1.0 | 0.9 | 1.0 | 0.8 |
| 26 | ICGV 07268 | 12.4 | 11.5 | 9.5 | 9.2 | 1.0 | 0.9 | 0.9 | 0.8 |
| 27 | ICGV 07273 | 11.4 | 13.1 | 10.9 | 8.5 | 1.0 | 0.9 | 0.9 | 0.8 |
| 28 | ICGV 07356 | 9.6 | 8.4 | 7.7 | 5.1 | 1.0 | 0.7 | 0.7 | 0.5 |
| 29 | ICGV 86325 | 5.1 | 6.2 | 5.7 | 5.3 | 0.6 | 0.6 | 0.5 | 0.5 |
| 30 | ICGV 87128 | 8.2 | 9.5 | 8.3 | 8.8 | 0.9 | 0.9 | 0.8 | 0.8 |
| 31 | ICGV 87141 | 7.3 | 6.8 | 7.1 | 6.5 | 0.7 | 0.7 | 0.6 | 0.6 |
| 32 | ICGV 87846 | 7.4 | 6.1 | 8.9 | 7.2 | 0.7 | 0.5 | 0.7 | 0.6 |
| 33 | ICGV 89280 | 10.6 | 9.7 | 9.7 | 9.1 | 0.8 | 0.7 | 0.8 | 0.7 |
| 35 | ICGV 91114 | 9.2 | 8.0 | 7.3 | 8.0 | 0.8 | 0.8 | 0.7 | 0.7 |
| 36 | ICGV 92035 | 8.8 | 10.3 | 9.5 | 8.8 | 0.8 | 0.8 | 0.6 | 0.6 |
| 37 | ICGV 92195 | 8.1 | 7.8 | 8.8 | 6.7 | 0.8 | 0.7 | 0.8 | 0.6 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 38 | ICGV 93468 | 9.3 | 9.6 | 9.8 | 12.9 | 1.0 | 1.0 | 0.8 | 0.9 |
| 39 | ICGV 95390 | 7.9 | 9.7 | 8.9 | 7.3 | 0.8 | 0.8 | 0.7 | 0.7 |
| 40 | ICGV 96346 | 9.2 | 7.8 | 10.9 | 9.2 | 0.9 | 0.7 | 0.9 | 0.8 |
| 41 | ICGV 97182 | 9.9 | 9.1 | 9.7 | 11.1 | 0.9 | 0.8 | 0.7 | 0.8 |
| 42 | ICGV 97183 | 11.9 | 10.1 | 7.4 | 7.2 | 1.0 | 0.8 | 0.6 | 0.7 |
| 43 | ICGV 98294 | 9.7 | 9.2 | 8.7 | 10.5 | 1.0 | 0.8 | 0.9 | 0.9 |
| 44 | TAG 24 | 10.9 | 10.4 | 10.7 | 13.2 | 1.1 | 1.1 | 1.0 | 1.1 |
| 45 | TCGS 1043 | 8.4 | 8.4 | 10.9 | 12.1 | 0.8 | 0.7 | 0.9 | 0.8 |
| 46 | TG 37 | 11.1 | 10.9 | 11.9 | 11.7 | 1.0 | 1.0 | 1.0 | 0.9 |
| 47 | TMV 2 | 5.8 | 6.1 | 6.6 | 5.9 | 0.6 | 0.7 | 0.6 | 0.5 |
| 48 | TPG 41 | 9.4 | 7.3 | 8.2 | 5.5 | 0.7 | 0.6 | 0.6 | 0.5 |
| 49 | VRI 6 | 7.4 | 6.4 | 7.7 | 5.9 | 0.6 | 0.5 | 0.6 | 0.5 |
| 50 | Abhaya | 8.4 | 7.0 | 6.8 | 7.0 | 0.8 | 0.7 | 0.7 | 0.6 |
| 51 | Chico | 7.9 | 8.6 | 9.3 | 7.1 | 0.9 | 0.9 | 0.8 | 0.7 |
| 52 | GJG 31 | 7.9 | 10.1 | 11.5 | 11.7 | 0.8 | 0.9 | 0.9 | 0.8 |
| 53 | ICGS 11 | 9.3 | 7.0 | 7.7 | 5.9 | 0.8 | 0.8 | 0.7 | 0.6 |
| 54 | ICGV 99001 | 5.2 | 7.0 | 6.3 | 3.1 | 0.6 | 0.7 | 0.6 | 0.4 |
| 55 | ICGV 01232 | 13.4 | 10.6 | 10.8 | 10.4 | 1.1 | 0.9 | 0.9 | 0.8 |
| 56 | ICGV 02266 | 10.2 | 9.1 | 9.9 | 9.7 | 0.9 | 0.8 | 0.7 | 0.7 |
| 57 | ICGV 02271 | 4.9 | 7.3 | 7.8 | 7.2 | 0.8 | 0.9 | 1.0 | 0.9 |
| 58 | GG 20 | 5.3 | 6.5 | 8.2 | 6.9 | 0.6 | 0.7 | 0.7 | 0.6 |
| 59 | J 11 | 8.3 | 7.4 | 8.0 | 7.6 | 0.8 | 0.8 | 0.8 | 0.7 |
| 60 | GPBD 4 | 6.6 | 7.8 | 7.2 | 6.2 | 0.8 | 0.8 | 0.6 | 0.6 |
| 61 | JL 24 | 6.6 | 6.2 | 6.9 | 7.1 | 0.7 | 0.6 | 0.6 | 0.6 |
| 62 | K 6 | 7.4 | 5.1 | 7.6 | 7.3 | 0.7 | 0.6 | 0.7 | 0.7 |
| 63 | 55-437 | NA | 5.7 | 7.2 | 5.8 | NA | 0.7 | 0.7 | 0.6 |
| Co-efficient of Variation | | 16.2 | 12.6 | 14.2 | 18.0 | 9.9 | 7.4 | 9.0 | 9.3 |
| Mean | | 9.4 | 9.0 | 9.4 | 8.6 | 0.8 | 0.8 | 0.8 | 0.7 |
| Least Significant Difference | | 3.1 | 2.3 | 2.7 | 3.1 | 0.2 | 0.1 | 0.1 | 0.1 |
| R-Square | | 0.8 | 0.9 | 0.8 | 0.8 | 0.9 | 0.9 | 0.9 | 0.9 |
| Range | MINIMUM | 4.9 | 5.1 | 5.7 | 3.1 | 0.6 | 0.5 | 0.5 | 0.4 |
| | MAXIMUM | 13.4 | 13.1 | 12.8 | 13.2 | 1.1 | 1.1 | 1.0 | 1.1 |

were found to yield below overall mean of the environment among which ICGV 99001 (582 Kg $ha^{-1}$) was the minimum yielder for oil.

The scrutiny of mean values revealed that in E2, nine genotypes yielded higher than the overall mean of the environment. The maximum oil yielding genotype was

ICGV 06039 (2241 Kg ha$^{-1}$). Further, four genotypes were found to be low oil yielders. K 6 (540 Kg ha$^{-1}$) was identified as minimum yielder.

In E3, six genotypes were observed to yield significantly higher than the overall mean of the environment and the genotype ICGV 06040 (2407 Kg ha$^{-1}$) had maximum OY. Also, six genotypes yielded oil significantly lower than the overall mean of the environment wherein ICGV 99001 (504Kg ha$^{-1}$) recorded with minimum oil yield.

In E4, seven genotypes yielded significantly higher than overall mean of the environment. Genotype ICGV 07038 (2107 Kg ha$^{-1}$) had maximum oil yield. Among 62 genotypes under study three were recorded for low oil yield. In E4 also genotype ICGV 99001 (328 Kg ha$^{-1}$) was minimum.

ICGV 99001 had minimum oil yield in all the environments except in E2.

### 4.4.11 Harvest index (HI)

A perusal of data regarding harvest index in E1 revealed that five genotypes perform significantly higher than the overall mean of the environment. TAG 24 (65.2 %) had highest HI. Further, seven genotypes had significantly low HI wherein ICGV 99001 (33.1%) had the lowest values.

Performance of ten genotypes for HI in E2 was found to be significantly higher than the overall mean of the environment. In E2 also TAG 24 (64.7%) recorded highest HI. Moreover, ten genotypes were found to have lower HI percent where VRI 6 (31.7%) had lowest value of mean HI in E2.

In E3, four genotypes performed significantly higher than overall mean of the environment. The genotype TAG 24 (62.6%) had highest HI. Among 62 genotypes under study four were recorded for low harvest index. However, in E3 genotype ICGV 86325 (31.7%) was the lowest.

The scrutiny of harvest index in E4 revealed that three genotypes had significantly higher HI than the overall mean of the environment while TAG 24 (64.6%) had the highest. Out of remaining genotypes three genotypes had significantly low HI. ICGV 99001 had lowest HI (24.6%) in E4.

TAG 24 had the highest harvest index (62.6-65.2%) across the environments.

### 4.4.12 Crop Growth Rate (CGR)

The results pertaining to CGR in E1 revealed that nine genotypes were found to have significantly higher CGR than overall mean of the environment. ICGV 06424 (14.6 $gm^{-2}day^{-1}$) had highest CGR in E1. Further, seven genotypes had significantly lower growth rates where E1 ICGV 02271 (5.7 $gm^{-2}day^{-1}$) was recorded to have lowest CGR.

In E2 ten genotypes were observed with significantly higher CGR where ICGV 06039 (15.6 $gm^{-2}day^{-1}$) had highest CGR. Moreover, 14 had lower CGR of which 55-437 (8.1 $gm^{-2}day^{-1}$) had the lowest value.

For crop growth rate, in E3 ICGV 00351 (15.7 $gm^{-2}day^{-1}$) was the only genotype which performed significantly superior in this environment and while ICGV 02271 (8.4 $gm^{-2}day^{-1}$) was the one performing the least.

In E4 ICGV 05032 (15.9 $gm^{-2}day^{-1}$) was the only genotype identified to be have significantly higher CGR than overall mean of the environment. However, three genotypes were found to be having lower growth rates. ICGV 99001 (7.4 $gm^{-2}day^{-1}$) was identified as the genotype with lowest crop growth rates.

### 4.4.13 Pod Growth Rate (PGR)

The present results showed significant differences among genotypes with respect to pod growth rate in E1. A clear perusal of the mean yield showed that four genotypes showed significantly higher growth rate than overall mean of the environment and genotype ICGV 01232 (13.4 $gm^{-2}day^{-1}$) exhibited highest PGR. Five genotypes were found to show significantly lower pod growth rate where ICGV 02271 (4.9 $gm^{-2}day^{-1}$) was recorded lowest.

In E2, six genotypes were recorded for higher PGR. The genotype with highest PGR was ICGV 07273 (13.1 $gm^{-2}day^{-1}$). Further, eight were estimated to have low PGR of which K 6 (5.1 $gm^{-2}day^{-1}$) was identified as lowest.

In E3, three genotypes were observed to have significantly higher and lower PGR than the overall mean of the environment and the genotypes where ICGV 06040 (12.8 $gm^{-2}day^{-1}$) showed highest while ICGV 86325 (5.7 $gm^{-2}day^{-1}$) exhibited lowest pod growth rate.

A perusal of PGR in E4 showed that five genotypes had significantly higher growth rate than overall mean of the environment. The genotype which performed significantly highest was TAG 24 (13.2 $gm^{-2}day^{-1}$). Among 62 genotypes under study four were recorded low growth rate where in E4 genotype ICGV 99001 (3.1 $gm^{-2}day^{-1}$) was the lowest.

**4.4.14 Partioning Factor (PF)**

The findings regarding partioning factor in E1 showed that two genotypes *viz.*, TAG 24 (1.1) and ICGV 01232 (1.1) were significantly higher than the overall mean of the environment while five genotypes had lower ratio than the overall mean of which VRI 6 (0.57) was the lowest.

The performance of genotypes TAG 24 (1.1), ICGV 93468 (1.0) and TG 37 (1.0) in E2 exhibited higher PF ratio than the overall mean of the environment. Further, eight genotypes had significantly lower ratio. ICGV 87846 (0.51) had the lowest PF ratio in E2.

In E3, five genotypes *viz.*, TAG 24 (1.0), ICGV 02271 (1.0), ICGV 07246 (1.0), ICGV 00308 (1.0) and TG 37 (1.0) respectively were found to have significantly higher PF ratio than the overall mean of the environment. Moreover, only one genotype *i.e.* ICGV 86325 (0.52) was identified to have least PF value.

A perusal of partitioning factor in E4 showed that six genotypes had significantly higher PF ratio than the overall mean of the environment. The genotype TAG 24 (1.1) had highest PF. Out of the remaining genotypes seven were significantly below the overall mean where ICGV 06175 with a mean value of 0.42 for PF was lowest in E4.

**Table 4.9.** Mean performance of genotypes and coefficient of variation for pod yield overall the environments.

| S.No. | GENOTYPES | E1 | E2 | E 3 | E 4 | Mean pod yield over environments | coefficient of variation |
|---|---|---|---|---|---|---|---|
| 1 | ICGV 00298 | 3582 | 4235 | 3634 | 3274 | 3646 | 11.0 |
| 2 | ICGV 00308 | 4501 | 3312 | 3336 | 3435 | 3532 | 16.2 |
| 3 | ICGV 00350 | 4737 | 5497 | 5428 | 4818 | 5010 | 7.9 |
| 4 | ICGV 00351 | 5544 | 4473 | 5492 | 4838 | 5008 | 10.4 |
| 5 | ICGV 03042 | 5662 | 5841 | 6192 | 6180 | 6034 | 4.3 |
| 6 | ICGV 03057 | 4692 | 5742 | 5844 | 5271 | 5334 | 9.9 |
| 7 | ICGV 03109 | 5429 | 4362 | 5246 | 3747 | 4755 | 16.5 |
| 8 | ICGV 05032 | 6188 | 4568 | 5482 | 5635 | 5357 | 12.5 |
| 9 | ICGV 05155 | 6219 | 5733 | 5817 | 4250 | 5473 | 15.8 |
| 10 | ICGV 07456 | 2855 | 2947 | 3299 | 2769 | 3240 | 7.2 |
| 11 | ICGV 06039 | 6041 | 6536 | 5308 | 5605 | 5999 | 8.9 |
| 12 | ICGV 06040 | 5884 | 4881 | 6767 | 5606 | 5725 | 13.6 |
| 13 | ICGV 06099 | 6080 | 4816 | 4840 | 5410 | 5331 | 11.2 |
| 14 | ICGV 06175 | 4462 | 3962 | 3888 | 2892 | 3927 | 16.7 |
| 15 | ICGV 06420 | 5089 | 5188 | 5198 | 5131 | 5147 | 1.0 |
| 16 | ICGV 06424 | 6586 | 4996 | 6597 | 4496 | 5569 | 19.5 |
| 17 | ICGV 07012 | 6761 | 5947 | 6072 | 5237 | 5869 | 10.6 |
| 18 | ICGV 07013 | 5250 | 4696 | 4717 | 4664 | 4851 | 5.8 |
| 19 | ICGV 07038 | 5206 | 5267 | 6521 | 5678 | 5557 | 10.9 |
| 20 | ICGV 05200 | 4482 | 4211 | 5154 | 4152 | 4381 | 10.5 |
| 21 | ICGV 07148 | 5714 | 4189 | 5815 | 4346 | 4886 | 17.8 |
| 22 | ICGV 07211 | 4002 | 2648 | 3539 | 3370 | 3465 | 16.2 |
| 23 | ICGV 07213 | 5360 | 5082 | 4483 | 4713 | 5019 | 7.7 |
| 24 | ICGV 07217 | 4155 | 4513 | 4609 | 3740 | 4327 | 9.1 |
| 25 | ICGV 07246 | 6416 | 6622 | 6761 | 5385 | 6195 | 10.1 |
| 26 | ICGV 07268 | 6248 | 5609 | 5051 | 4922 | 5348 | 11.3 |
| 27 | ICGV 07273 | 5379 | 5945 | 5212 | 4402 | 5301 | 12.0 |
| 28 | ICGV 07356 | 4682 | 4388 | 3685 | 2661 | 3873 | 23.2 |
| 29 | ICGV 86325 | 2205 | 2868 | 2854 | 1995 | 2532 | 17.7 |
| 30 | ICGV 87128 | 3923 | 3798 | 3774 | 3925 | 3871 | 2.1 |
| 31 | ICGV 87141 | 3511 | 3235 | 3705 | 3512 | 3466 | 5.6 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 32 | ICGV 87846 | 3529 | 3164 | 4622 | 4045 | 3815 | 16.6 |
| 33 | ICGV 89280 | 5246 | 4690 | 4648 | 4915 | 4915 | 5.6 |
| 35 | ICGV 91114 | 4026 | 3309 | 2751 | 3302 | 3336 | 15.7 |
| 36 | ICGV 92035 | 4066 | 4720 | 4941 | 3652 | 4387 | 13.5 |
| 37 | ICGV 92195 | 3429 | 3094 | 3452 | 2892 | 3204 | 8.5 |
| 38 | ICGV 93468 | 4220 | 3942 | 3954 | 5338 | 4322 | 15.3 |
| 39 | ICGV 95390 | 3841 | 4182 | 4064 | 3204 | 3830 | 11.4 |
| 40 | ICGV 96346 | 4062 | 3237 | 4259 | 3089 | 3758 | 15.6 |
| 41 | ICGV 97182 | 4482 | 4017 | 4824 | 4643 | 4485 | 7.7 |
| 42 | ICGV 97183 | 5393 | 4434 | 3761 | 3508 | 4236 | 19.9 |
| 43 | ICGV 98294 | 4244 | 3851 | 3600 | 4180 | 4068 | 7.4 |
| 44 | TAG 24 | 4603 | 4468 | 5149 | 4879 | 4804 | 6.3 |
| 45 | TCGS 1043 | 3988 | 3811 | 4256 | 4337 | 3922 | 6.2 |
| 46 | TG 37 | 4558 | 4397 | 5033 | 4494 | 4740 | 6.0 |
| 47 | TMV 2 | 2523 | 2630 | 2253 | 2357 | 2487 | 6.8 |
| 48 | TPG 41 | 4590 | 3846 | 3996 | 2941 | 3975 | 17.2 |
| 49 | VRI 6 | 3735 | 3106 | 3726 | 2841 | 3330 | 13.5 |
| 50 | Abhaya | 4715 | 3326 | 3302 | 3093 | 3453 | 21.6 |
| 51 | Chico | 3265 | 3587 | 3769 | 2522 | 3269 | 16.8 |
| 52 | GJG 31 | 3308 | 3942 | 3935 | 4895 | 4128 | 15.9 |
| 53 | ICGS 11 | 4484 | 3371 | 3645 | 3454 | 3757 | 13.6 |
| 54 | ICGV 99001 | 2225 | 2754 | 2034 | 1483 | 2236 | 23.5 |
| 55 | ICGV 01232 | 5576 | 4692 | 4119 | 4603 | 4698 | 12.9 |
| 56 | ICGV 02266 | 4982 | 4320 | 5399 | 4809 | 4801 | 9.3 |
| 57 | ICGV 02271 | 2459 | 3669 | 3442 | 2722 | 3180 | 18.1 |
| 58 | GG 20 | 2369 | 3104 | 3851 | 3607 | 3282 | 19.9 |
| 59 | J 11 | 3612 | 3099 | 3136 | 2302 | 3169 | 17.1 |
| 60 | GPBD 4 | 2954 | 3502 | 3396 | 2257 | 3089 | 18.3 |
| 61 | JL 24 | 2895 | 2480 | 2460 | 3039 | 2706 | 10.8 |
| 62 | K 6 | 3675 | 2235 | 2576 | 2435 | 2795 | 23.1 |
| 63 | 55-437 | NA | 2402 | 2602 | 2427 | 2477 | 4.4 |
| Co-efficient of Variation | | 15 | 12 | 15 | | | |
| Mean | | 4531 | 4144 | 4373 | | | |
| Least Significant Difference | | 1454 | 1081 | 1389 | 678 | | |
| Range | | | | | | | |
| MINIMUM | | 2205 | 2235 | 2034 | 2236 | | |
| MAXIMUM | | 6761 | 6622 | 6767 | 6195 | | |

E=Environment

**Screening of stable genotypes**

The results pertaining to average pod yield across the environments ranged from 2236 Kg $ha^{-1}$ (ICGV 99001) to 6195 Kg $ha^{-1}$ (ICGV 07246). However, seven genotypes were identified as top yielders (Table 4.9) and the performance of these genotypes in accordance of decreasing pod yield were ICGV 07246 (6195 Kg $ha^{-1}$), ICGV 03042 (6034 Kg $ha^{-1}$), ICGV 06039 (5999 Kg $ha^{-1}$), ICGV 07012 (5869 Kg $ha^{-1}$), ICGV 06040 (5725 Kg $ha^{-1}$), ICGV 06424 (5569 Kg $ha^{-1}$) and ICGV 07038 (5557 Kg $ha^{-1}$).

The coefficient of variation (CV) of individual genotypes for pod yield performance over all the four environments revealed a wide range for the test genotypes which ranged from 1.0 (ICGV 06420) to 23.5 (ICGV 99001). Hence, on the basis of coefficient of variation for pod yield/ha, ICGV 06420 was considered stable across the environment but the yield pertaining to ICGV 06420 was significantly lower than top yielding genotype (ICGV 07246). Among the top yielders the CV value of ICGV 03042 was least (4.3) while ICGV 06424 (19.5) was highest. The CV for best yielding genotype (ICGV 07246) was 10.1.

The genotypes showed continuously showed increase in pod yield performances with delayed sowing in respective environment, were GJG 31, ICGV 87846, ICGV 03057, ICGV 07038 and GG 20 whereas five genotypes *viz*., ICGV 07012, ICGV 07356, ICGV 97183, ICGV 07268 and Abhaya continuously decreases their pod yield performance on delayed sowing.

**Identification of genotypes tolerant to heat**

The result of stress susceptible index (SSI) and stress tolerance index (STI) for pod yield was calculated for three different environments E2, E3 and E4 using E1 as control (Table 4.10). Different response of heat over pod yield in groundnut genotypes were observed in each of the environment. In E2, the SSI value ranged from lowest of -5.8 (ICGV 02271) to the maximum of 4.6 for the genotype K6. In E3, the lowest SSI value -17.9 was scored by GG 20 with a maximum of 9.1 for the genotype ICGV 91114 whereas in E4 the SSI ranged from -4.0 for GG 20 up to a maximum of 3.3 for genotype ICGV 07356.

**Table 4.10.** Estimates of Stress susceptibility index and stress tolerance index in groundnut genotypes for three stressed environments (E2, E3 and E4).

| S.No. | Genotypes | Stress susceptible index | | | Stress tolerant index | | |
|---|---|---|---|---|---|---|---|
| | | E2 | E3 | E4 | E2 | E3 | E4 |
| 1 | ICGV 00298 | -2.1 | -0.4 | 0.7 | 0.7 | 0.6 | 0.6 |
| 2 | ICGV 00308 | 3.1 | 7.4 | 1.8 | 0.7 | 0.7 | 0.8 |
| 3 | ICGV 00350 | -1.9 | -4.2 | -0.1 | 1.3 | 1.3 | 1.1 |
| 4 | ICGV 00351 | 2.3 | 0.3 | 1.0 | 1.2 | 1.5 | 1.3 |
| 5 | ICGV 03042 | -0.4 | -2.7 | -0.7 | 1.6 | 1.7 | 1.7 |
| 6 | ICGV 03057 | -2.6 | -7.0 | -1.0 | 1.3 | 1.3 | 1.2 |
| 7 | ICGV 03109 | -2.6 | 1.0 | 2.4 | 1.2 | 1.4 | 1.0 |
| 8 | ICGV 05032 | 3.1 | 3.3 | 0.7 | 1.4 | 1.7 | 1.7 |
| 9 | ICGV 05155 | 0.9 | 1.9 | 2.4 | 1.7 | 1.8 | 1.3 |
| 10 | ICGV 07456 | -0.4 | -4.5 | 0.2 | 0.4 | 0.5 | 0.4 |
| 11 | ICGV 06039 | -1.0 | 3.5 | 0.6 | 1.9 | 1.6 | 1.6 |
| 12 | ICGV 06040 | 2.0 | -4.3 | 0.4 | 1.4 | 1.9 | 1.6 |
| 13 | ICGV 06099 | 2.4 | 5.9 | 0.9 | 1.4 | 1.4 | 1.6 |
| 14 | ICGV 06175 | 1.3 | 3.7 | 2.7 | 0.9 | 0.8 | 0.6 |
| 15 | ICGV 06420 | -0.2 | -0.6 | -0.1 | 1.3 | 1.3 | 1.3 |
| 16 | ICGV 06424 | 2.8 | 0.0 | 2.5 | 1.6 | 2.1 | 1.4 |
| 17 | ICGV 07012 | 1.4 | 2.9 | 1.7 | 2.0 | 2.0 | 1.7 |
| 18 | ICGV 07013 | 1.2 | 2.9 | 0.9 | 1.2 | 1.2 | 1.2 |
| 19 | ICGV 07038 | -0.1 | -7.2 | -0.7 | 1.3 | 1.7 | 1.4 |
| 20 | ICGV 05200 | 0.7 | -4.3 | 0.6 | 0.9 | 1.1 | 0.9 |
| 21 | ICGV 07148 | 3.1 | -0.5 | 1.9 | 1.2 | 1.6 | 1.2 |
| 22 | ICGV 07211 | 4.0 | 3.3 | 1.2 | 0.5 | 0.7 | 0.7 |
| 23 | ICGV 07213 | 0.6 | 4.7 | 0.9 | 1.3 | 1.2 | 1.2 |
| 24 | ICGV 07217 | -1.0 | -3.1 | 0.8 | 0.9 | 0.9 | 0.8 |
| 25 | ICGV 07246 | -0.4 | -1.5 | 1.2 | 2.1 | 2.1 | 1.7 |
| 26 | ICGV 07268 | 1.2 | 5.5 | 1.6 | 1.7 | 1.5 | 1.5 |
| 27 | ICGV 07273 | -1.2 | 0.9 | 1.4 | 1.6 | 1.4 | 1.2 |
| 28 | ICGV 07356 | 0.7 | 6.1 | 3.3 | 1.0 | 0.8 | 0.6 |
| 29 | ICGV 86325 | -3.5 | -8.4 | 0.7 | 0.3 | 0.3 | 0.2 |
| 30 | ICGV 87128 | 0.4 | 1.1 | 0.0 | 0.7 | 0.7 | 0.8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 31 | ICGV 87141 | 0.9 | -1.6 | 0.0 | 0.6 | 0.6 | 0.6 |
| 32 | ICGV 87846 | 1.2 | -8.9 | -1.1 | 0.5 | 0.8 | 0.7 |
| 33 | ICGV 89280 | 1.2 | 3.3 | 0.5 | 1.2 | 1.2 | 1.3 |
| 35 | ICGV 91114 | 2.1 | 9.1 | 1.4 | 0.6 | 0.5 | 0.6 |
| 36 | ICGV 92035 | -1.9 | -6.2 | 0.8 | 0.9 | 1.0 | 0.7 |
| 37 | ICGV 92195 | 1.1 | -0.2 | 1.2 | 0.5 | 0.6 | 0.5 |
| 38 | ICGV 93468 | 0.8 | 1.8 | -2.0 | 0.8 | 0.8 | 1.1 |
| 39 | ICGV 95390 | -1.0 | -1.7 | 1.3 | 0.8 | 0.8 | 0.6 |
| 40 | ICGV 96346 | 2.4 | -1.4 | 1.9 | 0.6 | 0.8 | 0.6 |
| 41 | ICGV 97182 | 1.2 | -2.2 | -0.3 | 0.9 | 1.1 | 1.0 |
| 42 | ICGV 97183 | 2.1 | 8.7 | 2.7 | 1.2 | 1.0 | 0.9 |
| 43 | ICGV 98294 | 1.1 | 4.4 | 0.1 | 0.8 | 0.7 | 0.9 |
| 44 | TAG 24 | 0.3 | -3.4 | -0.5 | 1.0 | 1.2 | 1.1 |
| 45 | TCGS 1043 | 0.5 | -1.9 | -0.7 | 0.7 | 0.8 | 0.8 |
| 46 | TG 37 | 0.4 | -3.0 | 0.1 | 1.0 | 1.1 | 1.0 |
| 47 | TMV 2 | -0.5 | 3.1 | 0.5 | 0.3 | 0.3 | 0.3 |
| 48 | TPG 41 | 1.9 | 3.7 | 2.8 | 0.9 | 0.9 | 0.7 |
| 49 | VRI 6 | 2.0 | 0.1 | 1.9 | 0.6 | 0.7 | 0.5 |
| 50 | Abhaya | 3.4 | 8.6 | 2.7 | 0.8 | 0.8 | 0.7 |
| 51 | Chico | -1.2 | -4.4 | 1.8 | 0.6 | 0.6 | 0.4 |
| 52 | GJG 31 | -2.2 | -5.4 | -3.7 | 0.6 | 0.6 | 0.8 |
| 53 | ICGS 11 | 2.9 | 5.4 | 1.8 | 0.7 | 0.8 | 0.8 |
| 54 | ICGV 99001 | -2.8 | 2.5 | 2.6 | 0.3 | 0.2 | 0.2 |
| 55 | ICGV 01232 | 1.9 | 7.5 | 1.4 | 1.3 | 1.1 | 1.3 |
| 56 | ICGV 02266 | 1.6 | -2.4 | 0.3 | 1.0 | 1.3 | 1.2 |
| 57 | ICGV 02271 | -5.8 | -11.5 | -0.8 | 0.4 | 0.4 | 0.3 |
| 58 | GG 20 | -3.6 | -17.9 | -4.0 | 0.4 | 0.4 | 0.4 |
| 59 | J 11 | 1.7 | 3.8 | 2.8 | 0.5 | 0.6 | 0.4 |
| 60 | GPBD 4 | -2.2 | -4.3 | 1.8 | 0.5 | 0.5 | 0.3 |
| 61 | JL 24 | 1.7 | 4.3 | -0.4 | 0.3 | 0.3 | 0.4 |
| 62 | K 6 | 4.6 | 8.6 | 2.6 | 0.4 | 0.5 | 0.4 |
| 63 | 55-437 | Data for E1 is not available | | | | | |

E= environment

**Table 4.11.** Top ten genotypes identified according to stress tolerance indices (SSI and STI).

| HEAT TOLERANT GENOTYPES BASED ON STI | | | | | |
|---|---|---|---|---|---|
| **Genotypes** | **E2** | **Genotypes** | **E3** | **Genotypes** | **E4** |
| ICGV 07246 | 2.1 | ICGV 06424 | 2.1 | ICGV 07012 | 1.7 |
| ICGV 07012 | 2.0 | ICGV 07246 | 2.1 | ICGV 03042 | 1.7 |
| ICGV 06039 | 1.9 | ICGV 07012 | 2.0 | ICGV 05032 | 1.7 |
| ICGV 05155 | 1.7 | ICGV 06040 | 1.9 | ICGV 07246 | 1.7 |
| ICGV 07268 | 1.7 | ICGV 05155 | 1.8 | ICGV 06039 | 1.6 |
| ICGV 03042 | 1.6 | ICGV 03042 | 1.7 | ICGV 06040 | 1.6 |
| ICGV 06424 | 1.6 | ICGV 07038 | 1.7 | ICGV 06099 | 1.6 |
| ICGV 07273 | 1.6 | ICGV 05032 | 1.7 | ICGV 07268 | 1.5 |
| ICGV 06099 | 1.4 | ICGV 07148 | 1.6 | ICGV 06424 | 1.4 |
| ICGV 06040 | 1.4 | ICGV 06039 | 1.6 | ICGV 07038 | 1.4 |
| **HEAT TOLERANT GENOTYPES BASED ON SSI** | | | | | |
| ICGV 02271 | -5.8 | GG 20 | -17.9 | GG 20 | -4.0 |
| GG 20 | -3.6 | ICGV 02271 | -11.5 | GJG 31 | -3.7 |
| ICGV 86325 | -3.5 | ICGV 87846 | -8.9 | ICGV 93468 | -2.0 |
| ICGV 99001 | -2.8 | ICGV 86325 | -8.4 | ICGV 87846 | -1.1 |
| ICGV 03057 | -2.6 | ICGV 07038 | -7.2 | ICGV 03057 | -1.0 |
| ICGV 03109 | -2.6 | ICGV 03057 | -7.0 | ICGV 02271 | -0.8 |
| GJG 31 | -2.2 | ICGV 92035 | -6.2 | ICGV 03042 | -0.7 |
| GPBD 4 | -2.2 | GJG 31 | -5.4 | ICGV 07038 | -0.7 |
| ICGV 00298 | -2.1 | ICGV 07456 | -4.5 | TCGS 1043 | -0.7 |
| ICGV 92035 | -1.9 | Chico | -4.4 | TAG 24 | -0.5 |

E=environment
STI=Stress Tolerance Index
SSI=Stress Susceptible index

Stress tolerance index also determined genotypes for respective stressed environments. The STI values in E2 ranged from a minimum of 0.3 for ICGV 86325, TMV 2, ICGV 99001 and JL 24 up to a maximum of 2.1 for ICGV 07246. However, in E3 STI score was lowest for the genotype ICGV 99001 with a value of 0.2 while ICGV

07246 highest value of 2.1. Further, in E4 the STI values ranged between 0.9-1.7 with genotypes ICGV 99001 and ICGV 86325 as minimum while genotypes ICGV 03042, ICGV 05032, ICGV 07012 and ICGV 07246 with maximum values.

Based on the values of SSI and STI index top ten genotypes were identified as heat tolerant (Table 4.11). Out of these ten genotypes identified as tolerant using SSI index, four genotypes were common in all the three stressed environments *viz.*, E2, E3 and E4 according to SSI were ICGV 03057, GG 20, ICGV 02271 and GJG 31.

While six genotypes *viz*., ICGV 07246, ICGV 07012, ICGV 06039, ICGV 06040, ICGV 03042 and ICGV 06424 were identified as heat tolerant in each of the stressed environment using STI index.

Correlation between SSI and pod yield under stressed environment showed that E2 (-0.14) exhibited non-significant correlation with SSI while in E3 the correlation was negatively significant (-0.25) at 5% probability level (Table 4.12.). However, in E4 (-0.41) pod yield exhibited highly significant negative association with SSI at 1% probability level. Moreover, correlation analysis between STI and pod yield under stressed environment exhibited highly significant and positive correlation with a value of 0.95 in E2, 0.94 in E3 and 0.93 in E4 respectively.

**Table 4.12.** Correlation between pod yields in heat stressed environments and heat stress indices (SSI and STI).

| Pod Yield in Heat stress environments | Stress tolerance index | Stress susceptible index |
|---|---|---|
| E2 | 0.95** | -0.14 NS |
| E3 | 0.94** | -0.25* |
| E4 | 0.93** | -0.41** |

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

# Chapter V
# DISCUSSION

## Chapter-V

# DISCUSSION

High temperature is a major constraint for crop adaptation and productivity, especially when these temperature extremes coincide with drought and with critical stages of plant development (Mc William, 1980). Tolerance to heat is generally defined as the ability of the plant to grow and produce economic yield under high temperatures. For a successful planning of a breeding programme, knowledge of the extent and nature of genetic variability present in genetic resources for the desired traits is essential. Further, how these traits are associated with each other and with yield decide the selection strategy, which a breeder should follow. In the present study it was analyzed how the complex trait yield and its associated traits were influenced by the heat stress on delayed sowing.

**Analysis of Variance**

Analysis of variance of 14 different traits revealed highly significant differences among the genotypes across the environments. Significant differences for pod yield, days to maturity, 100 kernel weight and oil content have been reported by Shinde *et al*. (2010) while Nath and Alam (2002) and Injeti *et al*. (2008) supported the above findings for shelling percentage and harvest index. The large variation in crop growth rate, partitioning factor and pod yield have also been reported by Ntare *et al.* (2001). In accordance with the above findings Thakur *et al*. (2011) observed significant variations among genotypes for days to 75% flowering and Ashutosh and Prashant (2014) for kernel yield and sound mature kernel. Significant variations between traits measured on the groundnut genotypes were indicative of the wealth of the studied population as a source of parental materials for future improvement programme.

Effect of environment on phenotype of a particular trait can adversely change the advance upon selection. The combined visual assessment of the level of tolerance and its stability is a big advantage, and adds confidence in the decision to promote a superior genotype. However, GGE biplot is a data visualization tool, which graphically displays a genotype × environment (G×E) interaction in a two way table (Yan, 2000). GGE biplot is an effective tool for mega-environment analysis whereby specific genotype can be recommended to specific mega-environment, genotype evaluation and environmental evaluation (the power to discriminate among genotypes in target environments). GGE biplot analysis is increasingly being used in genotype × environment interaction data analysis in agriculture (Butron, 2004; Crossa *et al*., 2002; Samonte *et al*., 2005; Dehghani *et al*., 2006 and Kaya *et al*., 2006).

Genotype x environment interaction were important for days to 75% flowering, days to maturity, dry haulm weight, sound mature kernel percentage, hundred kernel weight and crop growth rate. In accordance to above findings Chauhan *et al*. (2009) reported significant G x E interaction for test weight and crop growth rate in mustard. This suggested that these characters were highly sensitive to the changes in the environmental conditions. Significant differences observed for days to 75% flowering and days to maturity among the genotypes reflect genotype x environment interaction. Stable genotypes identified for early flowering across the four environments were J 11 closely followed by ICGV 91114. Further, maximum variation among the genotypes was exhibited in E1 *i.e.*, it was most discriminating environment while E2 was most representative. Genotype J 11 was found to be earliest maturing across the environments followed by Chico and ICGV 91114 across the environments and was stable. Among the entire environment most early maturing genotypes were recovered in E4 which was most discriminating environment. It has also been observed that delayed sowing reduces the maturity of the genotypes. However lesser variation among the genotypes was exhibited in E2.

**Estimation of parameters of genetic variability**

The existence of genetic variation can be employed as the basis for improving yield and other potentials of crop plant (Morakinyo & Makinde, 1991; Muhammad *et al*., 2007; Jonah *et al*., 2010). The estimation of genotypic and phenotypic coefficient variability indicates the amount of genetic and non-genetic variation present for different desirable traits. In general, phenotypic coefficient of variability (PCV) was marginally higher than the genotypic coefficient of variability (GCV) for all the traits studied. The higher values of phenotypic coefficient of variation level than genotypic coefficient of variation suggested the influence of environmental factors. However, the effective selection for traits under improvement depends on sufficient genetic variation of the traits and their heritability values

Across the environment high estimates of genotypic coefficient of variation and phenotypic coefficient of variation was observed for pod yield, kernel yield, oil yield and haulm weight. In support of above findings Khote *et al.* (2009); Meta and Monopara (2010); Narasimhulu *et al.* (2012) and Gomes and Lopes (2005) reported high phenotypic and genotypic coefficient of variation for pod and kernel yield. John *et al.* (2007) found high coefficient of variations for haulm weight. High magnitude of genotypic coefficient of variation revealed the extent of variability present in these characters and suggests good scope for improvement through selection.

Moderate GCV to high PCV estimates for hundred kernel weight was observed which are in accordance to the findings of Thirumala *et al*. (2014) while moderate GCV and PCV was observed for harvest index and crop growth rate which slightly differ from the findings by Khote *et al.* (2009) and John *et al.* (2012) where they reported higher estimates for GCV and PCV. Days to 75% flowering, days to maturity, sound mature kernel shelling percentage and oil content were observed with low phenotypic and genotypic coefficient of variation. Similalar findings were reported for days to maturity and days to 50% flowering while moderate GCV and PCV was reported for oil content by Shinde *et al*. (2010). However, Narasimhulu *et al.* (2012) reported high GCV and PCV for sound mature kernel and shelling percentage.

High heritability estimates signify the effectiveness of the traits through selection for crop improvement (Singkhan *et al.* 2010). However, heritability values depend on the extent of genetic variability analyzed, unpredictable environment variation and experimental design (Kale *et al.* 1998). The estimates of genetic advance help in understanding the type of gene action involved in the expression of various polygenic characters (Lynch and Walsh, 1998; Singh and Narayanan, 1993). High values of genetic advance are indicative of additive gene action whereas low values are indicative of non-additive gene action (Singh and Narayanan, 1993) as they provides information needed in designing the most effective breeding program and relative practicability of selection (Lynch and Walsh, 1998).

In the present study high heritability estimates along with high genetic advance as percent of mean (GAM) was exhibited by pod yield, kernel yield, hundred kernel weight oil yield, haulm weight, harvest index, pod growth rate, crop growth rate and partioning factor in all the four environments. John *et al.* (2007) and Khote *et al.* (2009) also reported high broad sense heritability and GAM for pod yield, kernel yield, haulm weight and harvest index and concluded that role of additive gene action seems to be significant in the inheritance of these traits. Mahalakshmi *et al.* (2005) and Thirumala *et al*. (2014) reported similar results for 100-kernel weight whereas; Hiremanth *et al.* (2011) supported the above findings for oil, pod and kernel yield. This indicated that the traits having sufficient additive genetic variance which can be exploited through selection.

High heritability along with moderate genetic advance as percent of mean was observed for days to maturity and shelling percentage. The present findings are in accordance with of Mahalakshmi *et al.* (2005) and Narasimhulu *et al.* (2012) who observed high heritability and GAM for shelling percentage. However, Shinde *et al*. (2010) reported high heritability coupled with low GAM for days to maturity. Venkataramana (2001) and Johnson *et al.* (1955a) suggested that heritability when calculated together will be more useful in predicting the resultants effects of selection.

High heritability coupled with low genetic advance as percent of mean was exhibited by days to 75% flowering and oil content which suggested that these traits were influenced by environment. In such a situation selection would not be rewarding. Noubissie *et al*. (2012) found moderate heritability coupled with low GAM for oil content. However, sound mature kernel showed moderate heritability coupled low GAM. Madhura and Kenchanhgoudar (2012) reported high heritability coupled with moderate GAM for oil content, moderate heritability and GAM for SMK percentage and moderate heritability coupled with low GAM for days to maturity and 50% flowering. Moreover, John *et al.* (2012) reported high heritability along with GAM for sound mature kernels.

In the present study it was observed that pod yield, kernel yield, oil yield, harvest index, hundred kernel weight and partitioning factor had higher proportion of additive genetic variance and thus selection of desirable genotypes could be possible.

**Determination of association of traits**

Complex traits like yield are measures of several associated traits which directly or indirectly influence the expression of the trait. Correlation by contrast indicates whether two variables are independent or vary together, hence it is a measure of closeness. As the yield is a cumulative of several other traits, direct selection for yield per se may not be effective. Selection practice for one or more characters may bring the changes in other traits which may not be desirable. Thus, the information of magnitude and direction of association between yield and its contributing traits is essential for improvement in desired direction.

In the present study pod yield exhibited positive and highly significant correlations with days to maturity, kernel yield, oil yield, oil content, hundred kernel weight, harvest index, and haulm weight in all the four environments with an exception in E1 for hundred kernel weight. Similar findings were reported by Vekariya *et al*. (2011) and Babariya and Dobariya (2012) for kernel yield, harvest index and hundred kernel weight. However, crop growth rate, pod growth rate and partitioning factor showed positive and highly significant association with pod yield across the environment which were in accordance with the findings of Frimpong (2004). Hamidou *et al.* (2012) found that correlation analysis between pod weight and traits measured during plant growth showed that the partition rate, contributing in heat and drought tolerance could be a reliable selection criterion for groundnut breeding programme. Moreover, Meta and Monpara (2010) and Jogloy *et al*. (2011) contradict above findings for days to maturity.

High shelling percentage represents well filled pods with better kernel recovery; while100 kernel weight and SMK percentage is the indicator of higher proportion of uniform large kernels. All these pod features are desirable to attract both consumers and producers. A positive association of shelling out turn with SMK percentage indicated that an increase in shelling out turn would be responsible for higher SMK percentage. These results were supported by Meta and Monpara (2010). Kernel yield exhibited positive and significant associations with shelling percentage and 100-kernel weight and were in accordance with the findings of Shoba *et al*. (2012).

Oil content in groundnut is economically desirable characteristic which expressed positive and highly significant association with pod yield, days to maturity and kernel yield, oil yield, crop and pod growth rate over all the environments. Noubissie *et al*. (2012) supported the above findings for associations with kernel yield. However, Madhura and Kenchanagoudar (2012) supported above findings for positive associations between pod yield and oil content while Sumanthi and Muralidharan (2007) and Samone *et al*. (2010) reported negative significant correlation between pod yield and oil content.

Thus, the present study emphasized the importance of days to maturity, kernel yield, oil yield, oil content, hundred kernel weight, harvest index, haulm weight, crop growth rate, pod growth rate and partitioning factor as the most reliable and major yield attributes in all the four environments which can be exploited while constructing selection indices aimed at maximizing yield in groundnut. However higher pod, kernel and oil yield and also higher rates of crop and pod growth along with longer duration for maturity would allow enrichment for oil content in groundnut genotypes.

**Screening of heat tolerant genotypes**

Field tolerance of a genotype is a measure of tolerance of that very genotype for several growth stages. Specific physiological stages are more responsive to stresses than others and plant responses are different for each stage and also specific to genotypes. Reproductive stages are more sensitive to stresses in plants and leads to reduced yield (Hamidou *et al*., 2013). Plant responses at high temperature vary with species and phenological stages (Wahid *et al*., 2007). However, it is important to know the response of each trait under stress and non-stress environment to develop a strategic breeding programme. In the present study the variability observed for days to 75% flowering across the environment signified the role of environment. The overall mean for number of days to reach DF 75% significantly reduced from E1 with a percent reduction of 9.0 for E2, 15.5 for E3 and 21.6 for E4. Crauford *et al.* (2003) reported that reproductive processes in groundnut are sensitive to temperature. The duration of days to 75% flowering of all the genotypes in the stressed environment reduced when compared with E1. However, J11 and ICGV 91114 were early flowering genotypes across the environment whose stability was confirmed by GGE biplot. Non-stressed environment (E1) under present study was highly discriminating with large variations for days to flowering 75% flowering while E2 was least.

The reduced crop duration without reduced seed size and yield penalty is the most challenge of peanut breeding for earliness in case that the earliness is not extreme. Crops need duration of growth and good partitioning of assimilates to economic yield obtain high yield. In the present study effect of heat on days to maturity for the genotypes over environment was found significant. The maturity duration of genotypes over the environment reduced with increased heat on delayed sowing. The performance of individual genotypes for maturity significantly changed with increased heat that showed the interaction of genotypes with heat effect. Hence, there are chances to identify high yielding early maturing genotypes suitable for delayed sowing. However, J11 and ICGV 91114 were stable and early maturing genotypes screened across the environment using GGE biplot. The days to 50% flowering were delayed and maturity was accelerated in chickpea under heat stress and indicated that the vegetative period was longer than grain filling period. These genotypes represent ideal materials for further characterization of underlying mechanisms of tolerance involved (Krishnamurthy *et al*. 2011).

The overall response of genotypic performance for hundred kernel weight over the environment also differed significantly. Biplot analysis confirmed the genotype x environment interaction for hundred kernel weight. However, few genotypes say ICGV 05200 and TPG 41 showed higher performances over the environment. A significant correlation was also observed for hundred kernel weight and pod yield that showed the chances of improving both traits through selection. Among the four environments E3 was the most reducing environment for hundred kernel weight for most of the higher performing genotypes. However, E1 was most suitable environment for hundred kernel weight.

Non-significant differences between overall mean of respective environment was observed for oil content, hence variation due to environment was negligible. Across the environment ICGV 06420 had high oil percent followed by ICGV 05200. In this study it has been found that the heat stress does not have any effect on oil content of genotypes.

Identification of stable genotypes with lesser variation of yield performances over the environment has always remains an important issue for the breeder. Identification of suitable genotypes specific to environment or over the environment reflects the significance of stability analysis. A favorable genotype is one that combines both high mean yield and performance stability making it acceptable over a wide range of environmental conditions (Allard and Bradshaw, 1964). Wide variations for pod yield in each environment were observed. In the present study the genotype x environment interactions for pod yield across the environments was non-significant but genotypes showed significant differences. However, Hamidou *et al.* (2013) reported significant variation for pod yield in groundnut during high temperature.

The performance of genotypes over the environment is greatly affected with several factors. There are several parameters identified for determination of stable genotypes. One of the simplest parameters used is co-efficient of variation (Rahmatollah *et al*., 2012; Finlay and Wilkinson, 1963). The stability of individual genotypes was represented by co-efficient of variation in the present study in which ICGV 06420 as most stable was identified across the stressed and non-stressed environments.

Based on the mean pod yield across the environment, genotypes ICGV 07246, ICGV 03042, ICGV 06039, ICGV 07012, ICGV 06040, ICGV 06424 and ICGV 07038 were identified as top seven yielders of which genotype ICGV 03042 showed least co-efficient variation values. Among top yielders ICGV 03042 was the most stable along with higher yield performance in all the stressed and non-stressed environments. Besides the identification of stable genotypes in respect to heat effect, identification of suitable genotypes with increased yield performance on delayed sowing may have greater potential to developed heat tolerance genotypes through breeding programme. Five genotypes *viz*., GJG 31, ICGV 87846, ICGV 03057, ICGV 07038 and GG 20 showed increase yield performance at higher temperatures, which would be effective for better performance at elevated temperatures among which GJG 31 and GG 20 showed significantly higher yield than E1 in all other three environments

Differential response of genotypes for heat effect on various physiological traits makes the screening of genotypes for heat more complex. Several studies were conducted to screen out heat tolerant genotypes under control (Craufurd *et al*., 2003; Gangappa,*et al.* 2006; Selvaraj *et al*., 2011) and field conditions (Ntare *et al*., 2001; Devasirvatham *et al*., 2012; Hamidou *et al*., 2013). However, screening of genotypes and understanding of their responses under field condition is more accurate and important to screen out and to develop heat tolerant genotypes.

Several studies have been conducted to elucidate heat tolerant mechanisms in several crop species (Craufurd *et al*., 2003; Khattak *et al*., 2006 Hasan *et al*., 2007; Rehman *et al*., 2009; Devasirvatham *et al*., 2012 ). Few heat stress indices have been developed to evaluate genotypes for heat stress. Most of the indices were yield based and found more reliable for screening. Among the several indices STI was found more responsive to evaluate genotypes under heat stress both in stress and non-stress environment (Fernandez, 1992; Moghaddam and Hadizadeh, 2000; Porch, 2006).

In the present study the evaluation of two heat stress indices *i.e.*, Stress Susceptible Indices (SSI) and Stress Tolerance Indices (STI) was considered. Significant correlation co-efficient was found between STI and pod yield in the entire three stress environment than the SSI. Based on this criteria STI was considered more reliable parameter for screening of heat tolerant groundnut genotypes under both stress and non-stress environment. Porch (2006) in his evaluation of heat tolerance indices, reported that STI and GM, although correlated, were found to be effective stress indices for the selection of genotypes with good yield potential under stress and low-stress conditions.

Correlation analysis of stress tolerance and stress susceptible indices with pod yield showed high and significant associations for stress tolerance indices (STI) which showed the importance of screening of genotypes based on STI. Six genotypes (ICGV

07246, ICGV 07012, ICGV 06039, ICGV 06040, ICGV 03042 and ICGV 06424) were identified as tolerant to heat based on STI under E2, E3, and E4 which were also identified as top yielding genotypes.

In the present study it has been observed that days to 75% flowering, sound mature kernel percentage and days to maturity were highly affected by heat stress. However, on oil content of the genotypes heat had negligible effect. Overall environmental mean for pod yield did not change significantly from non-stressed to stressed environments but the specific responses were changed in the respective environment. It is possible to identify high yielding genotypes with early maturity so that delayed sowing of groundnut does not have significant changes in the overall crop production due to heat on the later stages.

# Chapter VI

# SUMMARY AND CONCLUSION

# Chapter-VI

# SUMMARY AND CONCLUSION

The present investigation "Screening of groundnut (*Arachis hypogaea* L.) genotypes for heat tolerance" was undertaken to recognize the constraints imposed by high temperature to crop adaptation and productivity.

The materials for investigation comprised of 63 groundnut genotypes which included advanced breeding lines, released cultivars and germplasm lines which were collected from Groundnut breeding department, ICRISAT, Patancheru, Hyderabad. The experiment was undertaken into four different environments (E1, E2, E3, and E4) created by four sowing dates *viz*., 25$^{th}$ January, 6$^{th}$ February, 18$^{th}$ February and 2$^{nd}$ March, 2013 on red precision soils in broad-bed and furrow system, laid out in alpha-lattice design in two replications. The observations were recorded on 14 traits *viz*., days to 75% flowering, days to maturity, haulm weight (Kg ha$^{-1}$), pod yield (Kg ha$^{-1}$), kernel yield (Kg ha$^{-1}$), shelling percentage, sound mature kernel percentage, hundred kernel weight (g), oil content (%), oil yield (Kg ha$^{-1}$), harvest index (%), crop growth rate (g m$^{-2}$ per day), pod growth rate(g m$^{-2}$ per day) and partioning factor.

The ANOVA for all the traits in respective four environments showed significant differences among genotypes which indicated the presence of genetic variability. Higher magnitude of GCV and PCV was reported for pod yield, kernel yield, oil yield and haulm weight while moderate GCV and PCV was observed for harvest index, crop growth rate and 100-kernel weight. High heritability along with high genetic advance as percent of mean was exhibited by pod yield, kernel yield, hundred kernel weight, oil yield, haulm weight, harvest index, pod growth rate, crop growth rate and partioning factor across the four environments.

Pod yield was positively and significantly associated with days to maturity, kernel yield, oil yield, oil content, hundred kernel weight, harvest index, haulm weight, crop growth rate, pod growth rate and partitioning factor. These associated traits could be considered for selection to enhance yield in groundnut genotypes while traits such as pod yield, days to maturity and kernel yield, oil yield, crop and pod growth rate could be exploited for enhancement of oil content in groundnut as these were highly associated with oil percentage, in the present study.

Genotype x environment interactions were important for six traits *viz.*, days to 75% flowering, days to maturity, dry haulm weight, sound mature kernel percentage, hundred kernel weight and crop growth rate. However, days to 75% flowering, days to maturity and sound mature kernel percentage were highly influenced by heat stress. Non-significant differences between overall mean of respective environment was observed for oil content, hence environmental variation was negligible. Across the environment ICGV 06420 had high oil percent followed by ICGV 05200.

Environmental mean for pod yield did not changed significantly from non-stressed to stressed environments but the responses of specific genotypes were changed in the respective environment. Based on the mean pod yield across the environment, genotypes ICGV 07246, ICGV 03042, ICGV 06039, ICGV 07012, ICGV 06040, ICGV 06424 and ICGV 07038 were identified as top seven yielders. Five genotypes *viz*., GJG 31, ICGV 87846, ICGV 03057, ICGV 07038 and GG 20 showed increase yield performance at higher temperatures, would be effective for better performance at elevated temperatures. The stability of individual genotypes was represented by co-efficient of variation in the present study in which ICGV 06420 was most stable across the stressed and non-stressed environments. Among top yielders ICGV 03042 was most stable along with higher yield performance in all the stressed and non-stressed environments.

The evaluation of two heat stress indices *i.e.* Stress Susceptible Indices (SSI) and Stress Tolerance Indices (STI) was considered to identify the heat tolerant genotypes. Significant correlation coefficient was found between STI and pod yield in all the three stressed environments. STI was considered more reliable parameter for screening of heat tolerant groundnut genotypes under both stress and non-stress environment. Six genotypes (ICGV 07246, ICGV 07012, ICGV 06039, ICGV 06040, ICGV 03042 and ICGV 06424) were identified as tolerant to heat based on STI under E2, E3 and E4 which were also identified as top yielding genotypes.

# Chapter VII

# BIBLIOGRAPHY

Chapter-VII

# BIBLIOGRAPHY

Allard (1960). Principles of plant breeding. John Wiley and Sons. Inc. New York.

Allard, R.W., Bradshaw, A.D. (1964). Implications of genotype-environmental interactions in applied plant breeding. *Crop Science*. **4**: 503-508.

Ashutosh, K.S. and Prashant, K. R. (2014). Evaluation of Groundnut Genotypes For Yield And Quality Traits. *Annals of Plant and Soil Research*. **16**(1): 41-44.

Babariya, C.A. and Dobariya, K. L. (2012). Correlation coefficient and path coefficient analysis for yield components in groundnut (*Arachis hypogaea* L.). *Electronic Journal of Plant Breeding.* **3**(3): 932-938.

Bolhuis, G.G. and De Groot, W. (1959). Observations on the effect of varying temperatures on the flowering and fruit set in three varieties of groundnut. *Netherlands Journal of Agricultural Sciences*. **7**: 317-326.

Burton, G.W. (1952). Quantitative inheritance in grasses.Proceeding of Sixth International Grassland Congress. **1**: 277-283.

Butron, A., Velasco, P., Ordas, A. and Malvar, R. A. (2004). Yield evaluation of maize cultivars across environments with different levels of pink stem borer infestation. *Crop Science*. **44**: 741-747.

Byth, D.E. (1981). Genotype × Environment interaction and Environmental adaptation in plant Improvement - An overview. In: interpretation of plant response and adaptation to Agricultural Environments. D. E. Byth and Montgomery V. E. (eds.) Brisbane, Queensland.

Chauhan, J.S., Meena, M.L., Saini, M., Meena, D.R., Singh, M., Meena, S.S. and Singh, K.H. (2009). Heat stress effects on morpho-physiological characters of Indian mustard (*Brassica juncea* L.). Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur, Rajasthan, India. 321-303.

Cox, F.R. (1979). Effect of temperature treatment on peanut vegetative and fruit growth. Peanut Science. **6**:1 14-117.

Craufurd, P.Q., Wheeler, T.R., Ellis, R.H., Summerfield, J., Vara Prasad, J.V. (2000). Escape and tolerance to high temperature at flowering in groundnut (*Arachis hypogaea* L.). *Journal of Agricultural Science.* **135**: 371-378.

Craufurd, P.Q., Prasad, P.V., Kakani, G.V., Wheeler, T.R. and Nigam, S.N. (2003). Heat tolerance in groundnut. *Field Crops Research*. **80**: 63-77.

Crossa, J. and Cornelius, P.L. (1997). Site regression and shifted multiplicative model clustering of cultivars trial sites under heterogeneity of error variance. *Crop Science.* **37**: 405-415.

Crossa, J., Cornelius, P.L. and Yan, W. (2002). Biplots of linear-bilinear models for studying crossover genotype environment interaction. *Crop Science.* **42**: 136-144.

Dehghani, H., Ebadi, A. and Yousefi, A. (2006). Biplot analysis of genotype by environment interaction for barley yield in Iran. *Agronomy Journal*. **98**: 388-393.

Department of agriculture and cooperation, Ministry of agriculture, government of India. [Available online] (http://agricoop.nic.in/statistics 2003/ chap 4b.html).

Devasirvatham, V., Tan, D.K.Y., Gaur, P.M., Raju, T.N. and Trethowan, R.M. (2012). High temperature tolerance in chickpea and its implications for plant development. *Crop and Pasture Science*. **63**: 419-428.

Directorate of Economics and Statistics. Department of agriculture, Government of Bihar, 2012. [Available online] (http://www.krishi.bih.nic.in/Statistics.html)

Dolma, T., Sekhar, M. R. and Reddy, K. R. (2010). Genetic variability, correlation and path analysis for yield, its components and late leaf spot resistance in groundnut (*Arachis hypogaea*). *Journal of Oilseeds Research*. **27**(2):154-157.

Duncan, W. G., McCloud, D. E., McGraw, R. L. and Boote, K. J. (1978). Physiological aspects of peanut yield improvement. *Crop Science.* **18**: 1015-1020.

Ezatollah, F., Mahnaz, R., Mohammad, M.J. and Hassan, Z. (2013). GGE Biplot analysis of genotype × environment interaction in chickpea genotypes. *European Journal of Experimental Biology.* **3**(1): 417-423.

FAO, 2012. Production Year Book (2012). Food and Agricultural organization, Rome, Italy.

Fernandez, G.J. (1992). Effective Selection Criteria for Assessing Plant Stress Tolerance. In: " Proceeding of the International Symposium on Adaptation of Vegetables and other Food Crops in Temperature and Water Stress ". Aug 13- 16, Taiwan. pp: 257-270.

Finlay, K.W. and Wilkinson, G.N. (1963). The analysis of adaptation in a plant breeding programme. *Australian Journal of Agricultural Research*. **14**: 742–754.

Fischer, R. A. and Maurer, R. (1978). Drought Resistance in Spring Wheat (*Triticum aestivum* L.) Cultivars Grain Yeild Response. *Australian Journal Agriculture Research.* **29**: 897-912.

Fisher, R. A. and Yates, A.H. (1938). Statistical tables for biological, agricultural and medical research. *Olivar and Boyd. Edinbargh*. 134-135.

Fortanier, E. J. (1957). Control of flowering in Arachis hypogaea L. Ph.D. Thesis. Mededelingen van de LandouwhoogexhoolteWageningen, The Netherlands.

Frimpong, A. (2004).Characterization of groundnut (*Arachis hypogaea* L.) in Northern Ghana.*Pakistan Journal of Biological Sciences*. **7**(5): 838-842

Gabriel, K.R. (1971). Biplot display of multivariate matrices with application to principal components analysis. *Biometrika.* **58** 453-467.

Gangappa, E., Ravi, N. and VeeraKumar, G. N. (2006). Evaluation of groundnut (*Arachis hypogaea* L.) genotypes for temperature tolerance based on Temperature Induction Response (TIR) technique. *Indian Journal of Genetics*. **66**(2): 127-130.

Golakia, P.R., Makne, V.G., Monpara, B.A. (2005). Heritable variation and association in Virginia runner and Spanish bunch group of groundnut. *National Journal of Plant Improvement*.**7**(1): 50-53**.**

Gomes, R.L.F. and Lopes, A.C.A. (2005). Correlations and path analysis in peanut.*Crop Breeding and Applied Biotechnology*. **5:**105-112.

GopinathJatti, Venkataravana, P. and Prasad, V.L.M. (2007). Character contribution to oil yield in selected water use efficient germplasm of groundnut. *Crop Research (Hisar)*. **34**(1/3): 84-87.

Gross, Y. and Kigel, J. (1994). Differential sensitivity to high temperature of stages of the reproductive development of common bean (*Phaseolus vulgaris* L.). *Field Crops Research*. **36**: 201-212.

Hall, A.E., 1992. Breeding for heat tolerance. *Plant Breeding Reveiw*. **10**: 129-167.

Hamidou, F. and Vadez, V. (2012). Phenotypic Evaluation of Groundnut Germplasm under Drought and Heat Stress. In: Proceedings of CORAF/WECARD 3rd Agricultural Science Week and 10th General Assembly, 14 to 17 May 2012, Ndjamena, Chad.

Hamidou, F., Halilou, O. and Vadez, V. (2013). Assessment of groundnut under Combined Heat and Drought Stress. *Journal of Agronomy and Crop Science.* **199**: 1–11.

Hasan, M.A., Ahmed, J.U., Bahadur, M.M., Haque, M.M. and Sikder, S. (2007). Effect of late planting heat stress on membrane thermostability, proline content and heat susceptibility index of different wheat cultivars. *Journal of Natural Science Foundation*, Sri Lanka. **35**(2): 109-117.

Hiremath, C.P., Nadaf, H.L. and Keerthi, C.M. (2011). Induced genetic variability and correlation studies for yield and its component traits in Groundnut (*Arachis hypogaea* L.). *Electronic Journal of Plant Breeing.* **2**(1): 135-142.

Hyderabad – weather spark (https://weatherspark.com/history/33947/2013/Hyderabad)

ICRISAT. (1994). West Africa Programs Annual Report. Niger: ICRISAT

Injeti, S. K., Venkataravana, P. and Rao, M. R. G. (2008). Evaluation of new germplasm and advanced breeding lines of groundnut (*Arachis hypogaea* L.) under late kharif situation. *Legume Research*. **31**(4): 254-258.

Jogloy, C. P., Jaisil, C., Akkasaeng, T., Kesmala and Jogloy, S. (2011). Heritability and Correlation for Maturity and Pod Yield in Peanut. *Journal of Applied Sciences Research.* **7**(2):134-140.

Johanson, R. E., Robinson, H. W. and Comstock, H. F. (1955a). Estimates of genetic and environmental variability in soyabeans. *Agronomy Journal*. **47**: 314-318.

John K., Vasanthi R. P. and Venkateswarlu, O. (2007). Variability and correlation studies for pod yield and its attributes in $F_2$generation of six Virginia × Spanish crosses of groundnut (*Arachis hypogaea* L.). *Legume Research.* **30**: (4) 292-296.

John, K., Reddy, P.R., Reddy, P.H., Sudhakar, P., Reddy, N.P. and Eswar (2012). Genetic parameters for morphological, physiological and yield attributes related to moisture stress tolerance in groundnut - a review. *Agricultural Reviews*. **33:** 104-113.

Jonah, P.M., Adeniji, O.T. and Wammanda, D.T. (2010). Variability and genetic correlations for yield and yield characters in some Bambara groundnut (*Vigna subterranea*) cultivars. *International Journal Agricultural Biology*. **12**: 303-307.

Kale, D.M., Gadgil, J.D. and Muthy, G.S.S. (1998). Relationship between seed size, oil and protein contents in groundnut. *Journal of Oilseeds Research*. **5**: 170-175.

Karimizadeh, R., Mohammadi, M., Sabaghni, N., Mahmoodi, A. A., Roustami, B., Seyyedi, F. and Akbari, F. (2013) GGE Biplot Analysis of Yield Stability in Multi-environment Trials of Lentil Genotypes under Rainfed Condition. *Notulae Science Biology*. **52:** 256-262.

Kaya, Y., Akura, M. and Taner, S. (2006). GGE Biplot analysis of multi-environment yield trial in bread wheat. *Turk Journal Agriculture*. **30**: 325-337.

Kaya, Y., Palta, C. and Taner, S. (2002). Additive Main Effects and Multiplicative Interactions Analysis of Yield Performance in Bread Wheat Genotypes across Environments. *Turk Journal Agriculture Horticulture*. **26**: 275- 279.

Khattak, G.S.S., Saeed, I. and Muhammad, T. (2006) Breeding for heat tolerance in mungbean {*Vigna radiata* (L.) Wilczek}. *Pakistan Journal of Botany*. **38**(5): 1539-1550.

Khodarahmpour , Z., Choukan, R., Bihamta, M.R. and MajidiHervan, E. (2011). Determination of the Best Heat Stress Tolerance Indices in Maize (*Zea mays* L.) Inbred Lines and Hybrids under Khuzestan Province Conditions. *Journal of Agricultural Science Technology*. **13**: 111-121.

Khote, A.C., Bendle, V.W., Bhave, S.G. and Patil, P.P (2009) Genetic variability, heritability and genetic advance in some exotic genotype of groundnut (*Arachis hypogaea* L.). *Crop Research*. **37**: 186-191.

Korat, V.P., Pithia, M.S., Savaliya, J.J., Pansuriya, A.J. and Sodavadiya, P.R. (2010). Studies on characters association and path analysis for seed yield and its components in groundnut (*Arachis hypogaea* L.) *Legume Research*. **33**(3): 211-216.

Krapovickas, A. (1968). The origin, variability and spread of groundnut (*Arachis hypogaea* L.) (English translation). In The domestication and exploitation of plants and animals (Ucko, P.J., and Falk, I.S., eds.). London, U.K: G. Duck Worth.

Krishnamurthy, L., Gaur, P.M., Basu, P.S., Chaturvedi, S.K., Tripathi, S., Vadez, V., Rathore, A., Varshney, R.K. and Gowda, C.L.L. (2011). Large genetic variation for heat tolerance in the reference collection of chickpea (*Cicer arietinum* L.) germplasm. *Plant Genetic Resources.* **9**: 59-61.

Kroonenberg P.M. (1995). Introduction to biplots for GxE tables. Department of Mathematics, Research Report 51. Australia: University of Queensland. (<http://three-mode.leidenuniv.nl/document/biplot.pdf>)

Lynch, M. and Walsh, B. (1998). Genetics and analysis of quantitative traits. Sinauer Associate, Sunderland, Mass, USA. pp:112-136.

Madhura, C. and Kenchanagoudar, P.V. (2012). Assessment of genetic variability and inter-relationship among minicore collection of groundnut (*Arachis hypogaea*). *International Journal of Plant Sciences*. **7**(2): 307-312.

Mahalakshmi, P., Manivannan, N. and Muralidharan, V. (2005). Variability and correlation studies in groundnut (*Arachis hypogaea* L.). *Legume Research***. 28**(3): 194-197.

Makinde, S.C.O. and Ariyo, O.J. (2013). Genetic Divergence, Character Correlations and Heritability Study in 22 Accessions of Groundnut (*Arachis hypogaea* L.). *Journal of Plant Studies*. **2**: 1.

Marshall, H.G. (1982). Breeding for tolerance to heat and cold. In Breeding Plants for Less Favourable Environments. Eds M N Christiansen and C F Lewis. pp: 47-70. John Wiley ans Sons, New York USA.

Matthews, R.B., Horie, T., Kropff, M.J., Bachelet, D., Centeno, H.G., Shin, J.C., Mohandass, S., Singh, S., Defeng, Z. and Moon, H.L. (1995). A regional evaluation of the effect of future climate change on rice production in Asia. In: Modeling the Impact of Climate Change on Rice Production in CAB International, Wallingford, Oxon, United Kingdom. pp. 95-139.

McWilliam, J.R. (1980). Summary and Synthesis- adaptation to high temperature stress. In: Turner, N.C., Krammer, P.J. eds. *Adaptation of plants to high Temperature stress*. New York. *John Wiley*. pp: 444-446.

Meta, H.R. and Monpara, B.A. (2010). Genetic variation and trait relationships in summer groundnut (*Arachis hypogaea* L.). *Journal of Oilseeds Research.* **26**: 186-187.

Moghadam, A. and Hadizadeh, M. H. (2000). Study use of compression stress in drought stress tolerance varieties selection in maize ( *Zea mays* L.). *Journal of Crop Science*. **2**(3): 25-38.

Morakinyo, J. A., and Makinde, S. C. (1991). Variability and heritability in local cultivars of okra (*Abelmoschus esculentus* (L.) Moench.). *Nigeria Journal of Botany*. **4:** 33-40.

Muhammad, F.A.M., Muhammad, A., Afsari, S.Q., and Abdul, G. (2007). Assessment of genetic variability, correlation and path analyses for yield and its componentsn in soybean. *Pakistan Journal Botaty*. **39** (2): 405-413.

Nandini, C. and Savithramma, D.L. (2012). Character association and path analysis in $F_8$ recombinant inbred line population of the cross NRCG 12568 x NRCG 12326 in groundnut (*Arachis hypogea* L.). *Asian Journal Biological Science*. **7** (1): 55-58.

Narasimhulu, R., Kenchanagoudar, P.V. and Gowda, M.V.C. (2012). Study of Genetic Variability and Correlations in Selected Groundnut Genotypes. *International Journal of Applied Biology and Pharmaceutical Technology.* **3** (1): 66-69.

Nath, U.K. and Alam, M.S. (2002). Genetic Variability, Heritability and Genetic Advance of Yield and Related Traits of Groundnut (*Arachis hypogaea* L.). *Journal of Biological Sciences.* **2**: 762-764.

Noubissie, T.J.B., Njintang, N.Y. and Dolinassou, S. (2012). Heritability studies of Protein and oil contents in groundnut (*Arachis hypogaea* L.) Genotypes. *International Journal of Innovations in Bio-Sciences.* **2** (3): 162-171.

Ntare, B.R. and Williams, J.H. (1998). Heritability and Genotype × Environment interaction for yield and components of yield. Model in the segregating populations under semiarid conditions. *African Crop Science Journal*. **6**: 119-127.

Ntare, B.R., Williams J.H. and Dougbedji, J. (2001). Evaluation of groundnut genotypes for heat tolerance under field conditions in a Sahelian environment using a simple physiological model for yield. *Journal of Agricultural Science*, Cambridge. **136**: 81-88.

Ong, C.K., (1986). Agroclimatological factors affecting phenology of peanut. In: *Agrometeorology of groundnut*. Proceedings of an International Symposium, 21-26 August 1985, ICRISAT Shelian Center, Niamey, Niger, Patancheru. A.P. 502324, India: International Crops Research Institute for the Semi-Arid Tropics. pp: 115-125.

Padmaja, D., Rao, B., Eswari, K.B. and Reddy, S.M. (2013). Genetic variability, heritability foulturalr late leaf spot tolerance and productivity traits in a recombinant inbred line population of Groundnut (*Arachis hypogaea* L.) *Journal of Agricultural and Veterinary Science.* **5**: 36-41

Patterson, H.D. and Williams, E.R. (1976). A new class of resolvable incomplete block designs. *Biometrika.* **63**: 83-92.

Paulsen, G. M. (1994). High temperature responses of crop plants. In physiology and determination of crop Yield. Eds. K.J. Boote, J. M.Bennett, T.R. Sinclair and G.M. Paulsen. American society of agronomy, Wisconsin, USA. pp: 365-389.

Porch, T.G. (2006). Application of Stress Indices for Heat Tolerance Screening of Common Bean. *Journal of Agronomy & Crop Science*. **192**: 390-394

Pradhan, K. and Patra, R. K. (2011). Variability and correlations studies on groundnut (*Arachis hypogaea* L.) germplasm. *Legume Research*. **34**(1): 26-30.

Prasad, P.V.V., Craufurd, P.Q., Summerfield, R.J., and Wheeler, T.R. (2000a). Effects of short episodes of heat stress on flower production and fruit-set of groundnut (*Arachis hypogaea* L.). *Journal of Experimental Botany*. **51**: 777-784.

Prasad, P.V.V., Craufurd, P.Q., and Summerfield, R.J. (2000b). Effect of high air and soil temperature on dry matter production, pod yield and yield components of groundnut. *Plant Soil*. **222**: 231-239.

Rahmatollah, K., Mohtasham, M., Naser, S. and Mohammad K.S. (2012). Using different aspects of stability concepts for interpreting genotype by environment interaction of some lentil genotypes. *Australian Journal of crop science.* **6** (6): 1017-1023.

Rao, V. (1988). Botany. Groundnut (Reddy, P.S., eds.). New Delhi: Indian Council of Agricultural Research. pp: 24-64.

Rehman, A., Habib, I., Ahmad, N., Hussain, N., Arif Khan, M., Farooq J., and Amjad, M. (2009). Screening wheat germplasm for heat tolerance at terminal growth stage. *Plant Omics Journal.* **2** (1): 9-19.

Roy, D., Patel, R. K. and Ojha, O. P. (2003). Study on podding index and other traits in groundnut (*Arachis hypogaea* L.). *Legume Research*. **26**: 310-312.

Sadeghi, S.M. and Noorhosseini-Niyaki, S.A. (2012). Correlation and path coefficient analysis in peanut (*Arachis hypogaea* L.) genotypes under drought stress and irrigated conditions. *Annals of Biological Research*. **3** (6): 2593-2596.

Samonte, S.C.P.B., Wilson, L.T., McClung, A.M. and Medley, J. C. (2005). Targeting cultivars unto rice growing environments using AMMI and SREG GGE biplot analysis. *Crop Science.* **45:** 2414-2424.

Savage, G.P. and Keenan, J.I. (1994). The composition and nutritive value of groundnut kernels, In: smart Journal (eds). The Groundnut crop: scientific basis for improvement. London, Chapman and Hall. pp: 173-213.

Selvaraj, M., Burow, G.B., Burke, J.J., Belamkar, V., Puppala, N., Burow, M. (2011). Heat stress screening of peanut seedlings for acquired thermotolerance. *Journal of Plant Growth Regulation.* **65**: 83-91.

Shinde, P.P., Khanpara, M.D., Vachhani, J.H., Jivani, L.L. and Kachhadia, V.H. (2010). Genetic variability in virginia bunch groundnut (*Arachis hypogaea* L.). *Plant Archives.* **10** (2): 703-706.

Shoba, D., Manivannan, N. and Vindhiyavarman, P. (2012). Correlation and path coefficient analysis in groundnut (*Arachis hypogaea* L.). *Madras Agricultural Journal*. **99 (**1/3): 18-20.

Singh, K., Sharma, S.N. and Sharma, Y. (2011). Effect of high temperature on yield attributing traits in bread wheat. *Bangladesh Journal of Agricucltural Research*. **36** (3): 415-426.

Singh, P. and Narayanan, S.S. (1993). Biometrical techniques in plant breeding. Kalyani Publishers, New Delhi, India.

Singkhan, N., Jogloy, S., Keomala, T., Swatsitang, P., Jaisil, P., Puppala, N. and Patanothai, A. (2010). Estimation of heritability by parent-offspring regression for high oleic acid in peanut. *Asian Journal of Plant Science*. **9** (6): 358-363.

Sivasubramanian, V. and Madhavamenon, P. (1973). Path analysis for yield and yield components of rice. *Madras Agricultural Journal.* **60**: 1217-1221.

Smith, M.E. and Zobel, R.W. (1990). Plant genetic interactions in alternative cropping systems considerations for breeding methods. *Crop Sciences* (In press).

Sonone, N.G., Navhale, V.C., Gaikwad, K.J. and Thaware, B.L. (2010). Correlation and path coefficient analysis among yield contributing characters in groundnut. *Annals of Plant Physiology*. **24** (1): 47-51.

Sudheer, K.V.S., Rao, S.B.S.N. and Murthy,V.R. (2011). Behaviour of growth of groundnut under different environments and row spacing. *Crop Research (Hisar)*. **42** (1/2/3): 120-124.

Sumathi, P. and Muralidharan, V. (2007). Character association and path coefficient analysis in confectionery type groundnut (*Arachis hypogaea* L.). *Madras Agricultural Journal*. **94** (1/6): 105-109.

Summerfield, R.J., Virmani, S.M., Roberts, E.H. and Ellis, R.H. (1990). Adaption of chickpea to agroclimatic constraints. In ‘Chickpea in the Nineties. (Eds. van Rheenen HA, Saxena MC) Proc. of the Second International Workshop on Chickpea Improvement. 4-8th Dec. 1989. ICRISAT Publishing, India. pp. 50-61.

Thakur, S.B., Ghimire, S.K., Chaudhary, N.K., Shrestha, S.M. and Mishra, B. (2011). Genic variabilty, heritabilty and genic advance of pod-yield component traits of groundnut (*Arachis hypogaea* L.). *Journal of Instant Agriculture Animal Science.* **32**: 133-141.

ThirumalaRao, V., Venkanna, V., Bhadru, D. and Bharathi, D. (2014). Studies on Variability, Character Association and Path Analysis on Groundnut (*Arachis hypogaea* L.). *International Journal of Pure Applied Bioscience.* **2** (2): 194-197.

Vara Prasad, P. V., Craufurd, P. Q. and Summerfield, R.J. (1999). Fruit number in relation to pollen production and viability in groundnut exposed to shorter episodes of heat stress. *Annals of Botany*. **84**: 381-386.

Vasanthi, R.P. and Reddy, C. R. (2002). Remove from marked Records Variability in $F_2$ generation of five groundnut crosses involving foliar disease resistant genotypes. *Journal of Research ANGRAU.* **30** (2): 37-142.

Vekariya, H.B., Khanpara, M. D., Vachhani, J. H., Jivani, L.L., Vagadiya, K.J., Revar, H.J. (2011). Correlation and path analysis in bunch groundnut (*Arachis hypogaea* L.). *International Journal of Plant Sciences (Muzaffarnagar)*. **6** (1): 11-15.

Venkataravana, P., Sheriff, R. A., Kulkarni, R. S., Shankaranarayana, V., Fathima, P. S. (2000). Correlation and path analysis in groundnut (*Arachis hypogaea* L.). *Mysore Journal of Agricultural Sciences*. **34:** 321-325

Wahid, A., Gelani, S., Ashraf, M. and Foolad, M.R. (2007). Heat tolerance in plants: An overview. *Environmental and Experimental Botany*. **61**: 199-223.

Wheeler,T.R., Chatzialioglou, A., Craufurd, P.Q., Ellis, R.H. and Summerfield, R.J. (1997). Dry Matter Partitioning in Groundnut Exposed to High Temperature Stress. *Crop Science*. **37**: 1507–1513.

Williams, J. H. & Saxena N. P. (1991). The use of non- destructive measurement and physiological models of yield determination to investigate factors affecting differences in seed yield between genotypes of 'desi' chickpeas (*Cicer arietum*). *Annals of Applied Biology*. **119**: 105-112.

Wood, I.M.W. (1968). The effect of temperature at early flowering on the growth and development of peanuts (Arachis hypogaea). *Australian Journal Agriculture Research*. **19**: 241- 251.

Yan, W. and Kang, M.S. (2003). GGE biplot analysis: A graphical tool for breeders geneticists and agronomists. CRC Press Boca Raton FL.

Yan, W. and Rajcan, I. (2002). Biplot analysis of test sites and trait relations of soybean in Ontario. *Crop Science*.**42**: 11-20.

Yan, W., Hunt, L., Sheng, Q. and Szlavnics, Z. (2000). Cultivar evaluation and mega-environment investigation based on GGE biplot. *Crop Science.* **40** (3): 597-605.

Yoshida, S., Satake, J., MacKill, D.J. (1981). High-temperature stress in rice. IRRI Research paper Series **67**.

Zaman, M. A., Tuhina-Khatun, M., Ullah, M. Z., Moniruzzamn, M. and. Alam, K. H. (2011). Genetic Variability and Path Analysis of Groundnut (*Arachis hypogaea* L.). *The Agriculturists.* **9**(1&2): 29-36.