

**GENETIC INVESTIGATION ON END-OF SEASON DROUGHT
STRESS IN ADVANCED BREEDING LINES OF GROUNDNUT
(*Arachis hypogaea* L.)**

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NAVILE, SHIVAMOGGA

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COLLEGE OF AGRICULTURE, SHIVAMOGGA
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CERTIFICATE

This is to certify that the thesis entitled “**GENETIC INVESTIGATION ON END-OF SEASON DROUGHT STRESS IN ADVANCED BREEDING LINES OF GROUNDNUT (*Arachis hypogaea* L.)**” submitted in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (AGRICULTURE) in GENETICS AND PLANT BREEDING** to the University of Agricultural and Horticultural Sciences, Shivamogga, is a bonafide record of research work done by **CHANDRASHEKHARA, G., ID No. MA1TAE0122, (psmc.chandru@gmail.com)** during the period of his study in this university under guidance and supervision and no part of this thesis has previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

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Genetic Investigation on End-of Season Drought Stress in Advanced Breeding Lines of Groundnut (*Arachis hypogaea* L.)

(Chandrashekhara, G.)

Abstract

The present investigation focused on the study of morphological, physiological and biochemical response of forty groundnut genotypes under both managed drought stress (end season drought stress) and normal moisture conditions was conducted at College of Horticulture, Hiriyr using randomized complete block design with two replications. The analysis of variance revealed the existence of highly significant differences among the genotypes under study for all the traits studied. A wide range of variability and high heritability coupled with high genetic advance were recorded for most of the yield contributing traits. The association studies revealed that, pod yield per plant showed significant positive correlation with number of mature pods per plant, number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant, fresh seedling weight, harvest index, oil content and root to shoot ratio. The results of path analysis reflected that, the yield related traits viz., relative water content, phenolic content of leaves, oil content, root to shoot ratio, plant height, number of secondary branches per plant, number of mature pods per plant, number of immature pods per plant, number of kernels per plant, test weight, kernel yield per plant, fresh seedling weight, harvest index and days to maturity had direct positive effect on pod yield under moisture stressed field condition. The genotypes Dh - 234, R - 2001 - 3, ICGV - 15151, ICGV - 15138, SB - 14, ICGV - 15145, ICGV - 15154, ICGV - 15146, ICGV - 15159 and ICGV - 15158 have been identified as drought tolerant genotypes in view of their better drought tolerance ability and these can be used as donor parents to develop drought tolerant varieties in further breeding programme.

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ಶೇಂಗಾ (ಅರ್ಯಾಚಿಸ್ ಹೈಪೋಜಿಯ) ದ ಸುಧಾರಿತ ಪ್ರಜಲನ ಸಾಲುಗಳ ಋತುವಿನ ಅಂತ್ಯದಲ್ಲಿ
ಬರ ಒತ್ತಡದ ಬಗ್ಗೆ ಅನುವಂಶೀಯ ತನಿಖೆ
(ಚಂದ್ರಶೇಖರ, ಜಿ)

ಸಾರಾಂಶ

ವ್ಯವಸ್ಥಿತ ಜಲಕ್ಷಾಮದ ಒತ್ತಡ (ಋತುವಿನ ಅಂತ್ಯದಲ್ಲಿ ಬರ ಒತ್ತಡ) ಹಾಗೂ ತೇವಾಂಶ ಕ್ಷೇತ್ರ ಪರಿಸ್ಥಿತಿಗಳಲ್ಲಿ ಶೇಂಗಾದ ನಲವತ್ತು ತಳಿಗಳ ಸ್ವರೂಪ, ಶಾರೀರಿಕ ಕ್ರಿಯೆ ಮತ್ತು ಜೈವಿಕ-ರಾಸಾಯನಿಕ ಪ್ರತಿಕ್ರಿಯೆಗಳ ಅಧ್ಯಯನದ ಮೇಲೆ ಕೇಂದ್ರೀಕರಿಸಿದ ಪ್ರಸ್ತುತ ಅನುವಂಶೀಯ ತನಿಖೆಯನ್ನು ಎರಡು ಪ್ರತಿಕ್ರಿಯೆಗಳನ್ನೊಳಗೊಂಡ ಯಾದೃಚ್ಛಿಕ ಸಂಪೂರ್ಣ ಪಟ್ಟಿ ವಿನ್ಯಾಸವನ್ನು ಬಳಸಿಕೊಂಡು ತೋಟಗಾರಿಕೆ ಮಹಾವಿದ್ಯಾಲಯ, ಹಿರಿಯೂರು, ೨೦೧೬-೧೭ ರಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ವ್ಯತ್ಯಾಸದ ವಿಶ್ಲೇಷಣೆಯು ದಾಖಲಾದ ಎಲ್ಲಾ ಗುಣಲಕ್ಷಣಗಳಿಗೆ ಸಂಬಂಧಿಸಿದಂತೆ ವಂಶವಾಹಿ ರೂಪಕಗಳ ನಡುವೆ ಹೆಚ್ಚು ಮಹತ್ವಪೂರ್ಣ ವ್ಯತ್ಯಾಸಗಳ ಅಸ್ತಿತ್ವವನ್ನು ಬಹಿರಂಗಪಡಿಸಿತು. ಇಳುವರಿಗೆ ಸಂಬಂಧಿಸಿದ ಬಹುತೇಕ ಗುಣಲಕ್ಷಣಗಳಿಗೆ ಅತ್ಯಧಿಕ ವ್ಯತ್ಯಾಸ, ಹೆಚ್ಚಿನ ಅನುವಂಶೀಯ ಸಾಮರ್ಥ್ಯದ ಜೊತೆಗೆ ಹೆಚಿನ ಜಿ.ಎ.ಎಂ. (ಸರಾಸರಿ ಅನುವಂಶೀಯ ಮುಂಚಲನ) ಕಂಡುಬಂದಿರುತ್ತದೆ. ಗುಣಸಂಯೋಜನೆ ಅಧ್ಯಯನವು ಪ್ರತಿ ಸಸ್ಯಕ್ಕೆ ಕಾಯಿಯ ಇಳುವರಿಯು ಇತರೆ ಗುಣಲಕ್ಷಣಗಳಾದ ಪ್ರತಿ ಸಸ್ಯಕ್ಕೆ ಬಲಿತ ಕಾಯಿಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಸಸ್ಯಕ್ಕೆ ಬಲಿತಿಲ್ಲದ ಕಾಯಿಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಸಸ್ಯಕ್ಕೆ ಕಾಯಿಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಸಸ್ಯಕ್ಕೆ ಬೀಜಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಗಿಡಕ್ಕೆ ಬೀಜನ ಇಳುವರಿ, ಪ್ರತಿ ಗಿಡದ ತಾಜಾ ತೂಕ, ಸುಗ್ಗಿಯ ಸೂಚ್ಯಂಕ, ತೈಲಾಂಶ ಮತ್ತು ಬೇರು-ಕಾಂಡ ಅನುಪಾತಗಳ ಜೊತೆ ಗಮನಾರ್ಹ ಧನಾತ್ಮಕ ಗುಣಸಂಯೋಜನೆಯನ್ನು ಹೊಂದಿರುತ್ತದೆ ಎಂದು ತಿಳಿದುಬಂದಿದೆ.

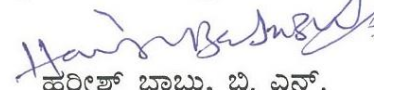
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LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTION
PEG-6000	Poly Ethylene Glycol 6000
DAS	Days After Sowing
SCMR	SPAD Chlorophyll Meter Reading
SPAD	Soil and Plant Analyser Development
RWC	Relative Water Content
MSI	Membrane Stability Index
HI	Harvest Index
ANOVA	Analysis of Variance
d.f.	Degrees of freedom
S.Em	Standard Error Mean
CV	Coefficient of Variation
CD (P=0.05%)	Critical Difference at 5 per cent level
PCV	Phenotypic Coefficient of Variation
GCV	Genotypic Coefficient of Variation
h^2b	Broad sense Heritability
GA	Genetic advance
GAM	Genetic Advance as per cent of Mean
F ₁	First filial generation
F ₂	Second filial generation
F ₃	Third filial generation
F ₈	Eight filial generation
Anon,	Anonymous
et al.	And others
viz.,	Namely
Per se	As such mean
i.e.,	That is
%	Per cent
/	Per
l	Litres
cm	Centimetres
g	Grams
mg	Milligrams
ha	Hectare
kg	Kilogram
kg ha ⁻¹	Kilogram per hectare
M.ha	Million hectares
No.	Number

Tons	Tonnes
Fig.	Figure
°C	Centigrade
Min	Minimum
Max	Maximum
>	Greater than
<	Less than
Mpa	Mega Pascal
EC	Electrical conductivity
BSA	Bovine Serum Albumin
PWP	Percentage of wilted plants
PFD	Pre flowering drought
ESD	Early season drought
SLN	Specific leaf nitrogen
LTR	Leaf transpiration rate
CMS	Cell membrane stability
CID	Carbon isotope discrimination
STI	Stress tolerance index
DTE	Drought tolerance efficiency
GMP	Geometric mean productivity
DSI	Drought susceptibility index
DTI	Drought tolerance index

Introduction

I INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the principal oilseed crops ranking fourth among the oil seed crops of the world (Cuc *et al.*, 2008 and Coulibaly, 2013). It is popularly called as groundnut, peanut, earthnut, wonder nut, monkey nut, panilla, manila nut *etc.* It is an important food legume cash crop having adaptability to a variable soil and climatic conditions. In India, it is known by many local names *viz.*, Moongphali (Hindi), Shenga (Kannada), Verusenagalu (Telugu), Nilakadalai (Tamil), Mandavi (Gujarati) and so on.

Groundnut is cultivated worldwide in tropical, sub-tropical and warm temperature areas located between 40° N to 40° S latitude. The extensive cultivation of groundnut is found in Asia, Africa and majority of American countries. India ranks first in acreage (6.4 m. ha.), which accounts for 28.44 per cent of the total world groundnut area (25.54 m. ha.) and contributes 24.69 per cent (7.21 m.t.) to the world production (40.47 m.t.). The average productivity of groundnut in India is 996 kg per ha, which is far below the world average pod yield of 1646 kg per ha (www.agricoop.com). Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Rajasthan and Tamil Nadu states account for about 90 per cent of the total groundnut area in the country (Anon, 2014). In Karnataka, groundnut is an important oilseed crop grown in *kharif* and occupies 0.73 m. ha with a production and productivity of 0.66 m. t and 907 kg per ha, respectively, which is lower than the national average productivity of groundnut.

It has been reported that, Brazil was the place from where cultivation of groundnut was originated and distribution of the crop to Africa, Asia, Europe and India occurred presumably in the sixteenth century by Portuguese (Ramana, 1987). India has been considered as the secondary center of origin of groundnut due to vast genetic variability and diversity.

The groundnut belongs to the family *Leguminosae*, subfamily *Papilionoidae*, tribe *Aeschnomeneae*, sub-tribe *Stylosanthinae*, genus *Arachis* (stems from Greek, a-rachis meaning without spine) and species *hypogaea* (stems from Greek, hupo-ge meaning below earth). Cultivated groundnut has two subspecies, *hypogaea* and *fastigiata*, which in turn have two botanical varieties (var *hypogaea* and var *aequatoriana*). Each of these botanical varieties have different plant, pod and seed characteristics. However, most of the commercially cultivated varieties belongs to the *hypogaea* (common name/market type: *Virginia or runner*), *fastigiata* (Valencia), and *vulgaris* (Spanish) botanical variety groups. Nearly all *Arachis* species are diploid, but cultivated groundnut is an allotetraploid (AABB genome) with somatic chromosome number of $2n = 4x = 40$ and basic chromosome number of $x = 10$ (Kochert *et al.*, 1996) and a genome size of about 2891 Mbp (www.oar.icrisat.org).

Groundnut is a self-pollinating (autogamous) legume with cleistogamous flowers. Natural cross pollination also occurs due to atypical flowers and/or action of bees (Duke, 1981 and Coffelt, 1989). Groundnuts are considered as an excellent and affordable source of nutrition, supplementing vital nutrients to the human body such as proteins (25-28 %), oil (43-55 %), carbohydrates, lipids, vitamins (Vitamin E -6.6 mg, Niacin - 12.9 mg, Riboflavin - 0.3 mg and Thiamin - 0.6 mg), minerals (calcium - 62 mg, magnesium -184 mg, phosphorus -336 mg, iron - 2 mg, zinc - 3.3 mg, potassium - 332 mg and manganese - 2.0 mg) and fiber comparable to other dried nuts. Groundnut oil is a rich source of oleic acid (46 %), linoleic acid (32 %) and palmitic acid (17 %). It is a potential crop to battle against malnutrition (www.unicef.org) with high calorific value (564 kilo calories of energy / 100 g of kernels) (Ayoola, 2012) and with biological value of 65.1. Hence, it is considered as the “King” of oilseeds, “poor man’s Almond” and high value energy crop. Oil cake can also be used as organic manure or as animal feed and contains 7.8 per cent of nitrogen.

Groundnut is essentially a tropical plant and requires long and warm growing season grown under rainfed condition during *kharif* and to a small extent under irrigated condition in *rabi*. The crop needs 500 to 600 mm water for optimal growth and it can grow in regions having rainfall of 350 to 800 mm. Since the water requirement of groundnut crop is variety specific, short duration varieties (90 days) require < 500 mm, medium-duration varieties (105 days) require rainfall between 500 and 600 mm and long-duration varieties (120 days) require annual rainfall of > 600 mm (Coulibaly, 2013). The optimum temperature for vegetative growth period is between 27°C to 30°C depending upon the cultivar (De Beer, 1963). Reproductive growth is maximum between 24°C to 27°C. Maximum rate of growth of pods is between 30 °C to 34 °C (Dreyer, 1980 and Prasad *et al.*, 2000).

Groundnut is mainly cultivated by small and marginal farmers, mostly under arid and semi-arid tropical conditions which are characterized by unpredictable periods of water deficit. Groundnut yield in rainfed areas has been limited by drought stress because pod yield and other growth parameters have been severely affected. The area under groundnut farming is getting declined due to the non-adaptability of many varieties to water deficits.

Drought is posing a major threat to global agriculture in recent times. Among the environmental stresses, drought stress is one of the most adverse factors for plant growth and productivity. Drought stress can reduce grain yield, have estimated the average yield loss of 17 to 70 per cent in grain yield due to drought stress (Mostafa, 2013). Yield losses due to drought are highly variable in nature depending on its timing, intensity, and duration, coupled with other location specific environmental factors such as irradiance and temperature. The effects of drought on

groundnut are manifested in several ways, affecting both quantity and quality of the produce. Water deficit, depending on the timing of occurrence, can cause significant reduction in yield by affecting physiological processes such as nitrogen fixation, photosynthesis, biomass accumulation and calcium uptake by developing pods. The end-of-season drought can predispose the crop to aflatoxin contamination, which can severely affect the economic value of the crop (Nageswara Rao and Nigam, 2003 and Pasupuleti *et al.*, 2013).

The complex nature of drought tolerance is governed by monogenic as well as polygenic gene action (Jiban, 2001) and its expression depends on the action and interaction of physiological, molecular and biochemical features of plant. The influence of drought stress depends on the duration of stress, its magnitude, developmental stage and type of genotype. Depending on the time of occurrence, the most frequently encountered drought patterns in groundnut have been classified into four groups such as early season drought (immediately after germination to flowering), mid-season drought (flowering to pod formation), end-of-season drought (pod filling to pod maturity) and intermittent drought (Hamidou *et al.*, 2012 and Coulibaly, 2013). Mid and end-of-season droughts are critical as they affect the pod yield and quality parameters. The extremely variable nature of drought has made it difficult to define plant attributes required for improved performance under drought, consequently limiting plant-breeding efforts to enhance drought tolerance in groundnut. Genetic options for improvements in drought tolerance vary with most drought patterns experienced in a given environment. Many physiological features decide the tolerance to drought in groundnut like relative water content in leaf, specific leaf weight, which is a surrogate measure to water use efficiency or drought tolerance (Suvarna *et al.*, 2004 and Gopinath *et al.*, 2008).

In groundnut, genetic analysis of yield revealed a high influence of environment on pod yield that hinders the achievable genetic gain in breeding programs (Zhang *et al.*, 2011). High yielding cultivars with the smallest amount of $G \times E$ interactions are usually desirable. Developing drought tolerant variety is an economical, eco-friendly and best method of improving groundnut crop productivity under drought. Nevertheless studies on selective evaluation of advanced breeding lines for drought tolerance is scarce and is very much required to identify a few elite genotypes for their use in the groundnut breeding programme for developing varieties suited to drought prone areas. So, a high-yielding cultivar that continues to produce well under drought conditions is a priority to enable stability of production. Hence, much of research efforts in the last decade have attempted to improve performance by selecting plants with good pod yield under adverse environmental conditions.

In this context, an attempt has been made in the present study entitled as “Genetic investigation on end-of season drought stress in advanced breeding lines of Groundnut (*Arachis hypogaea* L.)” with the following objectives.

1. Assessment of the groundnut advanced lines for drought related parameters under drought stress and irrigated conditions
2. Assessment of the groundnut advanced lines for yield and yield components under drought stress and irrigated conditions
3. Assessment of the groundnut advanced lines for oil, protein and phenol content under drought stress and irrigated conditions
4. Assessment of correlations between drought, biochemical and yield parameters

Review of Literature

II REVIEW OF LITERATURE

Groundnut is grown widely under rainfed condition in the arid and semi-arid tropics. Drought is the most important factor limiting the productivity under rainfed condition. The breeding of high yielding and drought tolerant groundnut cultivars has been hampered by the lack of information on the genetics of physiological traits contributing to drought tolerance under limited water condition (Venkateswarlu *et al.*, 2007).

Researchers linked various physiological, morphological and biochemical responses of plant to drought with their tolerance mechanisms (Clarke and Mc Caig, 1982). Novel Breeding approaches utilizing physiological, morphological and biochemical traits have been proposed to improve selection efficiency for superior drought tolerant genotypes and to supplement the selection on the basis of yield (Blum, 1988).

Drought is a meteorological term and it is defined as a period without rainfall, the length depending on the region. In the field, drought can cause a lot of plant stresses including temperature, light and nutrient stresses. Therefore, it is difficult to mimic drought in the laboratory. However, the stress component that defines drought is a decrease in the availability of soil moisture. This diminished water availability can be quantified as a decrease in water potential (Kramer and Boyer, 1995). Reduced water potential (decreased free energy of the water) makes it more difficult for the plant to take up water and this in turn elicits a sort of responses that allow the plant to avoid water loss, allow water uptake to continue at decreased water potential or allow the plant to tolerate reduced tissue water content (Smith and Griffiths, 1993).

Drought is the major abiotic constraint affecting groundnut productivity and quality worldwide. In India, average productivity of groundnut is relatively low as it is mostly grown under rainfed condition. Because of high productivity under assured irrigation, groundnut cultivation in summer season is gaining popularity (Patel *et al.*, 2008).

Drought, a complex combination of stresses, involves both moisture stress and high temperature stress affects crop growth and final yields (ICRISAT 1994). A number of physiological, morphological and phenological traits have been reported to improve the performance of crop challenged by drought. Increasing demand for edible oil calls for urgent measure to increase water use efficiency (WUE), which is one of the main limiting factors in groundnut production. Water Use Efficiency is one such physiological trait which can contribute to productivity when water resources are scarce.

Drought tolerance in any crop depends on its intrinsic capabilities to maintain high WUE and high thermo-tolerance. Hence, identification of genotypes possessing

high WUE and thermo-tolerance is thereby important to enhance productivity. A thorough understanding of the effects of drought on physiology, growth and yield is absolutely essential. Further, information on magnitude of variability and its genetic components for these characters and their correlation with yield helps in the improvement of drought tolerance in groundnut.

Hence, the literature, which focuses on certain physiological traits, yield as well as biochemical traits and their relation to yield, are reviewed in the following sections.

2.1 Growth and yield related traits

2.2 Physiological traits

2.3 Drought tolerant traits

2.4 Biochemical traits

2.5 Genetic variability, heritability and genetic advance

2.6 Correlation and path coefficient analysis

2.1 Growth and yield related traits

Chuni *et al.* (2012) tested thirteen advanced breeding lines of groundnut in summer 2012 with three checks under irrigated and simulated water-deficit conditions. Highly significant differences due to genotypes were observed for most of the growth and yield traits. The advanced breeding line PBS 15031 was found to be the most tolerant one followed by PBS 16038 and PBS 30055. Varakumar *et al.* (2012) reported that, among the eleven groundnut cultivars (*viz.*, Abhaya, K-1271, TCGS-888, JL-24, K6, Narayani, Prasuna, Rohini, TG47, TPT1 and TPT4) which were subjected to moisture stress by withholding water for 5 and 10 days followed by rehydration, the cultivar K-1271 was more tolerant to moisture stress, recorded greater biomass and high yield associated with high antioxidant activity.

Vasanthi *et al.* (2012) made 62 crosses in line \times tester fashion and half-diallel fashion. About 160 breeding lines with different combinations of drought and water-use efficiency and desirable pod and seed features were selected in advanced generations and evaluated for yield and water use efficiency traits. Out of this, 16 lines with a good combination of yield, drought and water-use efficiency were isolated. From these, TCGS 1043, a breeding line with superior performance with respect to yield, drought tolerance, tolerance to groundnut bud necrosis, stem necrosis, stem rot and dry root rot, high shelling out-turn of 75.00 per cent in rainfed situation and 80 per cent under irrigated situation was released as a variety Dharani in 2012.

2.1.1 Plant height

Three mechanisms, namely escapism, avoidance and tolerance are involved in drought resistance. Morphological and physiological characters show different types of inheritance. Improving drought resistance in high yielding genotypes could be possible through incorporating morphological and physiological traits in breeding programme.

Plant height is one of the important characters of growth and development of the canopy in groundnut.

Patra *et al.* (1981) reported that ICGV-8614, ICGS-44, JL-24 and TG-24 groundnut varieties have recorded higher plant height and dry matter accumulation due to difference in phenologies and pattern of assimilate partitioning between vegetative and reproductive components.

Ike (1986) reported that, when a Spanish Groundnut variety was subjected to moisture stress during early flowering and pod formation stages, moisture stress did not reduce plant height significantly. Plant height had positive relation with Leaf Area Index (LAI), Crop Growth Rate (CGR) and Harvest Index (HI), where it had negative relationship with Net Assimilation Rate in groundnut. Generally plant height is influenced by the interaction of environmental conditions and genetic constitution of the plant. Plants grow taller under moisture stress free conditions because, the plant growth depends on cell division and cell expansion for which adequate water supply is essential (Naidu, 1992).

Ross (2007) reported that, high moisture was directly proportional to plant height in groundnut. However, there was greater reduction in the plant height when stress was imposed at the early flowering than at pod formation stage. Soil moisture depletion decreased plant height in groundnut (Jana *et al.*, 1989 and Watterott, 1991) due to low moisture content at planting which caused a considerable delay in seed emergence and reduction in early seedling growth.

Channappagoudar *et al.* (2010) reported that highest plant height was recorded in TMV-2 closely followed by JL-24 and the lowest plant height in Dh-86. The highest LAI was recorded in JL-24 followed by TMV-2 and the lowest was in Dh-86, followed by TAG-24. The lowest SPAD reading was recorded in Dh-2000 and highest photosynthetic rate was recorded in JL-24 (28.50 $\mu\text{mol}/\text{m}^2/\text{s}$) followed by TMV-2 and TAG-24. Significantly higher pod yield was recorded in GPBD-4 (30.00 q/ha) followed by Dh-86 (28.50 q/ha).

Nautiyal *et al.* (2012) reported that morphological traits such as plant height and SLA influenced significantly due to sources of variation like genotype, environment and G×E interaction.

In groundnut, the plant height increased progressively with the advancing age of the groundnut crop during summer. Among the genotypes TPG-41 (21.14 cm), ICG-8401 (25.59 cm) and ICG-8434 (24.74 cm) were dwarf, while ICG-8440 (30.91cm), ICG-8444 (30.61 cm) and ICG-8333 (30.42 cm) were tall genotypes (Dharanguttikar and Borkar, 2014).

2.1.2 Number of primary and secondary branches

Rudraswamy *et al.* (1999) found that the moderate estimates of GCV and PCV were observed for the number of mature branches per plant. Gopinath *et al.* (2008) reported that number of branches per plant showed moderate heritability estimates indicating substantial influence of environment on these characters.

Nandini *et al.* (2011) observed moderate estimates of PCV and GCV for the characters like plant height, number of branches per plant indicating presence of variability for these characters. Moderate heritability coupled with high genetic advance as per cent of mean was observed for number of branches per plant in both crosses studied in groundnut.

2.1.3 Number of days to maturity

In a two season study, Lakshmaiah (1978) recorded wide differences between *kharif* and *rabi* seasons for the GCV (66.37 % *kharif* and 39.63 % *rabi*), PCV (79.53 % *kharif* and 41.17 % *Rabi*), heritability (69.57 % *kharif* and 41.17 % *rabi*) and GA (1.38 % *kharif* and 5.10 % *rabi*) in groundnut.

Sumathi and Ramanathan (1995) showed that high heritability estimates were obtained for 100 kernel weight followed by days to maturity and haulm yield per plant which indicated that these characters are less influenced by environment. Suvarna *et al.* (2004) expressed that moderate to low heritability estimates for days to maturity indicating that they are more influenced by environment. Gopinath *et al.* (2008) observed that the high heritability and moderate genetic advance is being observed for the characters days to maturity, specific leaf area and oil content.

2.1.4 Number of pods per plant

Sudhakar Babu *et al.* (1996) expressed that pod number and pod weight in groundnut significantly increased with increased soil depth. The effect of soil depth was more significant on kernel and pod dry weight. Francies and Ramalingam (1999) revealed the predominance of non-additive gene action for the expression of number of pegs, number of mature pods, pod yield and kernel yield.

Reddy *et al.* (2003) noticed that, pod development stage is the most sensitive to drought stress, resulting in severe yield reduction by lowering number of matured pods. Similar results were reported by Nageswara Rao *et al.* (1985).

Jana *et al.* (1989) reported that two irrigations produced more number of pods per plant significantly than single irrigation as well as unirrigated condition in groundnut.

Chaudhary (1993) observed high GCV, GV and heritability in four groups of groundnut for unfilled pods.

Songsri *et al.* (2008a) reported that the genotypes with low number of mature pods under both non-stressed and stressed conditions were Tifton-8 and KK 60-3. These genotypes had low number of matured pods under stressed conditions due to less numbers of flowers and pegs.

Gopinath *et al.* (2008) reported that number of mature pods per plant showed moderate heritability estimates indicating substantial influence of environment on this character.

Nandini *et al.*, (2011) highlighted that the PCV and GCV estimate were relatively high for total number of pods per plant suggesting the presence of considerable variation. Hence, individual plant selection can be practiced for the above mentioned characters to get higher yields. Results are accordance with Parameshwarappa and Girish (2007) in groundnut.

Raja Babu *et al.* (2011) observed that under normal conditions, the number of mature pods was more in VG 77 (12.90) followed by CGC 4018 (12.50) while under moisture stress conditions, the number of mature pods per plant was 4.85, 4.15 and 3.55 in VG 77, VG.76 and JL.24, respectively. Thus moisture stress had affected the pod development to a greater extent. The highest yield was obtained in ICGV 1697 (85.40 g) closely followed by ICGV 77 (84.65 g).

2.1.5 Pod yield

Nageswara Rao *et al.* (1985) confirmed that irrigation could be withheld during much of the vegetative period without any apparent effect on pod yield, involving that water stress during vegetative stage had no effect on pod yield, implying that water stress had no effect on yield. Jayalakshmi *et al.* (1998) have observed no significant relationship between WUE and pod yield in F₃ material indicating the possibility for concurrent improvement of both the traits.

Thakur *et al.* (2013b) studied 25 groundnut genotypes for determining the genetic variability to drought tolerance. They reported considerable variability among the groundnut varieties and the genotypes ICGV-99171, ICGV-98089, ICGV-97100,

Baidehi, ICGV-00440 and B-4 were found to have drought tolerance with high pod yield.

Araus *et al.* (2002) reported that selection for pod yield under stress conditions could not be effective as it might lead to poor results due to the large G x E interaction. Vorasoot *et al.* (2003) reported that there was significant pod yield under stress and non-stress conditions at both locations and years. Similar results were observed in groundnut (Songsri *et al.* 2008a, Songsri *et al.* 2008b, Hamidou *et al.* 2012 and Ntare *et al.* 2001). Alam *et al.* (1985) reported high heritability coupled with high genetic advance as per cent of mean for kernel yield and pod yield.

John *et al.* (2007) mentioned that the PCV and GCV estimates were relatively high for pod yield per plant suggesting presence of considerable variation. Hence, individual plant selection can be practiced for the above mentioned character to get higher yields. Songsri *et al.* (2008a) found that the Groundnut genotypes with higher root length density (RLD) under drought could maintain high pod yield. Gopinath *et al.* (2008) in their study reported that high heritability coupled with high genetic advance as per cent of mean has been noticed for the characters like pod yield per plant and haulm yield per plant.

Girdthai *et al.* (2010) demonstrated that terminal drought has more effect on pod yield than on biomass. Terminal drought reduced pod yield by 35.00 per cent, 34.00 per cent in 2004/2005 and 2005/2006, respectively, but only reduced biomass by 21.00 per cent in each year.

Puangbut *et al.* (2011) noticed moderate heritability estimates for drought tolerant index (DTI) based on pod yield and biomass and suggested that this trait might be useful as a selection criterion for early season drought tolerance in Groundnut breeding programs. However, as heritability estimates for pod yield and biomass were rather low and prone to G×E interaction, selection for these traits may not be effective.

Bodre and Dhonde (2011) reported the maximum pod yield (28.96 q ha⁻¹), haulm yield (47.41 q ha⁻¹) and dry kernel yield (20.83 q ha⁻¹) in the treatment of white polythene mulch stress at pod development stage. Hamidou *et al.* (2012) showed that the heritability of pod yield was in the range of 78.00 to 87.00 per cent while the heritability of pod growth rate and partition were 76.80 and 69 per cent, respectively. Dharanguttikar and Borkar (2014) reported that groundnut genotypes, ICG-8029 (75.53 q ha⁻¹), ICG-8428 (68.77 q ha⁻¹), ICG-8437 (66.05 q ha⁻¹) and ICG-8468 (65.08 q ha⁻¹) were superior for pod yield during summer. Venkateswara Rao *et al.* (1986) reported that moisture stress reduced the total number of pods m⁻². In groundnut cultivar J-11, moisture stress at flowering, pegging and pod formation

stages reduced pod number by 44.85, 20.00 and 27.87 per cent, respectively over control.

Gangamma (1987) reported that both early and mid-season stress decreased productivity in groundnut, the latter being more detrimental. Wright *et al.* (1991) reported significant differences in pod yield of four groundnut cultivars viz., Mc Cubbin, Red Spanish, Virginia and Q 18801 by 17.00 to 25.00 per cent and variation in pod yield was largely due to differences in harvest index. Bhattacharya *et al.*, (1995) reported that, under soil moisture stress, seed yield is dependent mainly on biological yield followed by plant height and harvest index. Groundnut yields were significantly reduced under simulated drought conditions with no irrigation between 40 to 80 DAS, by 26.00 per cent compared to adequately irrigated treatment (Ramana Rao, 1994, and Babita and Reddy, 2001).

In groundnut, conventional empirical approach has been extensively used to select for high pod yield and other desirable agronomic traits under simulated mid and end-of-season drought conditions that has led to the identification of breeding lines performing under limited moisture conditions (Nageswara Rao and Nigam, 2001).

Reddy *et al.* (2003) reported that the moisture stress decreased the pod yield significantly primarily due to reduction in number of pods per plant (41.20 %) followed by 100 kernel weight (22.50 %) and number of seeds per pod (20.40 %) in groundnut.

Latha and Reddy (2005) reported that WUE among groundnut genotypes varied from 2.10 to 2.39 g kg⁻¹ under stress conditions. The groundnut genotypes Tir 16, Tir 14 and Tir 13 produced higher dry matter and pod yield under moisture stress conditions and also had high WUE values. These studies suggested the possibility of using this trait in breeding for drought tolerance. Among the groundnut genotypes, KGU 60, 14 PI 430238, F6-8-2, 11 PI 430231 and 200 PI 442566 performed well under well-irrigated conditions (Jongrunklang *et al.*, 2008). Bootang *et al.*, (2010) reported that number of mature pods in groundnut was slightly decreased from 23.70 to 22.10 pods plant⁻¹ and pod yield was decreased from 3011.30 to 2289.80 kg ha⁻¹ due to water stress.

Raja Babu *et al.* (2011) reported that, the groundnut genotypes viz., VG-77, JL-24, CO 2 and IGG 1697 recorded higher pod yield under moisture stress condition. This is because functional leaves at the time of harvest have contributed for higher pod yield. Groundnut genotypes, ICGV-95017, ICGV-92173 and ICGV-95005 recorded highest pods per plant under water stress condition (Thakur *et al.*, 2013a).

Kumaga *et al.* (2003) investigated the effect of imposed single and double water stress on the growth and yield of three grain legumes commonly grown in

sub-saharan Africa. Water stress significantly reduced growth of both cowpea and Bambara groundnut but not groundnut. In cowpea, it also reduced the number of seeds set but not the seed weight. For bambara, single water stress significantly reduced the number of pods per plant but not seed weight, although double water stress resulted in many immature pods of very low weight. Groundnut was the most tolerant for post-flowering water stress among the three legumes.

Mwale *et al.* (2003) reported that, Bambara groundnut responded to drought by reducing the rate of leaf area expansion, final canopy size and total dry matter during vegetative growth. Drought also caused significant reductions in pod dry matter, pod number, seed weight and harvest index (HI) leading to a decrease in final pod yield that was different between land races. Across land races, drought reduced mean pod yield from 298.00 g/m² to 165.00 g/ m² representing 45.00 % yield loss. Despite the reduction of mean pod yield in all land races, the mean pod yield across the drought treatments that had received no water for almost 100-days indicated the resistance of the species to drought.

Chetana Mandavia *et al.* (2007) reported that the crosses GG-2 x NCAC-17135, GG- 2 x PI 259747, J-11 x P5-259747, S-206 x FES-8 and Kisan x FESR- S-PI-BI-B and the genotypes JB-223 and 224 recorded consistently superior and stable yield and suggested for their cultivation under regions of limited rainfall. These lines may be used as parents in breeding programmes for developing drought tolerant groundnut cultivars. Songsri *et al.* (2008a) reported that, drought tolerance index for pod yield was calculated as the ratio of pod yield under stress treatment to that under well-watered conditions. The differences among water regimes were significant for pod yield, immature pods and mature pods per plant, seed per pod and 100-seed weight and differences among genotypes were significant for all traits. Drought reduced pod yield and mature pods per plant. Early peak flowering is important for the formation of mature pods under drought conditions. Two different strategies were used in maintaining pod yield under drought. High yield potential was important for ICGV-98300. Tiften-8 showed that the lowest pod yield and seed filling. High RSC and well-filled mature pods were the most important traits contributing to high pod yield in drought resistant genotypes.

Shinde *et al.* (2010) investigated that all groundnut varieties performed well. Agronomic and yield contributing characters were decreased under drought stress; and significant response of varieties were observed. TG-26 and WEST-20 were found more sensitive to drought stress, comparing with TAG-24 and WEST-44. Vurayai *et al.* (2011) reported that the highest yield amongst the stressed plants was obtained in plants stressed during the vegetative stage, followed by the flowering and lastly the pod filling stage. Bambara groundnuts reduced growth therefore reduced transpirational area thus reducing water loss under water stress. The results also

showed that bambara groundnuts have the ability to recover from water stress after rainfall or irrigation and is therefore capable to producing some yield under water limited conditions.

Various government organizations and research institutes made attempts to develop drought resistant varieties. Numerous drought tolerant germplasm lines were identified and released as varieties based on pod yield under drought stress condition (Nigam *et al.*, 2005). Since pod yield is a quantitative trait, the selection for pod yield under drought stress was difficult due to higher Genotype \times Environment (G \times E) interaction (Arunyanark *et al.*, 2008 and Wright *et al.*, 1996).

2.1.6 Shelling percentage

Mishra and Yadav (1992) recorded highest shelling percentage as a result of scheduling of irrigation to the groundnut during summer at 10 days interval. Hariprasanna *et al.* (2008) reported predominance of additive gene action in the expression of shelling out turn, 100-seed weight, while non additive gene action played an important role in the inheritance of seed size.

Moderate estimates of PCV and GCV were observed for the characters like plant height, shelling percentage and number of branches per plant indicating presence of variability for these characters by Nandini *et al.* (2011). A narrow difference between PCV and GCV for shelling per cent and significantly higher differences among 22 germplasm lines was reported by Vasanthi *et al.* (1998) and Abhay *et al.* (2002), respectively.

On the other hand, low genetic variability for shelling percentage was noticed in the studies of Yogendra *et al.* (2002). However, Sarala and Gowda (1998) noticed low variability for shelling per cent as compared to pod yield in F₂ population of interspecific crosses. Labana *et al.* (1980) observed high heritability estimates for shelling per cent in a study involving F₂ populations of a crosses between M₁₄₅ \times U₂₋₄₇₋₃. Swamy *et al.* (1988) recorded relatively low heritability and GAM for shelling per cent, while Manoharan *et al.* (1990) recorded low heritability estimates for shelling percentage. Varman and Raveendran (1996) in a study involving F₁ hybrids and parents indicated high heritability but low genetic advance for shelling per cent. Similarly, Rudraswamy *et al.* (1999) and Yogendra *et al.* (2002) also recorded high heritability and low genetic advance. Ramesh *et al.* (1984) reported that moisture stress at pod development phase decreased shelling per cent more significantly than at other stages.

Patel and Golakiya (1988) reported that, the shelling percentage was decreased due to stress at pegging to pod development stage. Jana *et al.* (1989) indicated that shelling percentage was reduced due to decrease in irrigation in groundnut.

Ramana Rao (1994) reported that, the shelling per cent was 66.50 under adequately irrigated conditions and it was 62.10 under simulated drought conditions.

Thakur *et al.* (2013b) reported that significant differences were observed among groundnut varieties in shelling percentage. ICGV-97093, Baidehi and ICGV-86124 showed highest shelling percentage of 77.20, 77.20 and 71.20 per cent respectively. This difference is due to high water use efficiency and photosynthesis. Shelling percentage was ranged between 67.50 and 73.00 per cent among groundnut genotypes during summer. The genotypes, ICG-8455 (73.00 %), ICG-8483 (72.50 %) and ICG-8468 (72.50 %) recorded higher shelling percentage (Dharanguttikar and Borkar, 2014).

2.1.7 Kernel yield

Vaghasia *et al.* 2010 studied the effect of soil moisture stress at various growth stages on growth and productivity of summer groundnut (*Arachis hypogaea* L.) genotypes. Pooled analysis of data indicated that, imposing a transient moisture stress significantly reduced the pods per plants, shelling, 100-kernal weight, harvest index and oil content. While, moisture stress at flowering and pod development stages by withholding irrigation does not affect the productivity of the groundnut crop significantly and save about 33.33 per cent of irrigation water by reducing the number of irrigations during summer season, but stress at flowering stage (25-47 days after sowing) and pod development stage (50-72 days after sowing) gave 18.45 per cent and 30.63 per cent reduction in pod yield than no moisture stress treatment, respectively. Different groundnut genotypes do not exerted their significant effect. The highest water use (84.35 cm) and benefit: cost ratio (2.42) was obtained under no moisture stress. While, maximum water-use efficiency (WUE) was achieved under water stress imposed at flowering stage. Among the genotypes GG 6 recorded higher water-use efficiency (WUE) and benefit: cost ratio. Groundnut was the most tolerant of post flowering stress among the different legumes.

Seed yield under water stress environment is the primary character for selection in breeding for drought tolerance. Drought effect on seed yield is due to the relation with period of watering from flowering until physiological maturity (EL-Midaoui *et al.*, 2003). Pavithra *et al.* (2012) imposed drought stress by withholding irrigation after 60 days after sowing for the drought stress trial. The results indicated that, genotypes differed significantly for pod and kernel yield per plant. Among the genotypes, 9 and 11 were found to be highly drought tolerant based on kernel and pod yield per plant, respectively. Among these genotypes, each three drought tolerant (ICGV 91114, K1375 and ICGV 02125) and drought susceptible (ICGV 01279, ICGV 98170 and ICGV 98175) genotypes were selected for hybridization programme to develop mapping populations.

2.1.8 Test weight

Venkateswara *et al.* (1986) reported that moisture stress at flowering in groundnut increased 100-kernel weight compared to control. Srinivasan and Arunan (1987) reported that 100 pod weight of groundnut decreased due to water stress. Moisture stress during flowering period caused highest reduction of 21.90 per cent in 100-kernel weight of groundnut (Pathak *et al.*, 1988). Nautiyal *et al.* (1991) reported that moisture stress during early vegetative phase resulted in an increase of 100-kernel weight in groundnut. Ramana Rao (1994) stated that there was decrease in 100-kernel weight due to moisture stress in both rainfed and simulated drought treatments compared to adequately irrigated conditions. Kaul (1999) in an experiment conducted on loamy sandy soil of Ludhiana during summer found that the 100 kernel weight of groundnut cultivar, ICGS 11 was higher followed by SG 84, TG 25 and TG 26. Nagada *et al.* (2003) noted that, the superiority in kernel yield was accompanied with superiority in harvest index, WUE and transpiration either alone or in combination.

Venkataravana *et al.* (2008) observed that, among all the characters, the chlorophyll content was maximum (24.20) followed by 100-kernel weight (19.80 %) and shelling percentage (11.60 %). Gopinath *et al.* (2008) studies revealed that high heritability coupled with high genetic advance as per cent of mean has been noticed for the character 100 kernel weight, chlorophyll content and plant height indicated the presence of lesser environmental influence and prevalence of additive gene action in their expression.

Bootang *et al.* (2010) reported that the reduction in 100-seed weight though significant was not too severe, ranging from 52.90 to 57.90 g on average. The reductions in seed size were also significantly differing among cultivars. Groundnut genotypes, ICGV-00440, ICGV-91104, ICGV-91074 and ICGV-88473 recorded the highest 100 kernel weight, while genotype ICGV-97243, had lowest 100 kernel weight under water stress condition. Genotypes, ICGV-00440 and ICGV-91104 recorded highest 100 kernel weight under normal condition. The differences in variation in water stress and normal condition is due to the high phosphorylation, carboxylation and photosynthesis under normal water (Thakur *et al.*, 2013b). Dharanguttikar and Borkar (2014) reported that groundnut genotypes, ICG-8029 (61.90 g), ICG-8542 (54.60 g), ICG-8444 (53.80 g) and TPG-41 (53.80 g) recorded high 100 kernel weight and were found to have bold seed size during summer.

2.1.9 Percentage of sound mature kernels

Wynne and Rawlings (1978) recorded greater magnitude of variability for SMK percentage as estimated from F₂ family mean in a cross between NL 5 x Florigant. Pallas *et al.* (1979) expressed that seed quality was most affected

by the early season drought extended up to 70 days which significantly reduced sound mature kernel.

Bhat (1995) recorded low realized heritability and low genetic gain for sound mature kernel percentage in segregating population of two single crosses. Sufficient variability was noticed in F₂ population for sound mature kernel percentage, it was relatively lower when compared to pod yield as reported by Sarala and Gowda (1998).

Low variability for SMK percentage was observed by Gowda *et al.* (1996) in a study of two single crosses. Venkataravana (2001) recorded low variability and high heritability and suggested additive gene action governing the sound mature kernel percentage in evaluation of groundnut genotypes. Similar reports were reported by Yogendra *et al.* (2002) in a set of Spanish bunch types.

Golakia *et al.* (2005) and John *et al.* (2007) reported high heritability coupled with GAM for sound mature kernel percentage along with kernel yield and pod yield in groundnut.

Parameswarappa and Girish (2007) reported that the PCV and GCV estimates were relatively high for total kernel yield per plant suggesting presence of considerable variation. Hence, individual plant selection can be practiced for the above mentioned character to get higher yields.

Nandini *et al.* (2011) observed that moderate estimates of PCV and GCV were observed for the sound mature kernel percentage and specific leaf area indicating presence of variability for these characters. Similar results were observed by Rudraswamy *et al.* (1999) in groundnut.

2.1.10 Days to fifty per cent flowering

Kannayan and Veluswamy (1969) investigated that the time of flower initiation the period and rate of flowering were found to vary with varieties and seasons. In summer, the onset of flowering was earlier and period of flowering was shorter but rate of flowering was higher. In some varieties, rate of flowering was so high to composite for total flower court in a short span of flowering period.

Shivakumar and Sharma (1986) imposed drought stress or soil moisture deficit at all the growth phases of groundnut during three growing season observed that stress from emergence to pegging gave increased yield over control in all the three years, while in other stages decreased the yield.

Meisner and Karnok (1992), Gowda and Hegde (1986) and, Janamatti *et al.* (1986) observed that the rate of flower production is reduced by drought stress during flowering but the total number of flowers per plant is not affected due to an increase in the duration of flowering.

Gopinath *et al.* (2008) reported that moderate heritability coupled with moderate genetic advance is being observed for the characters days to 50 per cent flowering and haulm yield, which indicated considerable influence of environment apart from non-additive gene action.

Vaghasia *et al.* (2010) reported water stress at flowering and pod development stages by withholding irrigation did not affect the productivity of the groundnut crop significantly and saved about 33.33 per cent of irrigation water by reducing the number of irrigation during summer season, but stress at flowering stage (25-47 DAS) and pod development stage (50-72 DAS) gave 18.45 and 30.63 per cent reduction in pod yield than no water treatments, respectively.

Bodre and Dhonde (2011) concluded that flowering and pegging stages of groundnut were sensitive to moisture stress and caused maximum yield reduction, while polythene mulch played an important role in conserving moisture and reducing weed growth ultimately enhanced the yield.

Nandini *et al.* (2011) highlighted that high heritability coupled with low genetic advance as per cent of mean was observed for days to 50 per cent flowering in both crosses studied were indicating the prevalence of narrow range of variability and the presence of non-additive gene action. This suggests limited scope for further improvement of these characters. Similar result was reported by Makhan *et al.* (2003) and Praveen Kumar (2006) in groundnut.

Puangbut *et al.* (2011) reported that recovery growth following release of pre-flowering drought (PFD) had a store deficit during the PFD. A combination of N₂-fixation, LA and root growth accounted for a major portion of the genotypic traits could be used as selection criteria for identifying genotypes with rapid recovery from PFD. A combined analysis of N₂-fixation during the recovery had low genotype x environment interaction indicating potential for using these traits for groundnut.

2.1.11 Root length

Madhusudhan and Sudhakar (2014) studied the morphological responses of a groundnut cultivar K-134, under different moisture stress regimes characterized as control, mild, moderate and severe stress represented by 100.00, 75.00, 50.00 and 25.00 per cent soil water levels, respectively, for eight days. Result illustrates that root length increased at mild, moderate stress treatments and inhibited at severe stress conditions on all days of sampling over control. Severe stress treatments had caused considerable inhibition in shoot growth on day 4 and 8. The fresh and dry weights of roots and leaves and also leaf area decreased over control in all stress treatments except under mild stress on day 4. They conclude that the changes in these traits were dependent on stress severity and duration.

2.2 Physiological traits

The potential of a genotype or species to acclimate to moderately high temperature, thereby reducing high temperature injury is an important factor in determining plant performance in high temperature environments.

Mostafa (2013) studied physiological and agro-morphological response to drought stress in groundnut. They observed that plants in drought stress make changes in some of their biochemical and physiological features. They found that the cultivars that have more chlorophyll content, cell membrane stability, more relative water content (RWC) and antioxidant enzyme activity were more tolerant to drought stress.

More simple, rapid and effective selection schemes have been explored to select of drought tolerant genotypes by using physiological attributes for drought resistance, such as SPAD Chlorophyll Meter Reading (SCMR) (Nigam *et al.*, 2005), Relative Water Content (RWC), Membrane Stability Index (MSI) and Harvest Index (HI). These physiological and biochemical parameters assist to screen the genotypes tolerance to drought stress and is helpful in selecting a genotype or developing new cultivars with tolerant mechanisms in future climatic conditions (Sunitha *et al.*, 2015).

Junjittakarn *et al.* (2016) studied the effect of mid-season drought and recovery on physiological traits and root system in groundnut (*Arachis hypogaea* L.) genotypes with an aim to examine the physiological traits for drought tolerance in diverse groundnut genotypes responses under mid-season drought. They concluded that drought significantly decreased RWC and stomatal conductance, but it increased root length density. High genotypic variation for root and physiological traits were observed at mid-season drought and after recovery. Association of physiological traits and biomass with pod yield was higher at mid-season drought and after recovery than at the initiation of drought. Genotypes KKV 60, ICGV 98305 and TIFTON 8 increase high water uptake by root system except for TAINAN 9 and KS 2. Selection for physiological traits using RWC and stomatal conductance might be effective improving groundnut for drought tolerance. The knowledge of this study will be useful for breeding of Groundnut for mid-season drought condition.

2.2.1 SPAD Chlorophyll Meter Reading (SCMR)

Nageswara *et al.* (2001) reported that SCMR could be used as a reliable and rapid measure to identify genotypes with low SLA or High specific leaf nitrogen (SLN) which are surrogate measures of transpiration efficiency (TE) in Groundnut.

Significant inverse relationship was observed between SCMR and SLA in groundnut and hand-held SPAD chlorophyll meter can be used effectively as surrogate measure of WUE (Rao *et al.*, 2001). Nageswara and Nigam (2003) suggested that SCMR could be used as a rapid, low-cost, non-destructive between techniques to screen large breeding populations for SLA. A significant positive

correlation SCMR and WUE in groundnut has provided an option to use SCMR as yet another potential technique to quantify variations in WUE in groundnut (Sheshshayee *et al.*, 2006 and Bindhu Madhava *et al.*, 2003).

Madhava *et al.* (2003) suggested that SCMR might be useful for screening Groundnut genotypes in early segregating populations as it is much simpler than SLW and SLW might be suitable for screening the advanced generations.

Nigam *et al.* (2005) indicated that yield was not stable across environments and selection for drought tolerance using yield alone can be difficult. Surrogate traits such as SCMR and SLA might be useful if they can identify genotypes with high pod yield under drought.

Babita *et al.* (2006) concluded that genotypic differences in water use efficiency and heat tolerance exist among groundnut genotypes, which are detectable by SLA, SCMR, chlorophyll fluorescence or membrane thermo stability hence these parameters may be used as practical tool for identifying water use efficient and high temperature tolerant genotypes.

The ability to maintain chlorophyll density under water deficit condition has been suggested as a drought resistant mechanism in groundnut (Arunyanark *et al.*, 2008 and Sheshshayee *et al.*, 2006).

Painawadee *et al.* (2009) reported significant interrelationship between SLA and SCMR and suggested that SCMR could be used as a reliable and rapid measure to identify genotypes with low SLA in groundnut.

Nigam and Aruna (2008) reported that SCMR and SLA had low G x E interactions, indicating that these traits are stable across a wide range of environments. These findings are in accordance with Songsri *et al.* (2008a).

Arunyanark *et al.* (2008, 2009) observed that the groundnut genotypes with high SCMR could maintain higher rate of photosynthesis per unit leaf area because of SCMR had positive chlorophyll contents and chlorophyll density. Same results were given by Sheshshayee *et al.* (2006).

Songsri *et al.* (2009) showed that the relationships between SLA and SCMR were consistent under different water regimes. Groundnut genotypes having an ability to maintain higher SCMR and lower SLA under drought stress should be more tolerant to drought and hence maintain higher WUE under severe drought conditions.

Boontang *et al.* (2010) expressed that SLW and SCMR could be effectively identifying Groundnut cultivars with higher pod yield under water limited conditions. KK 60-3, KKV 72-1 and KKV 60 were identified as drought tolerant because they had SCMR and SLW, which were similar to those of ICGV 98324 and ICGV 98308. KK 60-3 had high biomass under water limited conditions because of high potential

but it had poor pod yield, whereas KKV 60 had the highest pod yield and harvest index. KKV 60 also had the highest pod yield under well-watered condition.

Puangbut *et al.* (2011) reported high heritability estimates for SLA and SCMR under Early Season Drought (ESD) and recovery conditions indicated that selection for these traits after recovery could be achieved and these traits might be contributed to yield.

Drought stress manipulates the chlorophyll content in leaves of groundnut. Reddy *et al.* (2003) reported that higher chlorophyll content in some cultivars of groundnut under stress was presumably due to less reduction in leaf water potential under stress. Similarly, increase in total chlorophyll content under moisture stress in some groundnut varieties has been accounted by several workers (Ramesh *et al.*, 1984). However, Patil and Patil (1993) observed that water stress decrease the total chlorophyll content of groundnut.

2.2.2 Relative water content

Relative water content (RWC) is the ratio of actual water content to water content at saturation (fully turgid) and expressed in percentage. The RWC is often considered as an appropriate measure of plant water status in terms of physiological consequences of cellular water deficit. The RWC was thus reported to be a sensitive index of plant water content and any fluctuations in the plant water status influenced the leaf temperature, leaf diffusive resistance and net photosynthetic rate primarily through their direct effects on stomatal regulation and mesophyll resistance (Sandhu and Harton, 1978).

Relative water content (RWC) values in well watered groundnuts are typically in the range of 85-98 per cent (Bhagasani *et al.*, 1976 and Bennett *et al.*, 1981). Under drought conditions, RWC is as low as 29.00 per cent has been measured (Bhagasani *et al.*, 1976) indicating that groundnut has a very low lethal water status. This attribute should contribute to high level of dehydration tolerance and leaf survival in groundnut during intermittent drought stress (Ludlow and Muchow, 1988).

Babu and Rao (1983) studied drought stress effects on groundnut over 35 days from 20 to 55 days after sowing. They observed that the relative water content ranged between 100.00 and 87.00 per cent on the first days of stress imposition. At the end of this 35 days moisture stress period the plants were wilted and the lowest relative water content recorded was 29.70 per cent. The RWC of lower than 85.00 per cent was considered as severely stressed.

Joshi *et al.* (1988) studied two Spanish bunch varieties, GG-2 and JL-24, and found that GG-2 had higher RWC before, during and after stress compared with JL-24. Usually, drought tolerant cultivars have lower water potential but higher RWC. Drought resistant varieties characteristically showed smaller decrease in RWC per

unit decrease in leaf water potential compared to susceptible varieties. Osmotic adjustment has been suggested as a mechanism that leads to minor changes in RWC per unit decline in leaf water potential and consequently facilitates to maintain positive turgor potential during water stress (Reddy *et al.*, 2003).

Shinde and Laware (2014) screened four groundnut varieties *viz.*, TAG-24, TG-26, WEST-20 and WEST-44 for drought tolerance through physiological indices. Among four varieties screened for drought stress, it was observed that, TAG-24 and *var.*WEST-44 were found to be tolerant to drought stress, as compared to TG-26 and WEST-20. Basu and Nautiyal (2004) proposed a relationship between relative water content (RWC) and specific leaf area (SLA). They found that genotype with low SLA (thick leaf) are able to maintain more RWC under soil moisture deficit conditions and sustain the higher photosynthesis compared to the higher SLA (thin leaf) genotypes.

Painawadee *et al.* (2009) indicated that RWC was sensitive in identifying drought stress even in the same groundnut genotypes with different water regimes in case of appropriate stress level. In case of mild drought stress, the use of RWC would not be appropriate because there was no significant difference between stressed and non-stressed treatments earlier than 7 DAS. This is possibly due to slow response of Groundnut to declining water level whereas the response of soil to water depletion was more acute than groundnut plants.

Songsri *et al.* (2009) showed reasonably good management of soil moistures. Relative water content was significantly lower in the plants experiencing soil moisture deficit stress than their respective controls.

Ravindra *et al.* (1990) in a field experiment found that RWC was significantly reduced under stress at the vegetative phase in groundnut. Fitzner (1991) found that there was significant genotypic variation for RWC in water stressed environment and was correlated with yield during water stress.

Ramana Rao (1994) observed that there was reduction in RWC of groundnut in both simulated drought and rainfed treatments compared to adequately irrigated treatment at 9, 18 and 27 days after imposition of water stress. Babita (1996) reported that there was reduction in relative water content of groundnut in simulated drought compared to adequately irrigated treatment and also observed significant genotypic variation in RWC. Cv. ICGV 86031 and TAG 24 maintained higher RWC values of 81.50 and 80.50 per cent, respectively, whereas Cv. ICG 476 and CSMG 84-1 had lower RWC of 71.10 and 71.30 per cent, respectively.

Aruna *et al.* (1999) observed that the drought tolerant groundnut genotypes *viz.*, CR 143-2-2, Salam pikit and JD 8 however lower reduction in relative water content under water stress as compared to susceptible genotypes PR 110 and P 169.

Naidu *et al.* (2001) proposed from the studies that RWC of leaves and seed yield was decreased drastically as the crop was subjected to progressive drought. Relative water content in groundnut is usually in a range of 20-100 per cent and non-stressed plants had RWC in a range of 85-100 per cent (Reddy *et al.*, 2003).

Shinde *et al.* (2010) reported that drought stress considerably reduced RWC and considerable differences among groundnut varieties were observed. At control conditions groundnut varieties showed maximum RWC whereas at higher water stress level the variety TG-26 showed maximum reduction in RWC (19.11 %) over control while variety TAG-24 showed minimum reduction (9.72 %). RWC decreased remarkably in response to declining soil water availability.

Painawadee *et al.* (2009) investigated that difference between water treatments were also significant for RWC, SLA, root dry weight and biomass but not significant for SCMR, harvest index and pod yield. Drought stress reduced RWC, SLA, RDW and biomass but had no significant effect on SCMR, harvest index and pod yield. Significant differences among groundnut genotypes were found for SLA at both water treatments. ICGV-98353 had the lowest SLA at both water treatments. Groundnut genotypes were significantly different for RDW and RWC at 1/3 AW only. KK4 had the highest RDW. ICGV 98324 performed best for RWC and it also had the highest DTI for RWC. ICGV-98324 had the highest SCMR, which was significantly different among groundnut genotypes.

2.2.3 Membrane stability index

Cell membrane stability (CMS) refers to the ability of plant cell tissues to hold electrolytes under drought condition by retaining the cell membrane configuration undamaged (Sullivan, 1971). The CMS has been widely used as selection criterion against water stress. Cell membrane is the first target of plant stresses (Levitt, 1972). The ability of plants to maintain membrane integrity under drought stress is associated with drought tolerance.

Measurement of MSI is a technique that has been regularly used for screening against drought tolerance in various crops likes soybean (Premachandra *et al.*, 1990) and in groundnut (Sunitha *et al.*, 2015).

Tripathy *et al.* (2000) reported that the variation in CMS was genotypic in nature in case of rice. Baldini *et al.* (1997) found that considerable variability for RWC in sunflower.

Babita *et al.*, (2006) reported that RI (relative injury) differences indicated the cellular membranes of genotypes and with low RI are more thermo-stable than those of genotypes with high RI. Genotypic variation for RI was observed in groundnut (Nautiyal *et al.*, 2004).

Shinde *et al.* (2010) reported that MSI of groundnut was higher in genotypes viz., TAG-24, WEST-44, WEST-20 and TG-26 at unstressed conditions. At higher water stress level (40.00%) the groundnut varieties TAG- 24, WEST-44, WEST-20 and TG-26 showed 4.88 per cent, 4.99 per cent, 5.98 per cent and 8.22 per cent, respectively, decrease in MSI over control.

Pranusha *et al.* (2012) reported that significant genotypic variability existed between 15 groundnut genotypes for relative injury and Fv/Fm ratio values, which denote usefulness of these traits for screening groundnut genotypes for intrinsic thermotolerance. Groundnut is susceptible to high cellular damage due to high temperature stress at pod maturity stage compared to flowering and pegging stages.

Sunitha *et al.* (2015) evaluated six groundnut genotypes by imposing drought stress at flowering stage and observed that genotypes Dharani and Abhaya with higher membrane stability index (MSI) during stress period along with other physiological and biochemical traits indicating their tolerance to drought stress.

2.2.4 Harvest index

The harvest index is measure of economically important fraction of the total dry mass of the crop and thus in part of WUE. Any change in the total above grounds biomass may be reflected in change in HI. Pandey *et al.* (1984) reported that water stress affected seed formation more than the total dry matter yield and hence harvest index declined.

Venkateswara *et al.* (1986) reported that moisture stress reduced HI in groundnut. Nageswara Rao *et al.* (1993), Wright and Nageswara Rao (1994) stated that the genotypic variation in HI under drought conditions were associated with drought tolerance.

According to Wright *et al.* (1991), estimates transpiration efficiency derived from measurement of carbon isotope discrimination (CID) indicated only small variations in WUE whereas variation in pod yield among four groundnut cultivars was largely due to differences in HI characteristics.

Babita (1996) working with 13 groundnut genotypes observed high HI, WUE among genotypes like TAG-24, ICGS-76 and Somnath even under moisture stress conditions.

Nagada *et al.* (2003) reported that groundnut progenies with higher kernel yield were mostly from trait based approach. The superiority in kernel yield was due to higher levels of HI and transpiration efficiency in these genotypes. Bootang *et al.* (2010) reported that HI of groundnut cultivars were varied from 0.22 to 0.39 and 0.22 to 0.41 in well watered and in water limited conditions, respectively.

Dharanguttikar and Borkar (2014) reported that the performance of different groundnut genotypes in respect of harvest index was significantly significant. It was ranged between 38.99 to 65.32 per cent during summer.

2.3 Drought tolerance indices

Amir and Abouzar (2011) in a study to determine the drought tolerance of spring rapeseed (*Brassica napus* L.) varieties using drought stress tolerance indices (STI, MP and GMP) and identifying the most appropriate index for drought stress tolerance evaluation reported that Syn 3 variety produced the highest seed yield and STI under water stress condition among varieties, while under normal irrigation condition the highest seed yield obtained by Hyola 401 (Canada) variety.

Arunachalam and Kannan (2013) screened twenty nine groundnut lines and reported that soil moisture stress resulted in reduction of plant height, number of mature pods per plant and pod yield per plant. The genotypes *viz.*, ICGV 07240, ICGV 07241, ICGV 07245, ICGV 07247 and VRI 7 recorded high pod yield plant. These genotypes were sensitive to drought as indicated by high DSI and less DTE. Drought tolerant peanut lines ICGV 07219, ICGV 07268 and ICGV 07262 have shown consistence in pod yield performance with less DSI and High DTE.

Younes *et al.* (2013) conducted a study in order to grouping safflower varieties in three irrigation regimes of stress *viz.*, five and six irrigation, and stress free (seven times irrigation) conditions. They reported that the most sensitive varieties in both water stress levels and the most tolerated varieties to this condition regarding the stress tolerance index (STI) were Zargan local IV variety, Mianeh I and N51016, respectively. Also N51016 had the most values of indices like MP, GMP and STI.

Esmail *et al.* (2014) studied drought tolerance in cultivars and lines of sesame and reported that in the studied indices, three indices of MP, GMP and STI, with grain yield in stress and no stress conditions had the highest positive and significant correlations. Comparison of the values obtained from indices for each genotype showed that, "Darab-14" and "Sistan local" with having higher sustainability and performance in stress and non-stress conditions had the highest values of indices of STI, GMP and MP, and were determined as most tolerance genotypes with high yield, thus they can be used in breeding programs.

Pavithradevi *et al.* (2015) evaluated fifty genotypes of groundnut including released varieties and advanced breeding lines for drought susceptibility index (DSI) for pod yield per plant and kernel yield per plant and reported that 7 and 6 genotypes were observed as highly drought tolerant based on pod and kernel yield per plant respectively. A total of 6 and 9 genotypes recorded as highly susceptible to drought for pod and kernel yield per plant respectively.

2.4 Biochemical traits

Plant response to water stress include biochemical and morphological changes and later as the water stress become more severe, it may cause functional injury and loss of plant parts or entire plant (Sangtarash, 2010). The degree of adaptations to drought may vary considerably among species as well as within the species (Save *et al.*, 1995).

2.4.1 Phenolic content

Aninbon *et al.* (2016) investigated the effects of end of season water deficit on phenolic content in five groundnut genotypes and reported that terminal drought decreased phenolic content of seeds of both tolerant and sensitive genotypes. Phenolic content of leaves and stems increased under terminal drought stress in both years.

Kro *et al.* (2014) reported that levels of all phenolic content of leaves and roots decreased significantly under the drought stress.

2.4.2 Oil content

Yao *et al.* (1982) reported that drought at flowering increased the number of shriveled kernels with no effect on oil content but reduced the protein content. However moisture stress during the seed development phase reduced the seed oil content but increased the protein content.

Sarma (1983) observed that with the imposition of early moisture stress on Robut 33-1 (moisture stress imposed from emergence to peg initiation) increased the seed quality in terms of oil and protein content and also reported that when moisture stress was imposed from flowering to the end of pod set resulted in decreased oil but improved protein content. As with groundnut, in soybean with irrigation there was increase in oil content (Vasiliu *et al.*, 1980).

Shivakumar and Sharma (1986) imposed drought stress or soil moisture deficit at all the growth phases of groundnut during three growing seasons and observed that stress from emergence to pegging gave increased yield over control in all the three years While, stress in other stages decreased the yield and oil content of kernels significantly.

Oil content in kernels was more in irrigated crop than in rainfed crop in *kharif* season (Padma and Subbarao, 1992). (Andani Gowda and Hegade, 1986) reported that there were no significant differences in oil content under normal and drought conditions (30-DAS - 45 DAS). Similar observations were reported in sunflower (Razi and Assad, 1999).

Varman and Raveendran (1996) observed high estimates of heritability coupled with low genetic advance for all the traits except oil content and shelling per

cent. Rudraswamy *et al.* (1999) observed high heritability for oil yield per plant in a study involving parental, F₁, F₂ and F₃ population of six crosses.

Prakash *et al.* (2000) reported low variability and high heritability, indicated the least influence of environment on oil content. However, Venkataravana *et al.* (2001) observed high coefficient of variability at phenotypic and genotypic level and high heritability with high genetic advance for oil percentage indicating the presence of additive gene action.

Gopinath *et al.* (2008) reported that oil yield per plant showed moderate heritability estimates, indicating substantial influence of environment on these characters.

Dutta and Mondal (2006) reported that water stress due to withholding of irrigation at different stages of crop growth affected the oil content of groundnut.

Bodre and Dhonde (2011) reported that highest oil content was recorded in treatment of white polythene mulch with stress at pod development stage (47.79%) and was significantly superior over rest of the treatment.

Darlene *et al.* (2015) conducted that the interaction between groundnut genotypes and water restriction levels promote a decrease in plant growth, physiological factors, and biochemical production of oil, possibly due to a decrease in the photosynthetic metabolism, whereas the plants exposed to water stress conditions modulated all ecophysiological responses in favor of a better performance in the harsh environment.

2.4.3 Protein content

Proteins, as important organic nitrogenous constituents of plants, would be expected to play a role in the compensatory mechanisms of plant species during stress conditions. Environmental stress could evoke compensatory metabolic changes through modification and modulation of the quantity and quality of proteins.

Madhusudhan *et al.*, (2002) reported that the drought tolerant genotypes of groundnut had comparatively higher protein content than the drought sensitive groundnut genotypes. Protein synthesis is closely related to production of new tissues, which is the principal sink for nitrogen compounds and it is declined during stress. Under water stress, decreased amount of protein was observed in groundnut (Ali-Ahamad and Basha, 1998 and, Sulochana and Savithamma, 2002).

Water stress caused a marked change in protein synthesizing apparatus of plant. A sharp decline in the rate of protein synthesis was reported in two maize lines under increasing water stress (Botha and Botha, 1979).

Dwivedi *et al.* (1996) investigated that end-of-season drought significantly reduced total oil content, linoleic fatty acid content and significantly increased total protein and stearic and oleic fatty acid content.

2.5 Genetic variability, heritability and genetic advance

The estimation of nature and magnitude of genetic variability is a prerequisite for any crop improvement programme. The variability observed in any population might be due to the genetic (G) and environmental (E) factors and also owing to the interaction (G × E) between these factors. Johnson *et al.* (1955) recognized that the variation in a segregating population is due to heritable and non-heritable factors. The heritable portion of variance was now known as genetic variance. Therefore, estimation of genotypic variance, heritability and genetic advance in any crop for any quantitative trait are essential part of plant breeding programme to develop promising cultivars.

Alam *et al.* (1985) studied eighteen genotypes of groundnut for estimation of genetic variability and genetic parameters. Maximum significant variations were observed among the varieties for all the characters studied. The variety DG-2 performed best and gave highest pod yield (3.16 t ha⁻¹) and took maximum time for maturity (207.00 days). ICG-1908 gave lowest pod yield (0.28 t ha⁻¹) but it was dwarf (8.13 cm) and early in maturity (180 days). Highest genetic coefficient of variation was observed in pod yield per hectare followed by number of primary branches per plant, number of pods per plant and 100 kernels weight. High heritability values were observed for days to maturity (94.76 %) and 100 kernels weight (90.00 %) while high values of genetic gain were obtained in all the characters studied except days to maturity and shelling out turn percentage.

Parameshwarappa *et al.* (2005) assessed genetic variability in 48 diverse large seeded groundnut genotypes. High PCV and GCV were observed for number of primary branches, pod yield per plant, kernel yield and plant height. Considerable variability has also been noticed for number of pods, 100 kernel weight, seed size and protein content. However, the variability observed for oil content and sound mature kernels was low. High heritability coupled with genetic advance was noticed in respect of kernel yield, sound mature kernels and test weight indicating that additive genes govern these characters. The extent of genetic advance was quite low for kernel size, protein content and oil content indicating that these traits are influenced by environment.

Giri *et al.* (2009) made an attempt to study genetic variability in 20 genotypes of groundnut including four checks viz., JL-24, TAG-24, LGN-1 and GPBD-4 under replicated randomized block design with three replications. They recorded high estimate of heritability, PCV, GCV and genetic advance as per cent of mean for late

leaf spot disease severity, reducing sugars, pod yield per plant and kernel yield per plant.

Zaman *et al.* (2011) conducted a study in thirty four groundnut genotypes. The maximum genetic coefficient of variation was observed for kernel yield per hectare followed by 100 kernel weight, branches per plant, mature nuts per plant, immature nuts per plant, plant height and yield per plant. The maximum heritability was observed in kernel yield per pant, 100 kernel weight, kernel yield per hectare, immature nuts per plant, mature nuts per plant, 100 nut weight and branches per plant while high values of genetic advance were obtained for all the characters except days to 50 per cent flowering and days to maturity.

Nandini *et al.* (2011) made an effort to study the genetic variability in 196 F₈ recombinant inbred lines (RILs) of NRCG12568 × NRCG12326 groundnut. Maximum GCV recorded for pod yield per plant followed by number of pods per plant, kernel yield per plant, specific leaf area, number of branches per plant, sound mature kernel percentage, shelling out turn percentage, plant height and days to 50 per cent flowering. A moderate to high level of heritability and genetic advance was observed for kernel yield per plant, pod yield per plant, pods per plant, sound mature kernel percentage, number of branches per plant, SLA and plant height. Low heritability and moderate genetic advance as per cent of mean was observed for SPAD Chlorophyll meter reading (SCMR).

John *et al.* (2011) evaluated 28 F₂ populations for genetic parameters of morphological, physiological, yield and yield attributes. High GCV was observed for number of secondary branches per plant (54.58 %). Moderate GCV was observed for specific leaf weight (21.42 %) and dry haulms yield per plant (22.45 %). High PCV and high GCV was recorded for number of secondary branches per plant, whereas moderate PCV and moderate GCV was observed for dry haulms yield per plant. High heritability values were observed for number of secondary branches per plant, plant height, and days to 50 per cent flowering whereas moderate heritability was exhibited for specific leaf area, number of primary branches per plant, leaf area index, specific leaf weight, water use efficiency, harvest index, oil per cent and sound mature kernel per cent. High GAM was observed for leaf area index, number of well-filled, mature pods per plant, dry haulms yield per plant, number of secondary branches per plant and harvest index and moderate GAM was observed for plant height, specific leaf area, days to 50 per cent flowering and number of primary branches per plant.

Jogloy *et al.* (2011) made an effort to evaluate two hundred lines of 10 crosses of groundnut in a randomized complete block design with two replications. They observed variation among crosses for maturity, harvest index, 100 seed weight and pod yield. High heritability estimates were found for harvest index and maturity, but heritability estimates for 100 seed weight and pod yield were low to moderate. They

suggested that, selection for early maturity, high pod yield, large seeds, and high harvest index in this groundnut population would be successful.

Narasimhulu *et al.* (2012) conducted a genetic variability study in eighteen selected groundnut genotypes on nine characters. The PCV was higher than the GCV for all the characters. The lowest values were shown by shelling out turn percentage and sound mature kernel per cent while the highest values were shown by kernel yield per plant, pod yield per plant, three diseases and test weight. Maximum heritability along with high GAM was observed for kernel yield per plant, pod yield per plant, shelling out turn percentage, three diseases and test weight.

Padmaja *et al.* (2013) made an attempt to study the genetic parameters of BC₁F₂ population of four crosses of groundnut. Higher PCV, GCV, broad sense heritability and genetic advance as per cent of mean were observed for mature pods per plant, total pods per plant, immature pods per plant, immature seeds per plant, mature seeds per plant, LLS disease score at 75 DAS, pod yield per plant and haulm weight per plant. However, the direct crosses recorded high heritability along with high genetic advance as per cent of mean for LLS disease score at 90 DAS.

Patil *et al.* (2014) conducted a study on 58 Spanish bunch groundnut genotypes for 16 plant characters. Maximum broad sense heritability was recorded for plant height, days to 50 per cent flowering and 100 kernels weight. The highest genetic advance was found for 100 kernels weight, seed dormancy and plant height. Moderate to high heritability coupled with moderate to high genetic advance was noticed for days to plant height, 50 per cent flowering, 100 pods weight, 100 kernels weight, harvest index and shelling out turn per cent.

Satish (2014) carried out a genetic variability study in 16 genotypes on six characters. Analysis of variance shows highly significant variations among the genotypes for all the characters studied. The maximum genetic coefficient of variation was observed for days to 50 per cent flowering, plant height, number of pods per plant, number of branches per plant, 100 seed weight and pod yield. The highest heritability was observed in 100 seed weight (98.00 %) followed by days to 50 per cent flowering (79.00 %), pod yield (96.00 %), number of pods per plant (94.00 %), number of branches per plant (89.00 %) and plant height (88.00 %) and while high values of genetic advance were obtained in all the characters except days to 50 per cent flowering and plant height.

Ashutosh and Prashant (2014) evaluated thirty groundnut genotypes for yield and quality characters. The PCV was higher than GCV for all the traits studied. The extent of PCV and GCV was moderate to high for pod yield, primary branches per plant at 40 DAS, oil yield, oleic acid and kernel yield. Heritability was higher in most of the characters like plant height, kernel yield, hundred kernel weight, pod yield

(q ha⁻¹), sound mature kernel, oil content, oil yield, oleic acid and shelling out turn percentage. High heritability coupled with high genetic advance was observed for oil yield.

Mukesh *et al.* (2014) assessed genetic variability in fifteen groundnut genotypes on 13 quantitative parameters under randomized block design with three replications. High to moderate PCV and GCV were observed for pod yield per plant, pod yield per hectare, kernel yield per hectare and plant height (cm). Higher values for heritability (broad sense) were observed for seed index, days to 50 per cent flowering followed by matured kernel and plant height. Exhibited high values of genetic advance for seed yield per plant, pod yield per plant followed by seed index and field emergence. Depicted high values for genetic advance as mean per cent pod yield, kernel yield followed by pod yield per plant and seed yield per plant. Based on per se performance, genotypes ICG 2772, ICG 3027 and ICG 2777 were identified as best for pod yield per plant.

Satyanarayan *et al.* (2014) assessed genetic variability in fourteen groundnut genotypes on 14 quantitative parameters under randomized block design with three replications. Analysis of variance revealed highly significant differences among the genotypes for all the characters studied. High to moderate estimates of GCV and PCV were exhibited by number of pods per plant, pod yield and kernel yield. The exhibited high values for heritability, number of pods per plant and seed yield per plant, followed by pod yield per plant and kernel yield (q ha⁻¹). High values for genetic advance were observed for field emergence percentage, pod yield per plant followed by plant height and seed yield per plant. Depicted high values for genetic advance as mean per cent kernel yield, plant height followed by pod yield per plant and seed yield per plant. Based on per se performance genotypes, ICG 8567, ICG 7181 and ICG 8490 were found to be best for pod yield per plant.

John and Raghava (2014) evaluated 28 F₂ crosses for genetic parameters for water use efficiency traits. Studies revealed that, moderate PCV and moderate GCV were observed for dry haulms yield per plant. High heritability values were recorded for days to 50 per cent flowering (85.46 %). High genetic advance as per cent of mean was observed for dry haulms yield per plant, leaf area index, and harvest index. High heritability and moderate genetic advance as per cent of mean was recorded for days to 50 per cent flowering. Moderate heritability and high genetic advance as per cent of mean was observed for dry haulms yield per plant, harvest index and leaf area index, whereas moderate heritability and moderate genetic advance as per cent of mean was recorded for specific leaf area.

Krishna *et al.* (2014) evaluated fifteen groundnut genotypes on 14 qualitative parameters. The components of variance revealed that the PCV were higher than GCV for all parameters. The analysis of variance revealed the prevalence of

significant differences among the genotypes from the characters studied. The Moderate GCV was observed for days to 50 per cent flowering, seed yield per plant, kernel yield, and moderate PCV for kernel yield, field emergence, seed yield per plant, number of primary branches per plant, pod yield per plant, days to 50 per cent flowering. Plant height, days to 50 per cent flowering, pod yield per plant, seed index, shelling out turn percentage, pod yield per hectare, kernel yield and seed yield per plant exhibited high values for heritability (broad sense). High genetic advance as per cent of mean was recorded for kernel yield.

Hiralal *et al.* (2015) carried out genetic variability study in 50 genotypes of groundnut with K-6 as a check in randomized complete block design. The analysis of variance was significant for all characters such as days to 50 per cent flowering, plant height (cm), number of branches per plant, days to maturity, number of pods per plant, number of kernels per pod, seed index (100 seed weight), pod yield per plant, sound matured kernel and shelling out turn percentage. They identified genotypes *viz.*, ICG-10185 and ICG-10092 were found to be best for pod yield per plant. They reported high heritability for seed index (94.00 %), plant height (99.00 %) and pod yield per plant (83.00 %). They observed a high value of genetic advance for plant height (21.92), while moderate value of genetic advance for seed index (18.07) and shelling out turn percentage (12.67).

Padmaja *et al.* (2015) made an attempt to study variability in F₂ population of JL 24 × ICG 11337 and JL 24 × ICG 13919 groundnut. They found that among these F₂ populations of both the crosses showed high variability in the form of PCV, GCV heritability and GAM for LLS disease score at 75 DAS, mature pods per plant, total pods per plant, mature seeds per plant, haulm weight per plant, and pod yield per plant. High heritability coupled with moderate GAM for DS-90 in both the crosses. The cross JL 24 × ICG 11337 recorded high heritability and genetic advance as per cent of mean for DS-102. The result indicates that gains through selection is possible in this cross this may be due to the resistant parent, ICG 11337 may contribute gains through selection for LLS disease score at 102 DAS.

Sanjeevakumar *et al.* (2015) evaluated the genetic variability parameters in 49 groundnut genotypes. The highest genetic coefficient of variation was observed for mature pods, immature pods, secondary branches per plant, kernel weight per plant, pod bearing nodes and pod yield. The maximum heritability was observed for days to 50 per cent flowering, matured pods per plant, 100 kernel weight (98.00 %), kernel weight per plant (98.00 %), pod bearing nodes (98.00 %), plant height (96.00 %), immature pods per plant (97.00 %), secondary branches (96.00 %) and oil content (96.00 %).

2.6 Correlation and Path Coefficient analysis

Jinesh and Suzit, (2015) analyzed 20 Virginia cultivars, under normal and water deficit conditions during pod development stage. They concluded that pod yield was observed to be positively associated with harvest index ($r = 0.50^{**}$). Harvest index was also associated leaf phenol ($r = 0.47^*$) under water deficit conditions.

John and Reddy *et al.* (2015) reported that primary yield components of groundnut *viz.*, pod size, sound mature kernels, shelling percentage, 100 kernel weight, kernel yield and number of mature pods per plant showed positive correlation with each other and with pod yield.

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

Naazar *et al.* (2001) also reported that pod yield was positively and significantly correlated with seed yield and oil content of groundnut. Similarly, Venkataravana *et al.* (2000) revealed that pod yield had significant positive association with number of mature pods, shelling per cent, 100-kernel weight and kernel oil yield. Similarly, it was also observed that number of mature pods, shelling per cent and kernel yield were significantly and positively associated *inter-se* as well as with pod yield of groundnut.

Nagada and Joshi (2004) in their path coefficient analysis studies reported highest positive direct effect of HI on pod yield per plant followed by haulms yield. Among direct effects, the influence of 100-kernel weight through HI was positive and strong followed by indirect effect of shelling percentage through haulms yield.

Painawadee *et al.* (2009) evaluated one hundred and twenty eight entries were subjected to water stress during 28 to 70 days after sowing to estimate the heritability of drought resistance traits, yield and yield related components, and relationship among these traits and reported that correlation coefficients among root characters *viz.*, Root dry weight (RDW), Root Length (RL), Root surface (RS), Root volume (RV) were inter-related positively, whereas negative correlation coefficients observed among physiological characters *viz.*, Specific leaf area (SLA), SPAD Chlorophyll Meter reading (SCMR). Root characters were closely related to biomass production but they were not related to yield and yield components except for pod number per plant.

Patra *et al.* (1981) while studying correlations in advanced generations of groundnut reported significant positive association of pod yield with HI. Further, negative association between shelling per cent and HI was observed indicating that high shelling per cent was linked with low HI and pod yield.

Studies of Shivakumar and Sharma (1986) indicated that positive significant correlation existed between yield and shelling percentage. Alam *et al.* (1985) found that pod yield per plant had positive association with number of pods per plant, days to maturity and plant height. They also revealed that shelling percentage was negatively associated with 100-kernal weight.

Wright and Nageshwara Rao (1994) studied WUE versus partitioning ratio for seven groundnut cultivars grown under well watered and drought conditions and reported that the WUE and partitioning of dry matter to the pods were negatively correlated. Ramana Rao (1994) reported that significant negative correlation between HI and WUE in groundnut.

Bhattacharya *et al.*, (1995) reported that under non-irrigated condition, seed yield exhibited significant correlation with plant height (0.702), but under irrigation it is 0.429. Under soil moisture stress condition, seed yield was dependent mainly on biological yield followed by plant height and harvest index, while under non-stress condition, it was biological yield followed by seeds per plant, node number per plant and plant height. Since plant height was reduced and flowering time enhanced under stress condition extent of pod bearing nodes as well as number of pods/plant increased.

Vasanthi *et al.* (1998) in a study involving 35 groundnut genotypes, observed a strong positive correlation of pod yield with 100-kernel weight but weak negative association with shelling per cent.

Venkataravana *et al.* (2000) noticed pod yield had significant positive correlation with plant height, number of branches per plant, number of matured pods per plant, shelling per cent, 100-kernel weight and kernel yield per plant at genotypic and phenotypic level.

Ntare *et al.* (2001) reported a positive correlation between the partition and yield under water deficit and high temperature conditions and suggested partitioning as a screening tool for development of heat-tolerant genotypes, especially in the Sahelian environment.

De Costa and Nayakarathne (2001) observed that under moisture deficit, groundnut yields were positively correlated with pod number per plant, seed weight and the number of primary roots per plant.

Reddy *et al.* (2003) also reported correlation between SCMR and total chlorophyll content and SCMR and seed yield were positive in groundnut genotypes.

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

Suneetha *et al.* (2005) reported that HI had higher positive direct effect on pod yield per plant followed by number of mature pod per plant suggesting prime importance to be given in selection for those traits for improving pod yield.

Songsri *et al.* (2008) estimated the heritability (h^2) of drought resistance traits and the genotypic (r_G) and phenotypic (r_P) correlations between drought resistance traits and agronomic traits. They suggested that, SPAD chlorophyll meter reading is potentially useful as a selection trait for drought resistance because of high h^2 and positive correlation with pod yield and agronomic traits.

Songsri *et al.* (2008a) expressed that harvest index (HI), specific leaf area (SLA) and SPAD chlorophyll meter reading (SCMR) had high heritability and positive genetic correlation with pod yield under long duration drought and they suggested that SCMR is useful as a selection trait for drought resistance.

Songsri *et al.* (2008b) reported significant correlation coefficient for number of mature pods per plant and pod yield at mild (0.63 ; $p \leq 0.01$) and sever (0.87 ; $p \leq 0.01$) drought and correlation coefficients between mature pods number and DTI were also significant.

Giri *et al.* (2009) reported positive significant associations between pod yield with days to maturity, days 50 per cent flowering, oil content, kernel yield and test weight whereas negative significant associations with reducing sugar and late leaf spot disease severity. The path analysis revealed a high positive direct effect of kernel yield on pod yield as well as indirect effect of on content, sound mature kernel, days to maturity, days to 50 per cent flowering, nonreducing sugar through kernel yield and test weight. Hence, it would be rewarding to go with selection of these characters for rapid improvement in pod yield.

Vaithiyalingan *et al.* (2010) studied correlation and path coefficients for nine traits involving 40 hybrids and 14 parents in groundnut. Pod yield showed significant positive association with kernels weight, pods per plant, harvest index and dry matter production. The path analysis revealed maximum direct effect of pods per plant followed by dry matter production and kernels weight on pod yield.

John *et al.* (2011) worked out the character association and path analysis in F_2 population of groundnut and found that SCMR had significant positive association with photosynthetic rate, pod yield per plant, dry haulm yield per plant and the harvest index had significant negative association with specific leaf area and transpiration rate. The high positive direct effect contribution to pod yield per plant was from days to 50 per cent flowering. The direct effects of stomatal conductance, days to maturity, dry haulm yield per plant and specific leaf area were appeared to be positive with yield. The high direct effect of pods per plant was found to have a positive correlation with pod yield.

Babariya and Dobariya (2012) conducted a study on correlation and path coefficients in 100 genotypes of spanish bunch groundnut and found that the pod yield per plant was significantly and positively correlated with plant height, days to maturity, number of mature pods per plant, number of pods per plant, kernel yield per plant, biological yield per plant, harvest index and 100 kernel weight. Among these, harvest index and biological yield per plant showed significant high and positive direct effects on pod yield per plant. Whereas, number of pods per plant, kernel yield per plant and days to maturity exhibited moderate and positive direct effects on pod yield per plant.

Hamidou *et al.* (2012) showed a significant genotype and genotype by-year (G x Y) interaction effects for pod, haulm and harvest index at each of the two locations. The magnitude of the G x Y effect was higher than the magnitude of the G effect for pod and haulm yield. The difference of genotypes performance under water stress compared to well water conditions suggests that intermittent drought tolerance is adaptive. These results were in agreement with previous findings on groundnut (Girdthai *et al.*, 2010, Mothilal *et al.*, 2010, Hariprasanna *et al.*, 2008, and Ntare and Williams, 2001).

Nandini and Savithramma (2012) reported that pod yield per plant was positively correlated with kernel yield per plant, sound mature kernel percentage and pods per plant whereas, pod yield per plant was negatively correlated with days to shelling out turn percentage and days to 50 per cent flowering. However, kernel yield per plant recorded maximum direct effect on pod yield per plant than other characters. Sound mature kernel percentage, SLA and pods per plant recorded highest indirect effect on pod yield per plant through kernel yield per plant.

Ravi and Sekhar (2012) conducted a study on correlation and path coefficients in 50 genotypes of groundnut for pod yield and its component characters. They found that the pod yield exhibited significant positive association with total mature pods per plant, pods per plant, kernel yield per plant, harvest index, 100 seed weight, plant height, shoot weight and root weight. Result revealed that, kernel yield per plant and harvest index had high direct effects of on pod yield.

Seyyed *et al.* (2012) conducted a study on correlation and path coefficients in 23 groundnut genotypes for oil yield and its components under drought stress and irrigated conditions. The correlation coefficients revealed that in both conditions, plant height, 100 seed weight, seed yield and total number of kernels per plant had a high positive association with oil yield. Path analysis showed that, seed yield and total number of kernels per plant in irrigated condition and 100 seed weight, biomass and seed yield in drought stress condition had greatest positive direct effect on seed yield. High direct effects were contributed by 100 seed weight in drought condition and total

number of kernels per plant in non-drought condition although, 100 seed weight was positively associated with oil yield.

Thakur *et al.* (2013a) conducted a study on correlation and path coefficients in twenty five groundnut genotypes for pod yield and yield component traits in groundnut. It was observed that, the pod yield per hectare had highly significant and positive association with per cent sound matured kernel (SMK), pod width, pod length, kernel length and days to maturity, but had a highly significant and negative association with days to flowering, shoots length, pod per plant, specific leaf area and shelling out turn per cent. Path analysis shows that that root length, pod width, pod length, kernel length and days to maturity had a high positive direct effect on pod yield per hectare. While, shelling out turn per cent, 100 kernels weight, shoot length and days to flowering, had direct negative correlation with pod yield per hectare. Hence, root length, pod length, pod width, kernel length and days to maturity could be used in selection for yield.

Rao *et al.* (2014) conducted a study on correlation and path coefficients in 50 groundnut genotypes and found that pod yield was significant and positively correlated with number of pods per plant, kernel yield, dry haulm yield and hundred kernel weight. Path coefficient analysis showed that, hundred kernel weight and number of pods per plant were important traits for the improvement of yield.

Jayalakshmi and Nirmala (2015) carried out a study on character association among physiological and drought tolerant attributes in 30 groundnut genotypes and found that the characters pod yield per plant, shelling out turn percentage, harvest index, number of mature pods per plant, plant height, number of sound mature kernels, specific leaf area, relative growth rate at 75 DAS to harvest and crop growth rate at 75 DAS to harvest were significantly and positively inter related among themselves and also with the kernel yield per plant. Pod yield per plant exerted high positive direct effect on kernel yield per plant followed by shelling out turn percentage. Number of mature pods per plant, plant height, number of sound mature kernels, CGR at 75 DAS to harvest and harvest index exerted their indirect effect.

John and Reddy (2015) found that pod yield per plant had significant positive association with days to maturity, days to 50 per cent flowering, number of well-filled pods per plant, mature pods per plant, sound mature kernel per cent, shelling out turn per cent, kernel yield per plant, 100 kernel weight and protein per cent. The kernel yield per plant showed a significant and positive association with number of mature pods per plant, number of well filled pods per plant, number of secondary branches per plant, shelling per cent, protein per cent and 100 kernel weight. The path analysis indicated that, kernel yield per plant, protein per cent, days to maturity, number of well-filled pods per plant, number of mature pods per plant, number of primary

branches per plant and oil per cent had a high direct effect and pods per plant was the major factor that determines pod yield.

Material and Methods

III MATERIAL AND METHODS

The present inquisition or research entitled with “Genetic investigation on end-of season drought stress in advanced breeding lines of Groundnut (*Arachis hypogaea* L.)” with four different specific objectives, focused on morphological, physiological and biochemical responses of forty groundnut genotypes under both managed drought (stress) and normal moisture (non stress) conditions to identify the drought tolerant genotypes that withstand end-of-season drought and to find the correlation between yield and drought parameters.

The detailed information about the plan of work, different research materials used and different biochemical, physiological and statistical procedures adapted during the course of investigation to achieve the stated objectives are clearly presented in this chapter.

3.1 Plant material

3.2 Crop management and experimental design

3.3 Observations and measurements

3.3.1. Physiological, biochemical and root related traits under drought stress and irrigated conditions

3.3.2 Yield and yield component traits under drought stress and irrigated conditions

3.3.3 Drought Tolerance Indices

3.4 Statistical procedures

3.5 Correlations between drought, biochemical and yield parameters.

3.5.1 Correlation coefficients

3.5.2 Path coefficient analysis

3.1 Plant material

Forty groundnut genotypes including advanced breeding lines and local checks were obtained from International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad, National Bureau of Plant Genetic Resources (NBPGR), New Delhi and other institutes were included as genetic materials in this study. The details of the genotypes are presented in the table 1.

Table 1: List of genotypes employed in the present experimental study

Sl. No.	Genotype	Source of collection	Features (Branching type)
1	ICGV 15114	ICRISAT, Patancheru	Erect type
2	ICGV 15119	ICRISAT, Patancheru	Erect type
3	ICGV 15120	ICRISAT, Patancheru	Erect type
4	ICGV 15122	ICRISAT, Patancheru	Erect type
5	ICGV 15123	ICRISAT, Patancheru	Erect type
6	ICGV 15124	ICRISAT, Patancheru	Erect type
7	ICGV 15138	ICRISAT, Patancheru	Erect type
8	ICGV 15141	ICRISAT, Patancheru	Erect type
9	ICGV 15143	ICRISAT, Patancheru	Erect type
10	ICGV 15145	ICRISAT, Patancheru	Erect type
11	ICGV 15146	ICRISAT, Patancheru	Erect type
12	ICGV 15148	ICRISAT, Patancheru	Erect type
13	ICGV 15149	ICRISAT, Patancheru	Erect type
14	ICGV 15151	ICRISAT, Patancheru	Erect type
15	ICGV 15152	ICRISAT, Patancheru	Erect type
16	ICGV 15153	ICRISAT, Patancheru	Erect type
17	ICGV 15154	ICRISAT, Patancheru	Erect type
18	ICGV 15158	ICRISAT, Patancheru	Erect type
19	ICGV 15159	ICRISAT, Patancheru	Erect type
20	ICGV 15161	ICRISAT, Patancheru	Erect type

21	SB-1	NBPGR, New Delhi	Erect type
22	SB-14	NBPGR, New Delhi	Erect type
23	SB-15	NBPGR, New Delhi	Erect type
24	SB-17	NBPGR, New Delhi	Erect type
25	VB	NBPGR, New Delhi	Erect type
26	VB-11	NBPGR, New Delhi	Erect type
27	VB-14	NBPGR, New Delhi	Spreading type
28	DH-86	UAS, Dharwad	Erect type
29	DH-101	UAS, Dharwad	Erect type
30	DH-234	UAS, Dharwad	Erect type
31	K-9	UAS, Bangalore	Erect type
32	K-6	UAS, Bangalore	Erect type
33	GPBD-4	UAS, Dharwad	Erect type
34	GPBD-5	UAS, Dharwad	Erect type
35	KCG-6	UAS, Bangalore	Erect type
36	KCG-2	UAS, Bangalore	Erect type
37	TMV-2	UAS, Dharwad	Erect type
38	LOCAL-1	Local	Erect type
39	R-2001-3	UAS, Raichur	Erect type
40	G2-52	UAS, Dharwad	Erect type

ICRISAT – International Crops Research Institute for Semi-Arid Tropics

NBPGR – National Bureau of Plant Genetic Resources

UAS - University of Agricultural Sciences

3.2 Crop management and experimental design

The research material employed in the present study consisted of forty genotypes which were screened under drought condition (moisture stress) and optimum moisture (non-stress) conditions at College of Horticulture, Hiriya located in the Central Dry Zone (Zone-IV) of Karnataka at 13° 57' North latitude, 76° 40' East longitudes with an altitude of 630 meters above the mean sea level.

The experiment was laid out in a Randomized Complete Block Design (RCBD) in two replications. The experimental plot size per genotype was 0.6m length X 3m width which constitutes 1.87m². On the other hand plot to plot and replication to replication distance was 0.2 and 0.5 m respectively. Test materials were sown by hands in fields on 1st of October 2016. Seeds were sown in furrow at the depth of 4 cm approximately. General view of the field experiment is shown in plate 1 and instruments used in the present study are shown in plate 2.

3.2.1 Seed treatment

A pinch (25-30 g) of trichoderma is dissolved in one litre of 10% jaggery solution and well shaken. Then seeds were treated with the solution and allowed to shade dry for half an hour. Later the seeds were treated with Chloropyrifos just before the sowing.

3.2.2 Seed sowing

Each of the 40 genotypes was sown in 3 meter rows with two rows per genotype per replication with spacing of 30 cm between rows and 10 cm between plants within a row. Care was taken to ensure uniform depth of sowing. Sound, mature and good quality kernels were only used for sowing. All the plots were irrigated as per package of practices (once in 7-8 days) up to 90 days. For moisture stressed plots, moisture stress was imposed for 20 days starting from 90 days after sowing by withdrawing irrigation. However, regular irrigation was provided for the non-moisture stressed plots.

3.3. Observations and measurements

Observations on different morphological, physiological/drought related traits were taken at different stages of crop growth in both moisture stressed and normal moisture plots.

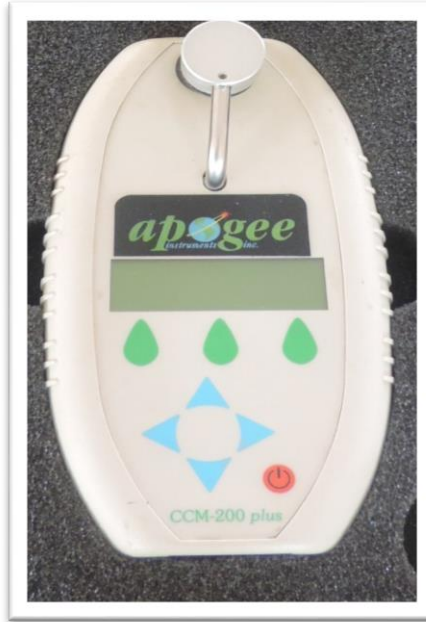
3.3.1. Physiological, biochemical and root related traits under drought stress and irrigated conditions

3.3.1.1. Per cent of wilted plants (after drought stress) (%)

After 20 days of water stress, the number of plants showing wilting symptoms was recorded and was expressed as percentage using the following formula:



Plate 1: General view of the field experiment



SPAD Meter



Spectrophotometer

Plate 2: Instruments used in the present investigation

$$\text{Percentage of wilted plants} = \frac{\text{Number of plants wilted}}{\text{Total number of plants}} \times 100$$

3.3.1.2. Leaf chlorophyll content (SPAD readings)

The SPAD meter (Soil Plant Analytical Development) is a simple hand held and portable instrument which operates with DC power of three volts and provides information on the relative amount of leaf chlorophyll. The chlorophyll content of leaves was measured by using SPAD Chlorophyll Meter (KONICA MINOLTA, SPAD 502 PLUS, Version: 1.20.0000) which measures the light attenuation at 430 nm (The peak wave length absorption by chlorophyll a and chlorophyll b) and at 750 nm (near infrared) with no transmittance. The unit-less value measured by the chlorophyll meter is termed as SCMR (SPAD Chlorophyll Meter Reading) which indicates relative amount of leaf chlorophyll.

The fully expanded second leaf from the top of the main stem was used to record SCMR. Observations were recorded from 9.00 AM to 11.00 AM in the morning. Selected leaflet was clamped avoiding the mid rib region and inserted into the sensor head of SPAD meter and gentle stroke was given to record the SPAD reading. The chlorophyll content was recorded on each of the four leaflets of the tetrafoliate leaf. An average SCMR for each plot was derived from 5 single observations (four leaflets \times 2 leaflets per plant per plot). Chlorophyll content was analyzed for both moisture stressed and non-stressed plants in both replications of each genotype.

3.3.1.3 Relative water content (RWC) of leaf tissue (%)

The leaf relative water content was estimated by the method of Bars and Weatherly (1962). Leaf discs from the leaves were collected randomly in each genotype from each replication in both moisture stressed and non-stressed conditions and weighed accurately up to fourth decimal on an electrically operated single pan analytical balance (FW). The weighed leaf discs were allowed to float on distilled water in a petridish and allowed to absorb water for 3-4 hours. After four hours, the leaf discs were taken out and their surface blotted gently and weighed which was referred to as turgid weight (TW). After drying in an oven at 70 °C - 80 °C for 48 hours, the dry weight (DW) was recorded and the RWC was calculated using the following formula according to Dhopte and Manuel (2002). Leaf relative water content expressed as percentage.

$$\text{RWC} = \frac{\text{FW} - \text{DW}}{\text{TW} - \text{DW}} \times 100$$

Where,

FW -Fresh weight,

DW -Dry weight and

TW -Turgid weight of leaf samples

3.3.1.4 Membrane damage or Membrane Stability Index (%)

One gram of leaf sample was taken from top fully opened leaf in each of the two replications per genotype in both moisture stressed and non-stressed plants and kept in distilled water for 2 hours with constant stirring. The electrical conductivity (EC) of this solution was measured and designated as EC_a. Then, the same samples were kept in hot water-bath at 55 °C for 30 minutes and EC was measured and designated as EC_b. Finally, the same sample was kept in hot water-bath at 100 °C for 30 minutes and the EC values were recorded as EC_c. Membrane stability index (MSI) was calculated using the method described by Blum and Ebercon (1981) and it was calculated using the following formula and it was expressed as percentage.

$$\text{Membrane stability index} = \frac{\text{EC}_b - \text{EC}_a}{\text{EC}_c} \times 100$$

3.3.1.5 Phenolic content of leaves and seeds

The total phenolic contents of leaves and seeds of each treatment in each replication were determined according to the method described by Malik and Singh (1980). Phenolic content of both leaves and seeds was expressed in milligram per gram of tissue.

3.3.1.5.1 Principle

Phenols react with phosphomolybdic acid in Folin-Ciocalteu reagent to produce a blue-coloured complex in alkaline medium, which can be estimated spectrophotometrically at 650 nm.

3.3.1.5.2 Procedure (Malik and Singh, 1980)

1. 500 mg leaf sample (1000 mg for seed sample) was cut into small bits.
2. Transfer the leaf bits or seed sample to beakers and add 5 ml of 80 % ethanol.
3. Keep the test tube in hot water bath for 10 minutes and cool the contents.
4. Macerate the leaf sample or seed sample using pestle and mortar along with another 5 ml of 80 % ethanol and centrifuge the contents at 5000 rpm for 10 minutes.
5. Collect the supernatant and make up the volume to 25 ml with distilled water.
6. Take 1 ml of supernatant and add 2 ml of 20 % sodium carbonate and 1 ml of Folin-Ciocalteu reagent

7. Wait for 10 minutes for colour development and measure the OD at 660 nm in a spectrophotometer against reagent blank. Prepare the standard by using catechol of 20, 40, 60, 80 and 100 ppm.
8. Dissolve catechol by using little ethyl alcohol and make up volume by using distilled water.
9. Draw the standard graph. Plot the sample OD in the standard graph and find out the corresponding concentration (x).

3.3.1.5.2 Calculation

Weight of the sample = 500 mg (Leaf sample), 1000 mg (seed sample)

Volume of supernatant made up = 25 ml

Volume taken for estimation = 1 ml

Concentration from graph = 'x'

Total phenolic content was estimated by the following formula:

$$\text{Total Phenolics (mg)} = \frac{x \times 25 \times 1000}{1 \times 500} \text{ of leaf sample}$$

$$\text{Total Phenolics (mg)} = \frac{x \times 25 \times 1000}{1 \times 1000} \text{ of seed sample}$$

3.3.1.6 Oil content of kernels (%)

Oil content of the seed samples of each genotype in each replication was estimated by Nuclear Magnetic Resonance spectrometer (NMR) at Indian Institute of Oilseeds Research (IIOR), Hyderabad and oil content of seeds was expressed as percentage.

3.3.1.7 Protein content of leaves and seeds (%)

By using Bradford's Assay of protein estimation, the protein content of leaf as well as seeds of each genotype in each replication of both moisture stressed and normal moisture plots was estimated and expressed in percentage (Bradford, 1976).

3.3.1.7.1 Extraction and estimation of proteins

1.0 gram seed/leaf of each genotype in each replication was ground in pestle and mortar with 2.0 ml of phosphate buffer (pH 7.4) for complete extraction of protein. These were centrifuged at 3000 rpm for 20 minutes. The supernatant was used for protein analysis and the pellet was discarded.

3.3.1.7.2 Bradford assay

Take 0.5 ml of supernatant and adjust the volume to 0.5 ml with phosphate buffer and to this 2 ml of Bradford reagent was added and absorbance was recorded at 595 nm against reagent blank. A standard calibration curve was drawn by using Bovine Serum Albumin (BSA) as standard. From the standard curve, the concentrations of proteins in samples were obtained.

3.3.1.8 Root to shoot ratio

It is the ratio of length of the root to the length of the shoot. This was calculated by using the formula.

$$\text{Root to shoot ratio} = \frac{\text{Length of root (cm)}}{\text{Length of shoot (cm)}}$$

3.3.1.9 Root length (cm)

Root length was measured on five tagged seedlings of respective treatments in all replications using scale from base of the shoot to the tip of root and it was recorded in centimetres.

3.3.2 Yield and yield components under drought stress and irrigated conditions

3.3.2.1 Days to fifty per cent flowering

The number of days from sowing until the time when fifty per cent of the plants flowered in each genotype of each replication in both normal moisture and moisture stressed conditions was recorded.

3.3.2.2 Plant height at 30, 60 and 90 days after sowing and at harvest (cm)

Plant height was measured from the soil surface to the tip of the five randomly selected plants of each genotype from each replication in both moisture stressed and non-stressed plots with the help of scale at 30, 60 and 90 days after sowing and also at harvest. Finally average plant height was computed and expressed in centimetres.

3.3.2.3 Number of primary branches per plant at 60, 90 DAS and harvest

The number of primary branches arising from the main stem in each of the sampled plants were counted in both moisture stressed and non-stressed plots of all the genotypes at 60, 90 DAS and also at harvest. The mean number of primary branches for each genotype was computed.

3.3.2.4 Number of secondary branches per plant at 60, 90 DAS and harvest

The number of secondary branches arising from the main stem was counted in five randomly tagged plants from which number of primary branches were taken in both moisture stressed and non-stressed plots of all the genotypes at 60, 90 DAS and also at harvest and their average was computed for each genotype.

3.3.2.5 Number of days to maturity

The number of days from emergence to maturity of pod was recorded as days to maturity. Ninety days after sowing, one plant was harvested from each plot to determine the percentage of developed pods. The plots were harvested when at least 75 per cent of the developed pods were mature as determined by the blackening of the internal shell wall (Williams and Drexler, 1981).

3.3.2.6 Number of pods per plant

Total number of pods of five randomly selected plants from each genotype in moisture stressed and non-stressed plots was counted and their average was taken as the number of pods per plant.

3.3.2.7 Number of mature pods per plant

Total number of mature pods was counted from five randomly selected plants from each genotype in moisture stressed and non-stressed plots and their average was taken as the number of mature pods per plant.

3.3.2.8 Number of immature pods per plant

It was calculated by deducting the total number of matured pods from the total number of pods of five randomly selected plants from each genotype in moisture stressed and non-stressed plots.

3.3.2.9 Pod yield per plant (g)

Pod yield was determined from pods harvested from five randomly selected plants from each genotype in moisture stressed and non-stressed plots after air drying to constant weight for two weeks and their average was taken as the pod yield per plant which was expressed in grams.

3.3.2.10 Pod yield per hectare (kg/ha)

The weight of pods in each plot was recorded, and then transformed to pod yield per hectare and expressed in kilograms.

3.3.2.11 Shelling percentage (%)

Randomly selected 100 g pods from each genotype in moisture stressed and non-stressed plots was weighed and recorded. Then the same pods were shelled with hand and kernels were separated. The weight of kernel and shell was weighted. The shelling percentage was calculated by using the following formula:

$$\text{Shelling out turn (\%)} = \frac{\text{Weight of kernels (g)}}{\text{Weight of pods (g)}} \times 100$$

3.3.2.12 Kernel yield per plant (g)

Kernel yield was calculated by using the following formula and expressed in grams as given by Bell *et al.*, 1991.

$$\text{Kernel yield} = \text{pod yield (g)} \times \text{shelling percentage (\%)}$$

3.3.2.13 Number of kernels per plant

Total number of kernels of five randomly selected plants from each genotype in moisture stressed and non-stressed plots were counted and their average was taken as the number of kernels per plant.

3.3.2.14 Test weight (hundred kernel weight) (g)

Randomly selected 100 well sun dried kernels/seeds from each genotype in moisture stressed and non-stressed plots separately were weighed and data was recorded in grams.

3.3.2.15 Sound mature kernel percentage (%)

This observation was made on the randomly selected 100 g of kernels of which mature sound and healthy seeds were separated, counted and recorded as sound mature kernel percentage according to the formula:

$$\text{Sound mature kernel (\%)} = \frac{\text{Number of mature sound kernels}}{\text{Total number of kernels}} \times 100$$

The sound mature kernel percentage was expressed as percentage.

3.3.2.16 Harvest Index (HI)

Harvest index was calculated by using the following formula and which was expressed as percentage. (Girdthai *et al.*, 2010)

$$\text{Harvest index (HI)} = \frac{\text{Total pod weight (g)}}{\text{Total Biomass weight (g)}} \times 100$$

3.3.2.17 Fresh weight of seedling (g)

Fresh weight of the five seedlings was measured using a precision balance after harvest and average seedling weight was computed and expressed in milligrams.

3.3.2.18 Total seedling length (cm)

It is the summation of total length of shoot and total length of root measured in centimetres. It was calculated by using the following formula

$$\text{Seedling length (cm)} = \text{Total length of shoot (cm)} + \text{Total length of root (cm)}.$$

3.3.3 Drought tolerance indices

Several drought tolerance indices have been suggested on the basis of a mathematical relationship between yield under drought stress and non-stressed conditions.

The response of the genotypes to moisture stress was assessed by the following drought tolerance parameters for pod yield per plant.

3.3.3.1 Drought Susceptibility Index (DSI) for pod yield, plant height, kernel yield and root length

For the calculation of Drought Susceptibility Index (DSI), the formula of Fischer and Maurer (1978) was used as follows:

$$DSI = \frac{(1 - Y_d/Y_p)}{D}$$

Where,

Y_d = Grain yield of the genotype under moisture stress

Y_p = Grain yield of the genotype under non-stress

D = 1- (Mean pod yield of all genotypes under stress / Mean pod yield of all genotypes under non-stress)

3.3.3.2 Drought tolerance index (STI) for pod yield, plant height, kernel yield and root length

Using the formula according to the Fernandez (1992), the stress tolerance index was calculated.

$$STI = \frac{(Y_d \times Y_p)}{(\text{Mean pod yield of all genotypes under nonstress})^2} \times 100$$

Where,

Y_d = Grain yield of the genotype under moisture stress (g)

Y_p = Grain yield of the genotype under non-stress (g)

3.3.3.3 Drought tolerance efficiency (DTE) for pod yield

Drought Tolerance Efficiency (DTE) was estimated by the equation of Fischer and Wood (1981) as given below:

$$DTE (\%) = \frac{\text{Yield under stress } (Y_d)}{\text{Yield under nonstress } (Y_p)} \times 100$$

DTE was expressed in percentage.

The genotypes with high value of DTE, STI and value below 1 for DSI were considered as drought tolerant genotypes.

3.4 Statistical procedure

The statistical analysis of the data on the individual characters was carried out on the mean values of five randomly tagged plants and analyzed by using GEN STAT 14.1 software package at ICRISAT, Patancheru, Hyderabad. Different statistical methods employed for the analysis are as follows.

3.4.1 Analysis of Variance (ANOVA) for field screening for drought tolerance

The analysis of variance for each character was analyzed by adopting Randomized Complete Block Design (RCBD) as given below using the GEN STAT 14.1 software. The details and design of ANOVA is given below.

Source of Variance	Degrees of Freedom	Sum of Squares	Mean Sum of Squares	F-Calculated Value
Treatments	t-1	SST	MSST	F=MSST/MSSE
Replications	r-1	SSR	MSSR	
Error	(t-1)(r-1)	SSE	MSSE	
Total	tr-1	TSS		

Where,

t – Number of treatments (genotypes),

r – Number of replications,

The standard error was calculated as, $S.Em = \sqrt{MSSE/r}$

Critical difference, $CD = \sqrt{2 \times S.EM \times t(\alpha, Edf)}$

Where,

α – level of significance (5 and 1%),

Edf – Error degrees of freedom.

The calculated F value is compared with the table F value for respective degrees of freedom (treatment df, error df) at 5 or 1 per cent level of significance.

3.4.2 Mean, range, variance and other genetic parameters

The mean, range, variance and other genetic parameters for each of the character and for each genotype were calculated using the formulae as presented below.

3.4.3 Mean, Range and Variance

Arithmetic mean is defined as the sum of all observations divided by the total number of individuals added.

Means were obtained for each traits separately and also for each genotype.

The mean, range and variance values of each character were calculated for each genotype.

$$\text{Mean} = \frac{(\text{Sum of observations of all the plants})}{(\text{Number of plants})}$$

Range= the minimum and maximum values for each trait.

$$\text{Variance } (\sigma^2) = \frac{[\Sigma (X - \bar{X})^2]}{n}$$

Where,

X = Individual value

\bar{X} = Population mean

n = Number of observations

$$\text{Standard of deviation (SD)} = \sqrt{\text{Variance}}$$

$$\text{Coefficient of variability (\% C.V.)} = \left(\frac{\text{S.D.}}{\bar{X}} \right) \times 100$$

Where,

S.D. = Standard deviation

\bar{X} = Mean

3.4.4 Estimation of genetic parameters

In order to identify and ascertain the genetic variability among genotypes and to assess the extent of environmental effect on various characters, different genetic parameters were estimated by using formulae as given below.

3.4.4.1 Genotypic and phenotypic variance

These were calculated according to the formula given by Lush (1940) and, Chaudhary and Prasad (1968).

$$\text{Genotypic variance } (\sigma_g^2) = \frac{\text{MSS (treatment)} - \text{MSS (error)}}{\text{Number of replications}}$$

$$\text{Phenotypic variance } (\sigma_p^2) = \sigma_g^2 + \text{MSS (error)}$$

3.4.4.2 Phenotypic and Genotypic Coefficient of variation

The coefficient of variation both at phenotypic and genotypic levels for all the characters were computed by applying the formula as suggested by Burton and Devane (1953).

$$\text{Genotypic Coefficient of Variation (GCV)} = \left(\frac{\sigma_g}{\bar{X}} \right) \times 100$$

$$\text{Phenotypic Coefficient of Variation (PCV)} = \left(\frac{\sigma_p}{\bar{X}} \right) \times 100$$

Where,

\bar{X} = Grand mean of the character

σ_p = Phenotypic standard deviation

σ_g = Genotypic standard deviation

PCV and GCV were classified into low, moderate and high as suggested by Subramanian and Menon (1973).

0 – 10 %	:	Low
11 – 20 %	:	Moderate
21 % and above	:	High

3.4.4.3 Heritability (h^2) in broad sense

Heritability in broad sense for all the characters was computed by the formula suggested by Hanson *et al.*, (1956) and expressed as percentage.

$$\text{Heritability } (h^2_{bs}) = (\sigma_g^2 / \sigma_p^2) \times 100$$

Where,

h^2_{bs} = Heritability (broad sense)

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

Heritability was classified into low, moderate and high as suggested by Robinson *et al.*, (1949).

Where,

0 – 30 %	:	Low
31 – 60 %	:	Moderate
61 % and above	:	High

3.4.4.4 Genetic Advance (GA)

The predicted genetic advance was estimated according to the formula given by Johnson *et al.*, (1955).

$$GA = h^2bs \times K \times \sigma P$$

Where,

h^2bs = Heritability in broad sense

K = Selection differential, a constant (z/p) the value of which is 2.06 at 5% selection intensities.

σP = Phenotypic standard deviation

3.4.4.5 Genetic Advance as per cent Mean (GAM)

This was calculated using the formula given below.

$$GAM (\%) = (GA/\bar{X} \times 100)$$

Where,

GA = Genetic advance

\bar{X} = General mean

The genetic advance as per cent of mean was categorized into low, moderate and high as suggested by Johnson *et al.* (1955).

0 – 10 %	:	Low
10.1 – 20 %	:	Moderate
> 20.1 and above	:	High

3.4.5 Analysis of variance for Genotype \times Environment interaction in field experiment for drought tolerance screening

The analysis of variance for G \times E interaction of each character was analyzed by adopting Factorial Randomized Complete Block Design (F-RCBD) as outlined by Gomez and Gomez (1984) using the GEN STAT 14.1 software.

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	f-calculated
Replications	r-1	SSR	SSR	
Factor A	a-1	SSA	MSA	=MSA/MSE
Factor B	b-1	SSB	MSB	=MSB/MSE
A X B	(a-1)(b-1)	SSAB	MSAB	=MSAB/MSE
Error (residual)	(ab-1)(r-1)	SSE	MSE	
Total	rab-1	TSS		

Where,

r – Number of replications,

a – Factor A (environments)

b – Factor B (genotypes)

Edf – Error degrees of freedom.

The calculated F value is compared with the table F value for respective degrees of freedom (Factor A df, error df; Factor B df, error df and Factor AB df, error df) at 5 or 1 per cent level of significance.

3.5 Correlations between drought, biochemical and yield parameters.

The degree of association among the drought, biochemical and yield parameters was calculated by correlation coefficients.

3.5.1 Correlation coefficients

The correlation coefficients were calculated to determine the degree of association of different characters with yield and also among the different yield components.

Phenotypic correlation coefficients between all pairs of characters were determined by using variance and covariance components as suggested by Al-Jibouri *et al.*, (1958). The Correlation analysis was done by using the WINDOSTAT software.

$$r_{xy} = \text{cov}(xy) / \sqrt{V(x) \cdot V(y)}$$

Where,

r = Correlation coefficient

x,y = Variables

cov(x,y) = Covariance between x and y

V(x), v(y) = Variance of x and y variable

The calculated value of r was compared with 'r' table value with (n – 2) degrees of freedom at 5 and 1 per cent level of significance, where n refers to number of pairs of observation.

3.5.2 Path coefficient analysis

Path coefficient analysis was done using the correlation coefficients to ascertain the direct and indirect effects of the yield components on yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959).

Standard path coefficients or standardized partial regression coefficients were obtained by solving the following set of ‘p’ simultaneous equations through the use of ‘DOHITTLE TECHNIQUE’. Data was analysed using WINDOSTAT software.

$$P_{01} + P_{02} r_{12} + \dots + P_{0p} r_{1p} = r_{01}$$

$$P_{01} r_{21} + P_{02} r_{22} + \dots + P_{0p} r_{2p} = r_{02}$$

↓

$$P_{0p} r_{1p} + P_{0p} r_{2p} + \dots + P_{0p} = r_{0p}$$

Where,

P_{01}, P_{02}, P_{0p} are the direct path coefficients of variables 1, 2, 3..... p on the dependent variable 0.

$r_{12}, r_{13} \dots Pr_{1p} \dots rr_{(p-1)}$ are the possible correlation coefficients between various independent variables and $r_{01}, r_{02} \dots r_{0p}$ are the correlations between dependent and independent variables. The indirect effects of the i^{th} variable via j^{th} variable were obtained $P_{0j} \times r_{ij}$.

The contribution of the remaining unknown factors was measured as the residual factor and calculated as below:

$$P^2_{ox} = 1 - (P^2_{01} + 2P_{01}P_{02}r_{12} + 2P_{01}P_{03}r_{13} + \dots + P^2_{02} + 2P_{02}P_{03}r_{13} + \dots + P^2_{0p})$$

$$\text{Residual factor} = \sqrt{P^2_{ox}}$$

Experimental Results

IV EXPERIMENTAL RESULTS

In the present study, forty genotypes of groundnut including advanced breeding lines were evaluated for their tolerance to end-of season drought stress by studying the performance of genotypes with respect to physiological, biochemical, drought related characters and also yield, under moisture stress and normal moisture conditions. The results obtained on these aspects are described in detail and given in tables accordingly and depicted in graphs wherever necessary in this chapter under the following headings.

4.1. Assessment of the groundnut advanced breeding lines for physiological, biochemical and root attributes under drought stress and normal moisture conditions.

4.1.1 Analysis of variance

4.1.2 Estimates of genetic parameters *viz.*, phenotypic and genotypic coefficient of variation, heritability, genetic advance and predicted genetic advance as per cent of mean

4.2. Assessment of the groundnut genotypes lines for yield and yield components under drought stress and normal moisture conditions

4.2.1 Analysis of variance

4.2.2 Estimates of genetic parameters *viz.*, phenotypic and genotypic coefficient of variation, heritability, genetic advance and predicted genetic advance as per cent mean

4.2.3 Drought tolerance indices

4.3. Assessment of correlations between drought or physiological, biochemical and yield parameters.

4.3.1 Character association

4.3.2 Path coefficient analysis

4.1. Assessment of the groundnut advanced breeding lines for physiological, biochemical and root parameters under drought stress and normal moisture conditions

4.1.1 Analysis of variance

Analysis of variance indicated that, the mean sum of squares due to genotypes were significant at one per cent level of probability ($p < 0.01$) for drought/physiological traits, biochemical and root attributes and it has revealed considerable genetic variability amongst the material under study in both moisture stress and normal moisture condition. The mean sum of squares for

drought/physiological, biochemical and root attributes is presented in tables 2 and 3 for normal moisture condition and moisture stress, respectively.

The mean sum of squares for interaction (genotype x environment) of physiological, biochemical and root attributes is presented in the table 4. The effect of environments (moisture stress and normal moisture) was significant on all the traits except oil content. Further, the genotype x environment (G x E) interaction was highly significant for almost all the traits except for oil content. This clearly indicates that the performance of the genotypes differed significantly for most of the traits across environments (moisture stress and normal moisture condition).

4.1.2 Genetic parameters viz., mean, range, phenotypic and genotypic coefficient of variation, heritability and predicted genetic advance as per cent of mean

The results with regard to overall mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense (h^2) and expected genetic advance as per cent mean (GAM) were computed for physiological, biochemical and root traits in groundnut genotypes under both normal moisture and moisture stress situations has been presented in tables 5 and 6, respectively.

4.1.2.1 Relative water content (%)

The mean relative water content (RWC) under drought condition was 56.16 per cent as against 75.66 per cent under normal moisture. The PCV and GCV under drought were 36.19 and 36.17 per cent, respectively. However, the PCV and GCV respectively, were 4.95 and 4.78 per cent under normal moisture. The heritability for this trait was 99.89 per cent under moisture stress as against 93.36 per cent under normal moisture condition. However, the genetic advance over mean under drought situation (74.47 %) was higher than that (9.51 %) of normal moisture. The range for this trait under normal moisture and moisture stress condition was in the range of 66.44 to 86.24 per cent and 20.50 to 86.03 per cent, respectively.

The maximum relative water content in leaves under moisture stress were recorded in the following genotypes viz., SB-14 (86.03 %), ICGV 15141 (85.26 %), K-9 (84.53 %), ICGV 15154 (83.27 %) and KCG-6 (80.44 %).

4.1.2.2 Membrane stability index (%)

In moisture stressed condition, the mean value of membrane stability index was 30.93 per cent with a range of 7.61 to 55.19 per cent. The phenotypic and genotypic coefficients of variation were 35.26 and 35.20 per cent, respectively. The heritability for the trait was 99.91 per cent with a genetic advance over mean of 72.40 per cent.

Table 2: Analysis of variance for various physiological, biochemical and root attributes under normal moisture condition

Source of variance	d.f.	RWC (%)	MSI (%)	SCMR	Proteins in leaves (%)	Proteins in seeds (%)	Phenols in leaves (µg/g)	Phenols in seeds (µg/g)	Oil content (%)	Root to Shoot ratio	Root length (cm)
Replications	1	25.43	1.02	45.62	0.05	0.21	4.02	1360.11	19.55	0.00	57.16
Genotypes	39	27.08**	606.78**	28.84**	0.02**	11.44**	113702.79**	105756.16**	17.86**	0.01**	2.16**
Error	39	0.93	0.39	6.44	0.01	1.39	209.72	498.31	0.19	0.00	1.04
S.Em		0.68	0.44	1.79	0.05	0.83	10.24	15.78	0.31	0.01	0.72
C.V. (%)		1.27	1.97	6.02	3.84	4.82	3.92	3.47	0.94	4.40	8.32
C.D. 5%		1.95	1.26	5.13	0.15	2.39	29.29	45.15	0.88	0.04	2.06
C.D. 1%		2.61	1.69	6.87	0.20	3.19	39.22	60.45	1.17	0.06	2.76

Where,

* - Significant at 5 %

** - Significant at 1 %

d.f.- degrees of freedom

RWC - Relative water content (%)

MSI - Membrane stability index (%)

SCMR - SPAD Chlorophyll Meter Reading

Table 3: Analysis of variance for various physiological, biochemical and root attributes under moisture stress condition

Source of variance	d.f.	RWC (%)	MSI (%)	SCMR	PWP (%)	Proteins in leaves (%)	Proteins in seeds (%)	Phenols in leaves (µg/gm)	Phenols in seeds (µg/gm)	Oil content (%)	Root to shoot ratio	Root length (cm)
Replications	1	14.51	0.01	89.06	10.58	0.02	0.03	1.99	3258.94	60.30	0.00	12.45
Genotypes	39	825.61**	237.71**	31.55**	275.50**	0.03**	9.43**	60216.46**	154404.64**	24.97**	0.00**	2.05**
Error	39	0.44	0.41	7.33	13.23	0.00	1.40	166.71	558.16	1.28	0.00	1.18
S.Em		0.47	0.45	1.91	2.57	0.05	0.84	9.13	16.71	0.80	0.02	0.77
C.V. (%)		1.18	2.07	6.26	12.17	3.16	4.29	3.53	3.82	2.35	4.80	9.75
C.D.5%		1.34	1.30	5.48	7.36	0.14	2.39	26.12	47.79	2.29	0.05	2.20
C.D. 1%		1.80	1.74	7.33	9.85	0.19	3.20	34.96	63.98	3.06	0.06	2.94

Where,

*- Significant at 5 %

** - Significant at 1 %

RWC - Relative water content (%)

MSI - Membrane stability index (%)

SCMR - SPAD Chlorophyll Meter Reading

PWP- Per cent of wilted plants (%)

Table 4: Analysis of variances (G x E interaction) for physiological, biochemical and root attributes under normal moisture and drought conditions

Source of Variance	d.f.	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
Replications	1	39.18	0.45	131.08	5.29	0.07	0.20	3779.00	2989.00	5.59	0.01	61.49
Genotype	39	440.14**	452.17**	53.71**	137.75**	0.03**	17.19**	98580.00**	13090.00**	38.49**	0.01**	2.94**
Environments	1	15221.80**	24.85**	45.67*	35743.16**	0.11**	380.66**	35586.00**	298041.00**	179.41	0.02**	49.52**
G x E	39	412.55**	392.31**	6.67**	137.75**	0.03**	3.69**	16246.00**	5651.00**	4.33	0.01**	1.27**
Error (Residual)	79	0.69	0.40	6.84	6.60	0.00	1.38	14341.00	2671.00	1.66	0.00	1.20
Total	159											

Where,

* - Significant at 5 %

** - Significant at 1 %

d.f. – degrees of freedom

X1 – Relative water content (%)

X2 – Membrane stability index (%)

X3 – SPAD Chlorophyll Meter Reading

X4 – Per cent of wilted plants (%)

X5 - Protein content of leaves (%)

X6 - Protein content of seeds (%)

X7 - Phenolic content of seeds (µg/g)

X8 - Phenolic content of leaves (µg/g)

X9 - Oil content of seeds (%)

X10 - Root to shoot ratio

X11 - Root length (cm)

Table 5: Estimates of Genetic parameters for physiological, biochemical and root attributes under normal moisture condition

Characters	Mean	Range	GCV (%)	PCV (%)	h ² (%)	GAM (%)
RWC (%)	75.66	66.44-86.24	4.78	4.95	93.36	9.51
MSI (%)	31.72	6.31-71.49	54.88	54.92	99.89	112.99
SPAD Chlorophyll Meter Reading	42.17	35.13-50.37	7.93	17.64	63.50	13.02
Protein content of leaves (%)	0.73	0.40-0.88	11.73	15.28	58.90	18.55
Protein content of seeds (%)	24.44	20.67-28.66	9.16	10.78	78.30	16.71
Phenolic content of leaves (µg/g)	369.50	217.44-1548.94	64.47	64.59	99.63	74.26
Phenolic content of seeds (µg/g)	643.89	346.43-1638.50	35.63	35.80	99.06	73.05
Oil content (%)	45.98	40.46-51.37	6.46	6.53	97.93	13.19
Root to shoot ratio	0.47	0.35-0.61	11.00	11.85	86.19	21.04
Root length (cm)	12.25	9.45-15.38	10.45	11.99	75.95	18.76

Where,

- RWC (%) - Relative water content
- MSI (%) - Membrane stability index
- GCV (%) - Genotypic coefficient of variation
- PCV (%) - Phenotypic coefficient of variation
- h² (%) - Heritability in broad sense
- GAM (%) - Genetic advance over mean

Table 6: Estimates of Genetic parameters for physiological, biochemical and root attributes under moisture stress condition

Characters	Mean	Range	GCV (%)	PCV (%)	h ² (%)	GAM (%)
RWC (%)	56.16	20.50-86.03	36.17	36.19	99.89	74.47
MSI (%)	30.93	7.61-55.19	35.20	35.26	99.91	72.40
SPAD Chlorophyll Meter Reading	43.24	35.77-53.99	8.04	10.19	62.29	13.08
Per cent of wilted plants (%)	29.89	12.55-56.32	38.30	40.19	90.84	75.21
Protein content of leaves (%)	0.79	0.39-0.95	14.63	17.00	74.04	25.93
Protein content of seeds (%)	27.53	21.61-31.06	7.28	8.45	74.18	12.91
Phenolic content of leaves (µg/g)	366.19	198.17 - 1277.87	47.45	47.52	99.72	97.61
Phenolic content of seeds (µg/g)	618.86	206.84 - 1721.93	44.98	45.06	99.64	92.49
Oil content (%)	48.09	40.21-53.79	7.15	7.53	90.34	14.01
Root to shoot ratio	0.49	0.43-0.59	7.09	8.57	68.56	12.10
Root length (cm)	11.14	8.89-13.54	11.40	13.33	73.25	20.11

Where,

- RWC (%) - Relative water content
- MSI (%) - Membrane stability index
- GCV (%) - Genotypic coefficient of variation
- PCV (%) - Phenotypic coefficient of variation
- h² (%) - Heritability in broad sense
- GAM (%) - Genetic advance over mean

The membrane stability index in normal moisture situation was in the range of 6.31 to 71.49 per cent with a mean of 31.72 per cent. The phenotypic and genotypic coefficients of variation were 54.92 and 54.88 per cent, respectively. The heritability for this trait was 99.89 per cent with a genetic advance over mean of 112.99 per cent.

The genotypes *viz.*, GPBD-5 (55.19 %), ICGV 15124 (53.78 %), G2-52 (47.47 %), ICGV 15148 (47.02 %) and ICGV 15123 (46.11 %) exhibited higher membrane stability index under managed drought condition.

4.1.2.3 SPAD Chlorophyll Meter Reading

For SPAD Chlorophyll Meter Reading (SCMR), the accessions studied were in the range of 35.13 to 50.37 with a mean of 42.17. The GCV (7.93 %), PCV (17.64 %) and broad sense heritability (63.50 %) with a genetic advance over mean of 13.02 per cent were observed under normal moisture condition. However, in moisture stress condition, the mean SCMR was 43.24 with a range of 35.77 to 53.99. Further, the estimates of GCV (8.04 %), PCV (10.19 %), heritability (62.29 %) and genetic advance over mean (13.08 %) exhibited similar trend as observed under normal moisture situation.

Under stress condition, the genotypes with superior performance for SPAD Chlorophyll meter reading were VB (53.99), ICGV 15152 (51.43), KCG-2 (49.09), LOCAL-1 (48.62) and Dh-101 (47.78)

4.1.2.4 Per cent of wilted plants (%)

In moistures stressed pots, the percentage of wilted plants ranged from 12.55 to 56.32 per cent with a mean of 29.89 per cent. The phenotypic and genotypic coefficients of variation were 38.30 and 40.19 per cent, respectively. The heritability for the trait was 90.84 per cent with a genetic advance over mean of 75.21 per cent.

The genotypes like Dh-101 (12.55 %), Dh-234 (12.70 %), ICGV 15153 (13.39 %), ICGV 15154 (14.09 %), ICGV 15145 (14.84 %) and SB-14 (15.00 %) showed least per cent of wilted plants due to moisture stress imposed for 20 days from 90 DAS.

4.1.2.5 Protein content of leaves (%)

Under normal moisture condition, protein content in leaves varied from 0.40 to 0.88 per cent with a mean of 0.73 per cent. For this trait, GCV (11.73 %), PCV (15.28 %), and heritability (h^2) of 58.90 per cent with genetic advance over mean (18.55 %) recorded.

However, under moisture stress, the protein content recorded a mean value of 0.79 per cent with a range of 0.39 to 0.95 per cent. The GCV and PCV were 14.63 and 17 per cent, respectively. The heritability of 74.04 per cent and genetic advance over mean of 25.93 per cent was exhibited by the genotypes for this trait.

The genotypes with high protein content in leaf under moisture stress include ICGV 15120 (0.95 %), ICGV 15124 (0.93 %), Dh-86 (0.91 %), ICGV 15145 (0.91 %) and SB-15 (0.91 %).

4.1.2.6 Protein content of seeds (%)

The protein content in seeds under normal moisture was in the range of 20.67 to 28.66 per cent with a mean of 24.44 per cent. The genotypic and phenotypic coefficients of variation were 9.16 and 10.78 per cent, respectively. The heritability estimate was 78.30 per cent with a genetic advance over mean of 16.71 per cent was recorded for this trait.

On the other hand, under moisture stress condition the mean protein content of seeds was 27.53 per cent with a range of 21.61 to 31.06 per cent. The phenotypic and genotypic coefficients of variation were 8.45 and 7.28 per cent, respectively. The heritability estimate of 74.18 per cent with a genetic advance over mean of 12.91 per cent was recorded for this trait.

The genotypes viz., ICGV 15146 (31.05 %), VB (30.62 %), SB-17 (30.34 %), ICGV 15143 (30.29 %) and G2-52 (29.97 %) showed high protein content of seeds under managed drought stress or moisture stress condition.

4.1.2.7 Phenolic content of leaves ($\mu\text{g/g}$)

The phenolic content in leaves of groundnut genotypes under study was in the range of 217.44 to 1548.94 $\mu\text{g/g}$ with a mean of 369.50 $\mu\text{g/g}$. The GCV and PCV were 64.47 and 64.59 per cent, respectively. The heritability of 99.63 per cent with a genetic advance over mean of 74.26 per cent was recorded under normal moisture condition.

However, under moisture stress condition, mean phenolic content in seeds was 366.19 $\mu\text{g/g}$ with a range of 198.17 to 1277.87 $\mu\text{g/g}$. The GCV and PCV were 47.45 and 47.52 per cent, respectively. The heritability estimate of 99.64 per cent with a genetic advance over mean of 97.61 per cent was recorded.

Higher phenolic content in leaves was recorded in some genotypes viz., ICGV 15141 (1277.87 $\mu\text{g/g}$), LOCAL-1 (461.94 $\mu\text{g/g}$), K-9 (459.95 $\mu\text{g/g}$), GPBD-5 (457.26 $\mu\text{g/g}$) and K-6 (456.67 $\mu\text{g/g}$).

4.1.2.8 Phenolic content of seeds ($\mu\text{g/g}$)

The phenolic content in seeds of the groundnut accessions was in the range of 346.43 to 1638.50 $\mu\text{g/g}$ with a mean of 643.89 $\mu\text{g/g}$. The GCV (35.63 %), PCV (35.80 %) and broad sense heritability (h^2) of 99.06 per cent with a genetic advance over mean of 73.05 per cent were recorded under normal moisture condition.

However, in moisture stress condition, the phenolic content in seeds was 618.86 µg/g with a range of 206.84 to 1721.93 µg/g. The GCV and PCV were 44.98 and 45.06 %, respectively. The heritability of 99.64% with a genetic advance over mean of 92.49 per cent was recorded.

The genotypes which recorded high phenolic content in seeds under moisture stress include ICGV 15143 (1721.92 µg/g), ICGV 15154 (965.71 µg/g), K-9 (949.99 µg/g), SB-15 (851.42 µg/g) and G2-52 (847.86 µg/g).

4.1.2.9 Oil content in seeds (%)

In normal moisture condition, the mean value of oil content was 45.98 per cent with a range of 40.46 to 51.37 per cent. The phenotypic and genotypic coefficients of variation were 6.53 and 6.46 per cent, respectively. The heritability for this trait was 97.93 per cent with a genetic advance over mean of 13.19 per cent.

The oil content in moisture stressed situation was in the range of 40.42 to 53.79 per cent with a mean of 48.09 per cent. The phenotypic and genotypic coefficients of variation were 7.53 and 7.15 per cent, respectively. The heritability for the trait was 90.34 per cent with a genetic advance over mean of 14.01 per cent.

Some genotypes which have recorded more oil content of seeds under stress environment include ICGV 15152 (53.79 %), ICGV 15158 (53.53 %), ICGV 15123 (53.05 %), VB (52.74 %) and ICGV 15146 (51.91 %).

4.1.2.10 Root to shoot ratio

For root to shoot ratio, the accessions of groundnut studied were in a range of 0.35 to 0.61 with a mean of 0.47. GCV (11.00 %), PCV (11.85 %) and broad sense heritability (86.19 %) with a genetic advance over mean of 21.04 per cent was recorded under normal moisture condition.

However, in stressed condition, the mean root to shoot ratio of 0.49 was observed with a range of 0.43 to 0.59. The GCV (7.09 %), PCV (8.57 %), heritability (68.56 %) with genetic advance over mean of 12.10 per cent were recorded.

The maximum root to shoot ratio was recorded in five genotypes *viz.*, R-2001-3 (0.59), Dh-86 (0.57), SB-15 (0.56), VB-14 (0.56) and ICGV 15124 (0.55) under stress condition which may serve as potential germplasm to be used in the coherent breeding programs for drought tolerance in groundnut.

4.1.2.11 Root length (cm)

The minimum and maximum values of root length under normal moisture condition were 9.45 cm and 15.38 cm, respectively with a mean of 12.25 cm. The estimates of phenotypic coefficient of variation (11.99 %) and genotypic

coefficients of variation (10.45 %) were recorded while, the heritability for the trait was 75.95 per cent with a genetic advance over mean of 18.76 per cent.

On the contrary, the root length under moisture stressed situation was ranged from 8.89 to 13.54 cm with a mean of 11.14 cm. The phenotypic and genotypic coefficients of variation were 13.33 and 11.40 per cent, respectively. The heritability for the trait was 73.25 per cent with a genetic advance over mean of 20.11 per cent.

The genotypes viz., R-2001-3 (13.54 cm), TMV-2 (13.14 cm), Dh-86 (12.51 cm), VB-14 (12.39 cm) and SB-15 (12.67 cm) showed superior performance for root length under stress condition.

Comparative statement based on estimates of different genetic parameters for biochemical, physiological and root related characters in groundnut genotypes under stress condition were presented in table 7.

The comparative performance of forty genotypes for physiological, biochemical and root related traits under control and stress condition is presented in the table 8.

The comparative overall mean performance of the genotypes for physiological, biochemical and root related attributes under both stress and stress free condition is presented in the table 9.

4.2. Assessment of the groundnut advanced lines for yield and yield components under drought stress and irrigated conditions

4.2.1 Analysis of variance

The ANOVA indicating the sources of variation and mean squares for the yield and yield component traits among the groundnut genotypes which were evaluated under both normal moisture and moisture stressed condition are presented in tables 10 and 11, respectively. The results indicated highly significant differences among the genotypes for all the traits even at one per cent level of probability ($p < 0.01$).

The mean sum of squares for interaction (genotype x environment) of yield and component characters is presented in the table 12. The effect of environments (moisture stress and normal moisture) was significant on all the traits except plant height of 30 DAS and days to 50 per cent flowering. Further, the genotype x environment (G x E) interaction was highly significant for almost all the traits except for plant height at 60 DAS, number of primary branches per plant at 60 DAS and number of days to 50 % flowering. This clearly indicates that, the performance of the genotypes differed significantly for most of the traits across environments (moisture stress and normal moisture condition).

Table 7: Comparative statement based on estimates of different genetic parameters for biochemical, physiological and root attributes under moisture stress condition

Character	Genetic parameters				Gene effects	Effect of environment
	GCV (%)	PCV (%)	Heritability (%)	GAM (%)		
RWC (%)	High	High	High	High	Additive	Low
MSI (%)	High	High	High	High	Additive	Low
SPAD Chlorophyll Meter Reading	Low	Moderate	High	Moderate	Additive	Low
Per cent of wilted plants (%)	High	High	High	High	Additive	Low
Protein content of leaves (%)	Moderate	Moderate	High	High	Additive	Low
Protein content of seeds (%)	Low	Low	High	Moderate	Additive	Low
Phenolic content of leaves (µg/g)	High	High	High	High	Additive	Low
Phenolic content of seeds (µg/g)	High	High	High	High	Additive	Low
Oil content (%)	Low	Low	High	Moderate	Additive	Low
Root to shoot ratio	Low	Low	High	Moderate	Additive	Low
Root length (cm)	Moderate	Moderate	High	High	Additive	Low

Where,

- RWC (%) - Relative water content
- MSI (%) - Membrane stability index
- GCV (%) - Genotypic coefficient of variation
- PCV (%) - Phenotypic coefficient of variation
- h^2 (%) - Heritability in broad sense
- GAM (%) - Genetic advance over mean

Table 8: Comparative performance of forty groundnut genotypes under moisture stress and normal conditions for drought related traits-physiological, biochemical and root related traits

Sl. No.	Genotype	Relative water content (%)				Membrane stability index (%)			
		Stress	Non Stress	Mean Reduction	Change in % mean	Stress	Non Stress	Mean Reduction	Change in % mean
1	ICGV 15114	53.50	71.58	-18.07	-25.25	10.88	29.46	-18.58	-63.07
2	ICGV 15119	53.27	77.90	-24.64	-31.63	21.18	28.37	-7.19	-25.35
3	ICGV 15120	45.11	69.11	-24.00	-34.73	24.15	42.33	-18.18	-42.96
4	ICGV 15122	33.47	73.03	-39.56	-54.17	18.77	8.00	10.77	134.64
5	ICGV 15123	33.33	77.07	-43.74	-56.75	46.11	14.59	31.53	216.16
6	ICGV 15124	79.93	78.89	1.04	1.32	53.78	19.17	34.61	180.62
7	ICGV 15138	44.91	77.55	-32.64	-42.09	38.29	25.42	12.87	50.63
8	ICGV 15141	85.26	75.08	10.18	13.55	23.68	7.00	16.68	238.41
9	ICGV 15143	60.00	77.89	-17.89	-22.97	30.03	25.32	4.71	18.62
10	ICGV 15145	61.95	74.00	-12.05	-16.28	42.04	26.20	15.84	60.48
11	ICGV 15146	27.60	74.66	-47.07	-63.04	38.41	17.12	21.28	124.31
12	ICGV 15148	30.69	74.96	-44.27	-59.06	47.02	29.85	17.17	57.52
13	ICGV 15149	20.50	75.10	-54.60	-72.71	26.05	28.82	-2.76	-9.59
14	ICGV 15151	40.86	78.26	-37.40	-47.79	12.11	8.28	3.83	46.20
15	ICGV 15152	58.24	75.27	-17.03	-22.63	34.13	15.01	19.12	127.35
16	ICGV 15153	70.10	76.09	-5.99	-7.88	25.24	6.31	18.93	300.23
17	ICGV 15154	83.27	76.75	6.52	8.49	30.90	35.65	-4.75	-13.32
18	ICGV 15158	78.88	66.44	12.44	18.72	27.48	29.05	-1.57	-5.40
19	ICGV 15159	67.06	77.82	-10.76	-13.83	29.48	20.40	9.08	44.52
20	ICGV 15161	79.33	68.16	11.18	16.40	25.86	23.33	2.53	10.85
21	SB-1	20.57	74.66	-54.09	-72.45	34.32	65.80	-31.48	-47.84
22	SB-14	86.03	80.11	5.92	7.39	12.45	48.65	-36.21	-74.42
23	SB-15	73.21	74.05	-0.84	-1.13	35.14	11.56	23.59	204.05
24	SB-17	40.97	67.20	-26.23	-39.03	34.11	13.02	21.09	161.94
25	VB	37.59	77.74	-40.14	-51.64	38.12	30.58	7.54	24.64
26	VB-11	46.64	76.87	-30.23	-39.33	33.20	10.51	22.69	215.89
27	VB-14	49.23	76.23	-27.00	-35.42	25.82	29.27	-3.45	-11.77
28	Dh-86	53.06	74.91	-21.86	-29.18	36.32	46.11	-9.79	-21.24
29	Dh-101	59.53	76.50	-16.97	-22.19	23.72	36.90	-13.18	-35.72
30	Dh-234	22.37	79.13	-56.75	-71.72	36.22	56.57	-20.34	-35.96
31	K-9	84.53	86.24	-1.71	-1.98	32.67	59.63	-26.95	-45.20
32	K-6	22.42	78.23	-55.81	-71.35	33.68	71.49	-37.80	-52.88
33	GPBD-4	77.05	75.91	1.13	1.49	7.69	49.68	-41.99	-84.52
34	GPBD-5	72.26	73.60	-1.33	-1.81	55.19	56.26	-1.07	-1.91
35	KCG-6	80.44	77.68	2.76	3.56	30.85	58.39	-27.53	-47.15
36	KCG-2	76.86	78.89	-2.02	-2.56	38.14	57.57	-19.43	-33.75
37	TMV-2	57.52	74.22	-16.70	-22.50	28.33	31.19	-2.86	-9.17
38	LOCAL-1	71.54	78.34	-6.80	-8.68	19.74	11.11	8.63	77.68
39	R-2001-3	49.80	77.96	-28.16	-36.12	28.40	32.01	-3.61	-11.27
40	G2-52	57.34	72.44	-15.10	-20.85	47.75	31.90	15.86	49.72

Table 8: Continued..,

Sl. No.	Genotype	SPAD Chlorophyll Meter Reading				Per cent of wilted plants (%) in moisture stressed condition
		Stress	Non stress	Mean reduction	Change in % mean	Stress
1	ICGV 15114	35.77	35.83	-0.06	-0.17	15.26
2	ICGV 15119	39.40	40.58	-1.18	-2.92	32.05
3	ICGV 15120	43.90	41.17	2.73	6.63	36.94
4	ICGV 15122	40.47	41.03	-0.57	-1.38	43.65
5	ICGV 15123	38.05	38.38	-0.33	-0.87	46.41
6	ICGV 15124	38.03	38.18	-0.15	-0.39	56.32
7	ICGV 15138	38.99	35.38	3.61	10.20	40.28
8	ICGV 15141	41.16	39.78	1.37	3.45	36.67
9	ICGV 15143	40.93	39.43	1.50	3.80	19.09
10	ICGV 15145	37.93	36.42	1.51	4.14	14.84
11	ICGV 15146	36.90	35.13	1.76	5.02	25.00
12	ICGV 15148	44.91	44.28	0.62	1.41	38.68
13	ICGV 15149	41.25	42.93	-1.69	-3.93	37.65
14	ICGV 15151	47.13	46.88	0.25	0.52	28.64
15	ICGV 15152	51.43	46.38	5.04	10.87	33.33
16	ICGV 15153	47.03	42.94	4.09	9.51	13.39
17	ICGV 15154	44.15	41.83	2.31	5.53	14.09
18	ICGV 15158	41.20	41.15	0.05	0.12	26.79
19	ICGV 15159	43.20	43.25	-0.05	-0.12	21.11
20	ICGV 15161	43.10	39.50	3.60	9.12	31.67
21	SB-1	43.12	38.62	4.50	11.66	19.09
22	SB-14	43.02	43.38	-0.37	-0.85	15.00
23	SB-15	40.15	42.88	-2.73	-6.37	21.59
24	SB-17	41.95	43.72	-1.77	-4.05	33.33
25	VB	53.99	49.38	4.61	9.33	27.50
26	VB-11	45.94	49.70	-3.76	-7.56	25.83
27	VB-14	46.32	39.53	6.79	17.17	31.89
28	Dh-86	46.90	45.63	1.27	2.78	21.11
29	Dh-101	47.78	45.83	1.95	4.25	12.55
30	Dh-234	43.04	44.67	-1.63	-3.65	12.70
31	K-9	41.43	40.72	0.72	1.76	18.33
32	K-6	46.02	42.53	3.49	8.21	22.50
33	GPBD-4	45.66	44.02	1.65	3.74	31.88
34	GPBD-5	45.56	38.63	6.93	17.93	29.82
35	KCG-6	40.77	38.77	2.00	5.16	54.89
36	KCG-2	49.09	50.37	-1.28	-2.53	38.75
37	TMV-2	42.94	43.45	-0.51	-1.18	46.41
38	LOCAL-1	48.62	46.70	1.92	4.11	45.00
39	R-2001-3	40.57	44.32	-3.75	-8.47	40.83
40	G2-52	41.98	43.67	-1.68	-3.85	34.85

Table 8: continued..,

Sl. No.	Genotype	Protein content of leaves (%)				Protein content of seeds (%)			
		Stress	Non stress	Mean reduction	Change in % mean	Stress	Non stress	Mean reduction	Change in % mean
1	ICGV 15114	0.88	0.73	0.15	19.76	26.47	21.65	4.81	22.23
2	ICGV 15119	0.89	0.60	0.29	47.92	25.49	24.04	1.45	6.03
3	ICGV 15120	0.95	0.67	0.28	41.34	29.60	26.98	2.62	9.70
4	ICGV 15122	0.79	0.73	0.06	8.74	24.64	20.67	3.97	19.21
5	ICGV 15123	0.80	0.81	-0.01	-0.72	25.63	21.84	3.79	17.33
6	ICGV 15124	0.93	0.83	0.10	12.49	26.05	22.31	3.74	16.76
7	ICGV 15138	0.80	0.81	-0.02	-2.34	28.85	21.09	7.75	36.76
8	ICGV 15141	0.82	0.83	-0.02	-1.89	27.26	28.66	-1.40	-4.89
9	ICGV 15143	0.89	0.84	0.05	6.17	30.30	24.97	5.33	21.33
10	ICGV 15145	0.91	0.59	0.32	54.72	28.38	25.21	3.18	12.61
11	ICGV 15146	0.88	0.78	0.09	12.13	31.06	28.57	2.49	8.71
12	ICGV 15148	0.69	0.73	-0.04	-5.93	27.21	27.78	-0.56	-2.02
13	ICGV 15149	0.42	0.61	-0.18	-30.35	26.37	24.18	2.20	9.08
14	ICGV 15151	0.87	0.73	0.14	19.55	26.65	24.88	1.78	7.14
15	ICGV 15152	0.88	0.40	0.48	118.18	29.22	24.46	4.77	19.49
16	ICGV 15153	0.83	0.80	0.03	3.91	29.04	23.29	5.75	24.68
17	ICGV 15154	0.81	0.83	-0.02	-2.46	26.78	22.26	4.52	20.31
18	ICGV 15158	0.75	0.76	-0.01	-0.78	29.60	24.41	5.19	21.25
19	ICGV 15159	0.69	0.64	0.05	7.81	26.61	21.70	4.91	22.61
20	ICGV 15161	0.69	0.88	-0.19	-21.30	24.83	23.03	1.80	7.83
21	SB-1	0.39	0.87	-0.49	-55.85	26.37	24.64	1.73	7.02
22	SB-14	0.81	0.70	0.11	16.10	27.12	22.12	5.00	22.60
23	SB-15	0.91	0.64	0.26	40.80	29.55	26.61	2.94	11.06
24	SB-17	0.59	0.64	-0.05	-7.81	30.35	28.44	1.90	6.69
25	VB	0.86	0.74	0.11	15.42	30.63	28.48	2.15	7.55
26	VB-11	0.71	0.59	0.12	20.59	29.27	27.64	1.64	5.92
27	VB-14	0.59	0.77	-0.19	-24.50	24.74	24.04	0.70	2.92
28	Dh-86	0.91	0.83	0.09	10.64	29.38	27.73	1.65	5.96
29	Dh-101	0.90	0.70	0.20	27.95	27.92	25.30	2.62	10.34
30	Dh-234	0.81	0.87	-0.06	-7.17	22.25	21.65	0.60	2.75
31	K-9	0.80	0.73	0.06	8.63	28.99	25.44	3.55	13.96
32	K-6	0.83	0.70	0.13	18.57	28.39	26.79	1.60	5.97
33	GPBD-4	0.66	0.69	-0.03	-3.65	28.94	26.51	2.43	9.16
34	GPBD-5	0.85	0.79	0.05	6.83	21.61	21.28	0.33	1.54
35	KCG-6	0.84	0.79	0.05	6.10	26.98	22.67	4.31	19.03
36	KCG-2	0.84	0.85	-0.01	-1.32	27.92	24.50	3.41	13.92
37	TMV-2	0.84	0.84	0.01	1.16	25.45	22.64	2.81	12.42
38	LOCAL-1	0.84	0.73	0.11	15.48	28.41	23.66	4.75	20.07
39	R-2001-3	0.75	0.66	0.09	14.08	26.98	21.37	5.61	26.23
40	G2-52	0.77	0.82	-0.05	-6.28	29.97	24.36	5.61	23.01

Table 8: continued...

Sl. No.	Genotype	Phenolic content of leaves ($\mu\text{g/g}$)				Phenolic content of seeds ($\mu\text{g/g}$)			
		Stress	Non stress	Mean reduction	Change in % mean	Stress	Non stress	Mean reduction	Change in % mean
1	ICGV 15114	324.12	232.20	91.92	39.59	271.19	515.71	-244.53	-47.42
2	ICGV 15119	248.23	248.71	-0.48	-0.19	281.79	456.79	-175.00	-38.31
3	ICGV 15120	305.01	243.35	61.66	25.34	206.84	362.14	-155.30	-42.88
4	ICGV 15122	273.48	266.63	6.85	2.57	340.64	408.57	-67.93	-16.63
5	ICGV 15123	198.17	281.62	-83.44	-29.63	386.02	472.86	-86.83	-18.36
6	ICGV 15124	228.16	219.32	8.84	4.03	357.24	455.00	-97.76	-21.49
7	ICGV 15138	275.12	292.91	-17.79	-6.07	428.21	472.86	-44.64	-9.44
8	ICGV 15141	1277.87	914.57	363.30	39.72	319.29	488.93	-169.64	-34.70
9	ICGV 15143	242.33	388.96	-146.63	-37.70	1721.93	435.36	1286.57	295.52
10	ICGV 15145	232.54	360.98	-128.44	-35.58	376.43	438.93	-62.50	-14.24
11	ICGV 15146	300.70	234.41	66.29	28.28	369.29	394.29	-25.00	-6.34
12	ICGV 15148	360.42	259.95	100.47	38.65	438.93	492.50	-53.57	-10.88
13	ICGV 15149	291.06	689.73	-398.67	-57.80	419.29	530.00	-110.71	-20.89
14	ICGV 15151	241.85	228.18	13.67	5.99	358.57	419.29	-60.71	-14.48
15	ICGV 15152	613.73	1548.94	-935.21	-60.38	413.93	494.29	-80.36	-16.26
16	ICGV 15153	199.71	266.39	-66.68	-25.03	444.29	496.07	-51.79	-10.44
17	ICGV 15154	227.65	378.85	-151.21	-39.91	965.71	692.50	273.21	39.45
18	ICGV 15158	209.44	431.93	-222.49	-51.51	776.79	708.57	68.21	9.63
19	ICGV 15159	244.50	637.72	-393.22	-61.66	746.07	696.07	50.00	7.18
20	ICGV 15161	351.09	273.42	77.67	28.41	780.00	712.14	67.86	9.53
21	SB-1	381.50	367.38	14.12	3.84	762.14	701.43	60.71	8.66
22	SB-14	411.01	230.09	180.91	78.63	821.07	685.36	135.71	19.80
23	SB-15	346.96	277.52	69.44	25.02	851.43	812.14	39.29	4.84
24	SB-17	377.40	346.24	31.16	9.00	787.14	769.29	17.86	2.32
25	VB	453.51	228.55	224.96	98.43	509.87	451.43	58.44	12.95
26	VB-11	307.73	264.99	42.74	16.13	749.21	540.71	208.49	38.56
27	VB-14	422.86	291.80	131.05	44.91	695.61	472.86	222.75	47.11
28	Dh-86	447.07	270.26	176.81	65.42	479.23	569.29	-90.06	-15.82
29	Dh-101	420.78	217.44	203.35	93.52	618.71	885.36	-266.65	-30.12
30	Dh-234	445.91	309.40	136.51	44.12	465.79	676.43	-210.64	-31.14
31	K-9	459.95	268.55	191.41	71.27	949.99	740.71	209.28	28.25
32	K-6	456.67	258.19	198.49	76.88	782.27	678.21	104.05	15.34
33	GPBD-4	413.11	388.35	24.77	6.38	533.23	685.36	-152.13	-22.20
34	GPBD-5	457.26	288.99	168.27	58.23	764.52	717.50	47.02	6.55
35	KCG-6	441.53	344.17	97.36	28.29	715.20	762.14	-46.94	-6.16
36	KCG-2	431.94	360.16	71.78	19.93	842.50	676.43	166.07	24.55
37	TMV-2	451.05	290.62	160.43	55.20	708.57	631.79	76.79	12.15
38	LOCAL-1	461.94	363.00	98.95	27.26	805.24	624.64	180.60	28.91
39	R-2001-3	344.03	320.53	23.50	7.33	662.55	615.71	46.84	7.61
40	G2-52	455.85	309.40	146.45	47.33	847.86	747.86	100.00	13.37

Table 8: continued.,

Sl. No.	Genotype	Oil content of seeds (%)				Root to shoot ratio			
		Stress	Non stress	Mean reduction	Change in % mean	Stress	Non stress	Mean reduction	Change in % mean
1	ICGV 15114	50.51	48.14	2.37	4.92	0.44	0.45	-0.01	-3.27
2	ICGV 15119	48.63	46.01	2.62	5.69	0.48	0.47	0.01	1.34
3	ICGV 15120	46.17	45.59	0.58	1.27	0.44	0.41	0.03	7.90
4	ICGV 15122	50.40	45.94	4.46	9.71	0.44	0.43	0.00	0.27
5	ICGV 15123	53.05	49.23	3.82	7.76	0.49	0.43	0.06	15.04
6	ICGV 15124	50.62	48.41	2.21	4.57	0.55	0.48	0.07	15.67
7	ICGV 15138	50.11	46.10	4.01	8.70	0.49	0.47	0.02	4.68
8	ICGV 15141	48.25	44.12	4.13	9.36	0.50	0.43	0.07	15.97
9	ICGV 15143	49.34	45.25	4.09	9.04	0.49	0.53	-0.04	-8.24
10	ICGV 15145	50.14	48.20	1.94	4.02	0.48	0.47	0.02	3.50
11	ICGV 15146	51.91	49.28	2.63	5.33	0.50	0.50	-0.01	-1.56
12	ICGV 15148	50.80	48.94	1.86	3.80	0.55	0.52	0.03	6.23
13	ICGV 15149	49.58	48.83	0.75	1.54	0.50	0.52	-0.03	-5.15
14	ICGV 15151	47.71	50.92	-3.21	-6.30	0.50	0.52	-0.02	-3.03
15	ICGV 15152	53.79	49.24	4.55	9.24	0.48	0.56	-0.08	-14.00
16	ICGV 15153	50.11	48.88	1.23	2.51	0.50	0.54	-0.04	-8.12
17	ICGV 15154	50.08	47.94	2.14	4.45	0.47	0.50	-0.02	-4.60
18	ICGV 15158	53.53	49.21	4.32	8.77	0.48	0.49	-0.02	-3.06
19	ICGV 15159	51.11	47.59	3.52	7.40	0.45	0.49	-0.04	-7.69
20	ICGV 15161	49.82	47.38	2.44	5.15	0.43	0.52	-0.08	-16.08
21	SB-1	51.52	46.49	5.03	10.81	0.53	0.53	0.00	0.41
22	SB-14	49.69	46.33	3.36	7.25	0.47	0.50	-0.03	-5.42
23	SB-15	48.10	46.54	1.56	3.35	0.56	0.52	0.04	8.11
24	SB-17	47.66	43.18	4.47	10.36	0.52	0.52	0.00	0.79
25	VB	52.74	48.25	4.49	9.31	0.51	0.49	0.01	2.77
26	VB-11	47.07	45.53	1.54	3.38	0.47	0.44	0.03	6.48
27	VB-14	45.78	41.21	4.57	11.09	0.56	0.42	0.14	32.70
28	Dh-86	43.11	42.07	1.04	2.47	0.57	0.47	0.10	21.20
29	Dh-101	40.21	42.21	-2.00	-4.74	0.45	0.39	0.06	16.29
30	Dh-234	48.51	44.78	3.72	8.32	0.44	0.41	0.03	6.88
31	K-9	48.15	46.16	1.99	4.31	0.48	0.35	0.14	39.44
32	K-6	43.03	41.15	1.88	4.57	0.45	0.42	0.03	7.26
33	GPBD-4	46.68	46.43	0.25	0.54	0.51	0.48	0.02	4.48
34	GPBD-5	42.44	42.02	0.42	1.00	0.48	0.39	0.09	24.42
35	KCG-6	42.61	40.94	1.67	4.08	0.51	0.49	0.01	2.51
36	KCG-2	43.73	39.67	4.07	10.25	0.49	0.42	0.07	16.08
37	TMV-2	41.36	42.21	-0.85	-2.01	0.46	0.42	0.03	8.13
38	LOCAL-1	41.91	41.02	0.89	2.17	0.50	0.41	0.09	22.29
39	R-2001-3	47.43	48.89	-1.46	-2.99	0.59	0.61	-0.02	-2.57
40	G2-52	46.54	48.91	-2.37	-4.85	0.53	0.51	0.02	4.06

Table 8: continued..,

Sl. No.	Genotype	Root length (cm)			
		Stress	Non Stress	Mean Reduction	Change in % mean
1	ICGV 15114	8.89	9.96	-1.07	-10.70
2	ICGV 15119	10.55	12.45	-1.90	-15.26
3	ICGV 15120	10.88	9.45	1.44	15.19
4	ICGV 15122	10.63	12.08	-1.45	-12.00
5	ICGV 15123	10.81	12.02	-1.21	-10.07
6	ICGV 15124	11.60	12.45	-0.85	-6.83
7	ICGV 15138	10.71	11.92	-1.21	-10.15
8	ICGV 15141	12.38	12.76	-0.38	-2.98
9	ICGV 15143	9.78	12.35	-2.57	-20.79
10	ICGV 15145	10.14	11.50	-1.36	-11.83
11	ICGV 15146	11.01	12.36	-1.35	-10.92
12	ICGV 15148	11.13	12.49	-1.36	-10.89
13	ICGV 15149	10.72	12.55	-1.83	-14.58
14	ICGV 15151	10.60	12.74	-2.14	-16.80
15	ICGV 15152	10.42	12.74	-2.32	-18.21
16	ICGV 15153	9.49	12.92	-3.43	-26.55
17	ICGV 15154	10.41	11.60	-1.19	-10.26
18	ICGV 15158	10.43	12.06	-1.63	-13.52
19	ICGV 15159	9.74	12.45	-2.71	-21.77
20	ICGV 15161	9.23	12.30	-3.07	-24.96
21	SB-1	11.83	12.87	-1.04	-8.08
22	SB-14	11.12	12.78	-1.66	-12.99
23	SB-15	12.67	13.05	-0.38	-2.91
24	SB-17	11.91	13.54	-1.63	-12.04
25	VB	11.32	12.05	-0.73	-6.06
26	VB-11	11.13	11.23	-0.10	-0.89
27	VB-14	12.39	11.87	0.52	4.38
28	Dh-86	12.51	10.74	1.77	16.48
29	Dh-101	10.91	10.15	0.76	7.49
30	Dh-234	10.98	11.84	-0.86	-7.26
31	K-9	11.61	11.15	0.46	4.13
32	K-6	11.96	12.77	-0.81	-6.34
33	GPBD-4	11.21	12.48	-1.27	-10.18
34	GPBD-5	11.98	12.02	-0.04	-0.33
35	KCG-6	11.79	13.70	-1.91	-13.94
36	KCG-2	11.59	12.37	-0.78	-6.31
37	TMV-2	13.14	13.02	0.12	0.92
38	LOCAL-1	11.26	13.00	-1.74	-13.38
39	R-2001-3	13.54	15.38	-1.84	-11.96
40	G2-52	11.24	13.00	-1.76	-13.54

Table 9: Comparative overall mean performance of groundnut genotypes for physiological, biochemical and root related traits under moisture stress and normal moisture conditions

Characters	Normal Moisture	Moisture stress	Changes in mean value under stress condition compared to normal moisture	Change in per cent mean under moisture stress conditions compared to normal moisture
Relative water content (%)	75.66	56.16	-19.50	-25.77
Membrane stability index (%)	31.72	30.93	-0.79	-2.49
SPAD Chlorophyll Meter Reading	42.17	43.24	1.07	2.54
Per cent of wilted plants (%)	--	29.89		
Protein content of leaves (%)	0.74	0.79	0.05	6.81
Protein content seeds (%)	24.45	27.53	3.08	12.60
Phenolic content of leaves(µg/g)	369.50	376.19	6.69	1.81
Phenolic content of seeds (µg/g)	643.89	618.86	-25.03	-3.89
Oil content in seeds (%)	45.98	48.10	2.12	4.61
Root to shoot ratio	0.47	0.49	0.02	4.26
Root length (cm)	12.25	11.14	-1.11	-9.06

+ Sign indicates increase in mean value of the concerned trait in moisture stress condition over non-stress condition.

- Sign indicates decrease in mean value of the concerned trait in moisture stress condition over non-stress condition.

Table 10: Analysis of variance for yield and its component characters under normal moisture condition

Source of variance	d.f.	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
Replications	1	0.82	0.04	0.06	0.42	5.36	2.43	26.66	0.17	0.00	1.68
Genotypes	39	1.43**	6.76**	4.44**	9.82**	3.04**	3.43**	4.63**	0.34**	2.51**	3.73**
Error	39	0.70	1.93	1.91	3.21	0.37	0.24	0.30	0.03	0.04	0.25
S.Em		0.59	0.98	0.98	1.27	0.43	0.35	0.39	0.12	0.15	0.36
C.V. (%)		7.99	7.98	6.46	7.43	11.69	7.15	7.64	15.63	6.62	9.93
C.D. 5%		1.69	2.81	2.79	3.62	1.24	0.99	1.11	0.34	0.43	1.02
C.D. 1%		2.26	3.77	3.74	4.85	1.66	1.33	1.48	0.46	0.57	1.36

Source of variance	d.f.	X11	X12	X13	X14	X15	X16	X17
Replications	1	0.11	46.51	47.80	403.20	0.01	192.20	71.55
Genotypes	39	20.34**	13.93**	12.65**	1083.31**	0.06**	101.48**	52.66**
Error	39	0.93	1.69	5.63	359.86	0.01	30.46	28.82
S.Em		0.68	0.92	1.68	13.41	0.05	3.90	3.80
C.V. (%)		2.81	1.13	6.52	24.56	17.62	8.70	6.37
C.D. 5%		1.95	2.63	4.80	38.37	0.15	11.16	10.86
C.D. 1%		2.62	3.52	6.42	51.37	0.20	14.94	14.54

Table 10: Continued.,,

Source of variance	d.f.	X18	X19	X20	X21	X22	X23	X24	X25
Replications	1	140.45	1.68	6.61	0.04	15.84	1726739.59	48.67	0.54
Genotypes	39	31.60**	129.33**	95.04**	4.39**	65.18**	2595801.79**	137.05**	21.46**
Error	39	9.50	40.39	38.01	1.39	22.80	181619.48	57.35	11.13
S.E.m		2.18	4.49	4.36	0.83	3.38	301.35	5.35	2.36
C.V. (%)		7.06	12.48	16.30	12.36	9.11	18.81	8.21	11.84
C.D. 5%		6.23	12.85	12.47	2.38	9.66	862.01	15.32	6.75
C.D. 1%		8.35	17.21	16.69	3.19	12.93	1154.03	11.51	9.03

Where,

* - Significant at 5 %

** - Significant at 1 %

X1	Plant height at 30 DAS (cm)	X10	Secondary branches at harvest	X19	Number of pods per plant
X2	Plant height at 60 DAS (cm)	X11	Number of days to 50% flowering	X20	Number of mature pods per plant
X3	Plant height at 90 DAS (cm)	X12	Number of days to maturity	X21	Number of immature pods per plant
X4	Plant height at harvest (cm)	X13	Total seedling length (cm)	X22	Pod yield per plant (g)
X5	Primary branches at 60 DAS	X14	Fresh weight of seedling (g)	X23	Pod yield per hectare (kg)
X6	Primary branches at 90 DAS	X15	Harvest Index	X24	Number of kernels per plant
X7	Primary branches at harvest	X16	Shelling percentage (%)	X25	Kernel yield per plant (g)
X8	Secondary branches at 60 DAS	X17	Percentage of sound mature kernels (%)		
X9	Secondary branches at 90 DAS	X18	Hundred kernel weight (g)		

Table 11: Analysis of variance for various yield and its component characters under moisture stress condition

Source of variance	d.f.	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
Replications	1	0.86	7.97	172.20	0.04	0.57	2.46	0.05	0.05	0.02	0.0003
Genotypes	39	2.38**	4.60**	3.02**	8.40**	1.12**	1.23**	0.09**	0.09**	1.23**	1.16**
Error	39	0.54	1.13	1.73	4.92	0.24	0.14	0.03	0.03	0.05	0.04
S.Em		0.52	0.75	0.93	1.57	0.34	0.27	0.13	0.13	0.16	0.14
C.V. (%)		7.47	6.41	6.02	9.59	9.35	5.98	16.91	16.91	6.81	3.83
C.D. 5%		1.48	2.15	2.66	4.48	0.98	0.77	0.37	0.37	0.44	0.40
C.D. 1%		1.99	2.88	3.56	6.00	1.32	1.03	0.50	0.50	0.59	0.54

Source of variance	d.f.	X11	X12	X13	X14	X15	X16	X17
Replications	1	22.05	74.11	172.73	1049.37	0.0002	37.26	96.29
Genotypes	39	28.77**	16.03**	14.09**	358.90**	0.0052**	165.20**	37.57**
Error	39	0.95	1.27	7.70	16.40	0.0005	39.47	19.21
S.Em		0.69	0.80	1.96	2.86	0.02	4.44	3.10
C.V. (%)		2.75	0.99	8.35	6.47	10.05	10.87	5.28
C.D. 5%		1.97	2.28	5.61	8.19	0.04	12.71	8.87
C.D. 1%		2.64	3.05	7.51	10.96	0.06	17.01	11.87

Table 11: continued.,

Source of variance	d.f.	X18	X19	X20	X21	X22	X23	X24	X25
Replications	1	15.31	26.35	27.81	0.01	4.02	6.66	7.68	0.16
Genotypes	39	37.86**	25.21**	13.87**	1.77**	17.72**	1661.42**	51.92**	22.35**
Error	39	9.24	5.74	3.13	0.15	2.68	126.69	6.16	2.03
S.Em		2.15	1.69	1.25	0.28	1.16	7.96	1.75	1.01
C.V. (%)		7.22	16.41	12.45	18.78	14.27	14.44	12.73	15.59
C.D. 5%		6.15	4.84	3.58	0.79	3.31	22.77	5.02	2.88
C.D. 1%		8.23	6.49	4.79	1.05	4.43	30.48	6.72	3.86

Where,

* - Significant at 5 %

** - Significant at 1 %

X1	Plant height at 30 DAS (cm)	X10	Secondary branches at harvest	X19	Number of pods per plant
X2	Plant height at 60 DAS (cm)	X11	Number of days to 50% flowering	X20	Number of mature pods per plant
X3	Plant height at 90 DAS (cm)	X12	Number of days to maturity	X21	Number of immature pods per plant
X4	Plant height at harvest (cm)	X13	Total seedling length (cm)	X22	Pod yield per plant (g)
X5	Primary branches at 60 DAS	X14	Fresh weight of seedling (g)	X23	Pod yield per hectare (kg)
X6	Primary branches at 90 DAS	X15	Harvest Index	X24	Number of kernels per plant
X7	Primary branches at harvest	X16	Shelling percentage (%)	X25	Kernel yield per plant (g)
X8	Secondary branches at 60 DAS	X17	Percentage of sound mature kernels (%)		
X9	Secondary branches at 90 DAS	X18	Test weight (g)		

Table 12: Analysis of variance (G x E interaction) for physiological, biochemical and root attributes under normal moisture and drought conditions

Source of Variance	d.f.	X1	X2	X3	X4	X5	X6	X7	X8	X9
Replication	1	1.68	2.87	89.21	65.23	4.71	0.00	12.17	0.21	0.01
Genotype	39	3.18**	10.30**	4.08**	8.65**	3.58**	4.01**	5.45**	0.35**	3.60**
Environment (Drought)	1	16.07	27.05**	10.37**	14.62**	0.03**	11.68**	1.10**	0.02**	0.03**
G x E	39	0.63**	1.20	3.38**	2.32**	0.58	0.64	0.77**	0.07**	0.14**
Error (Residual)	79	0.61	1.61	2.85	1.25	0.32	0.25	0.42	0.03	0.05
Total	159									

Source of Variance	d.f.	X10	X11	X12	X13	X14	X15	X16	X17
Replication	1	0.82	9.51	119.03	206.23	75.80	0.00	15.62	166.92
Genotype	39	4.46**	46.60**	26.58**	23.81**	934.30**	0.03**	174.99**	79.30**
Environment (Drought)	1	0.85**	45.16	133.23**	403.02**	8542.50**	1.67**	1380.62**	67.54**
G x E	39	0.43**	2.52	3.38**	2.77**	507.90**	0.03**	82.51**	10.92**
Error (Residual)	79	0.16	1.09	1.48	7.17	203.20	0.00	38.75	23.72
Total	159								

Table 12: continued.,

Source of Variance	d.f.	X18	X19	X20	X21	X22	X23	X24	X25
Replication	1	31.51	12.16	3.65	0.04	1.95	41076816.00	8.85	0.65
Genotype	39	49.32**	110.15**	75.70**	4.25**	63.47**	378311.00**	137.80**	34.70**
Environment (Drought)	1	97.66	923.57	308.83	20.24	936.59	69778728.00	741.23	72.33
G × E	39	20.14	43.85	33.21	1.91	19.43	357573.00	51.16	9.12
Error (Residual)	79	10.82	24.11	20.70	0.76	12.81	955371.00	31.95	6.50
Total	159								

Where,

* - Significant at 5 %

** - Significant at 1 %

X1	Plant height at 30 DAS (cm)	X10	Secondary branches at harvest	X19	Number of pods per plant
X2	Plant height at 60 DAS (cm)	X11	Number of days to 50% flowering	X20	Number of mature pods per plant
X3	Plant height at 90 DAS (cm)	X12	Number of days to maturity	X21	Number of immature pods per plant
X4	Plant height at harvest (cm)	X13	Total seedling length (cm)	X22	Pod yield per plant per plant (g)
X5	Primary branches at 60 DAS	X14	Fresh weight of seedling (g)	X23	Pod yield per hectare (kg)
X6	Primary branches at 90 DAS	X15	Harvest index	X24	Number of kernels per plant
X7	Primary branches at harvest	X16	Shelling percentage (%)	X25	Kernel yield per plant (g)
X8	Secondary branches at 60 DAS	X17	Percentage of sound mature kernels (%)		
X9	Secondary branches at 90 DAS	X18	Test weight (g)		

4.2.2 Genetic parameters viz., mean, range, phenotypic and genotypic coefficient of variation, heritability, genetic advance and predicted genetic advance as per cent of mean.

The results with regard to overall mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2) and expected Genetic Advance as per cent of Mean (GAM) were computed for the yield and related traits studied in peanut genotypes under both normal moisture and managed drought situations is presented in tables 13 and 14, respectively.

4.2.2.1 Plant height at 30 days after sowing (cm)

Under normal moisture condition, plant height at 30 days after sowing varied from 9.32 to 13.23 cm with a mean of 10.45 cm. For this trait, phenotypic and genotypic coefficients of variation were 11.43 and 9.93 per cent, respectively and heritability estimate of 75.55 per cent with genetic advance over mean of 17.79 per cent was recorded.

However, under moisture stressed condition, the mean plant height at 30 days after sowing was 9.82 cm with a range of 8.38 to 12.08 cm. The PCV of 15.71 per cent, GCV of 14.80 per cent, heritability of 88.69 and genetic advance over mean of 28.71 per cent was exhibited by the genotypes for this trait.

4.2.2.2 Plant height at 60 days after sowing (cm)

The Plant height at 60 days after sowing under normal moisture condition was in the range of 14.35 to 22.13 cm with a mean of 17.42 cm. The genotypic and phenotypic coefficients of variation were 13.82 and 14.93 per cent, respectively. The heritability estimate was 85.70 per cent with a genetic advance over mean of 26.36 per cent was recorded for this trait.

On the other hand, under moisture stress condition, the mean plant height at 60 days after sowing was 16.62 cm with a range of 14.44 to 21.25 cm. The phenotypic and genotypic coefficients of variation were 12.91 and 12.09 per cent, respectively. The heritability estimate of 87.69 per cent with a genetic advance over mean of 23.32 per cent was recorded for this trait.

4.2.2.3 Plant height at 90 days after sowing (cm)

For plant height at 90 days after sowing, the accessions of groundnut exhibited a range of 18.80 to 24.87 cm with a mean of 21.37 cm. GCV (8.73 %), PCV (9.86 %) and heritability (78.52 %) with a genetic advance over mean of 15.94 per cent under moisture condition.

However, in moisture stressed condition, the mean plant height at 90 days after sowing was 21.88 cm with a range of 19.46 to 23.88 cm. The PCV and GCV were 7.95 and 6.71 per cent, respectively. The heritability (71.35 %) coupled with genetic advance over mean of 11.68 per cent were recorded.

Table 13: Estimates of Genetic parameters for yield and yield attributes under normal moisture condition

CHARACTERS	Mean	Range	GCV (%)	PCV (%)	h ² (%)	GAM (%)
Plant height at 30 DAS (cm)	10.45	9.32-13.23	9.93	11.43	75.55	17.79
Plant height at 60 DAS (cm)	17.42	14.35-22.13	13.82	14.93	85.70	26.36
Plant height at 90 DAS (cm)	21.37	18.80-24.87	8.73	9.86	78.52	15.94
Plant height at harvest (cm)	24.10	21.55-29.49	11.90	13.00	83.68	22.42
Primary branches at 60 DAS	5.23	4.40-11.75	32.32	33.36	93.86	64.49
Primary branches at 90 DAS	6.87	5.70-13.95	26.47	26.95	96.48	53.57
Primary branches at harvest	7.16	6.10-15.31	29.59	30.08	96.78	59.96
Secondary branches at 60 DAS	1.09	0.80-3.55	35.86	39.12	84.04	67.72
Secondary branches at 90 DAS	3.19	2.70-10.05	34.76	35.38	96.50	70.34
Secondary branches at harvest	5.07	3.80-13.20	25.99	27.82	87.27	50.02
Number of days to 50% flowering	34.34	29.50-42.50	9.07	9.50	91.23	17.85
Number of days to maturity	115.46	111.00-120.00	2.14	2.42	78.34	3.91
Total seedling length (cm)	36.42	31.80-41.91	8.38	9.70	74.50	14.89
Fresh weight of seedling (g)	77.23	31.60-116.20	38.92	42.62	83.39	73.22
Harvest index	0.42	0.17-0.72	37.96	41.85	82.27	70.92
Shelling percentage (%)	63.43	48.50-79.00	14.64	17.03	73.90	25.93
Sound mature kernels (%)	84.27	72.17-92.02	4.10	7.57	29.25	4.56
Test weight (g)	43.68	37.00-57.00	7.61	10.38	53.77	11.50
Number of pods per plant	19.57	8.00-35.50	34.08	47.08	52.41	50.83
Number of mature pods per plant	16.98	6.80-31.20	31.45	48.03	42.87	42.41
Number of immature pods per plant	2.78	0.40-6.20	44.06	61.12	51.96	65.42
Pod yield per plant (g)	16.32	6.40-26.60	44.95	49.48	82.51	84.11
Pod yield per hectare (kg)	1540.49	516.51-2919.58	47.56	61.17	60.46	76.18
Number of kernels per plant	23.80	10.50-42.50	43.74	49.19	79.08	80.13
Kernel yield per plant (g)	10.48	4.20-15.80	38.06	44.22	74.07	67.47

Table 14: Estimates of Genetic parameters for yield and yield attributes under moisture stress condition

Characters	Mean	Range	GCV (%)	PCV (%)	h ² (%)	GAM (%)
Plant height at 30 DAS (cm)	9.82	8.38-12.08	14.80	15.71	88.69	28.71
Plant height at 60 DAS (cm)	16.62	14.44-21.25	12.09	12.91	87.69	23.32
Plant height at 90 DAS (cm)	21.88	19.46-23.88	6.71	7.95	71.35	11.68
Plant height at harvest (cm)	23.11	19.15-28.53	10.54	12.54	70.72	18.26
Primary branches at 60 DAS	5.20	4.00-8.25	12.75	15.82	65.04	21.19
Primary branches at 90 DAS	6.33	5.20-9.53	11.62	13.07	79.05	21.28
Primary branches at harvest	7.32	6.20-11.62	11.50	12.83	80.27	21.22
Secondary branches at 60 DAS	1.09	0.80-2.15	22.56	25.53	78.06	41.05
Secondary branches at 90 DAS	3.22	2.80-8.00	24.82	25.28	96.38	50.19
Secondary branches at harvest	5.22	4.80-9.84	14.32	14.82	93.32	28.50
Number of days to 50% flowering	35.40	29.50-43.50	10.54	10.89	93.62	21.00
Number of days to maturity	113.64	108.50-119.50	2.39	2.59	85.35	4.55
Total seedling length (cm)	33.24	27.84-40.67	5.38	9.93	29.35	6.00
Fresh weight of seedling (g)	62.61	27.50-88.93	20.90	21.88	91.26	41.13
Harvest index	0.22	0.11-0.31	22.19	24.36	82.98	41.63
Shelling percentage (%)	57.79	43.00-76.00	13.72	17.50	61.43	22.15
Percentage of sound mature kernels (%)	82.97	70.01-92.39	6.42	7.43	74.72	11.44
Test weight (g)	42.11	35.00-57.00	8.98	11.52	60.78	14.43
Number of pods per plant	14.59	7.65-21.84	21.38	26.96	62.92	34.94
Number of mature pods per plant	14.20	9.11-23.35	16.32	20.53	63.19	26.72
Number of immature pods per plant	2.07	0.70-4.50	43.39	47.28	84.22	82.02
Pod yield per plant (g)	11.48	5.40-19.38	23.90	27.83	73.72	42.27
Pod yield per hectare (kg)	1321.03	690.91-1919.89	23.46	26.41	78.91	42.93
Number of kernels per plant	19.50	10.50-34.00	24.54	27.64	78.79	44.86
Kernel yield per plant (g)	9.13	5.00-19.00	34.90	38.23	83.36	65.65

4.2.2.4 Plant height at harvest (cm)

Under normal moisture condition, the mean value of plant height at harvest was 24.10 cm with a range of 21.55 to 29.49 cm. The phenotypic and genotypic coefficients of variation were 13.00 and 11.90 per cent, respectively. The heritability for the trait was 83.68 per cent with a genetic advance over mean of 22.42 per cent.

In case of moisture stressed situation, the plant height at harvest was in the range of 19.15 to 28.53 cm with a mean of 23.11 cm. The phenotypic and genotypic coefficients of variation were 12.54 and 10.54 per cent, respectively. The heritability estimate of 70.72 per cent coupled with genetic advance over mean of 18.26 per cent was observed for this trait.

The genotypes which have put up better plant height at harvest under moisture stress include TMV-2 (28.53 cm), K-6 (28.27 cm), K-9 (27.10 cm), GPBD-5 (26.26 cm) and KCG-6 (25.74 cm).

4.2.2.5 Primary branches at 60 days after sowing

The minimum and maximum primary branches at 60 days after sowing under normal moisture condition were 4.40 and 11.75, respectively with a mean 5.23. The phenotypic and genotypic coefficients of variation were 33.36 and 32.32 per cent, respectively. The heritability for the trait was 93.86 per cent with a genetic advance over mean of 64.49 per cent.

On the contrary, this trait under moisture stressed situation exhibited a mean of 5.20 with a range of 4.00 to 8.25. The phenotypic and genotypic coefficients of variation were 15.82 and 12.75 per cent, respectively. The heritability for the trait was 65.04 per cent with a genetic advance over mean of 21.19 per cent was noticed.

4.2.2.6 Primary branches at 90 days after sowing

In moisture condition, primary branches at 90 days after sowing were in the range of 5.70 to 13.95 with a mean 6.87. The phenotypic and genotypic coefficients of variation were 26.95 and 26.47 per cent, respectively. The heritability for the trait was 96.48 per cent with a genetic advance over mean of 53.57 per cent was observed.

Whereas, the mean primary branches at 90 days after sowing in moisture stressed situation was ranging from 5.20 to 9.53 with a mean of 6.33. The phenotypic and genotypic coefficients of variation were 13.07 and 11.62 per cent, respectively. The heritability estimate of 79.05 per cent coupled with a genetic advance over mean of 21.28 per cent was recorded for the trait.

4.2.2.7 Primary branches at harvest

Under normal moisture condition, the minimum and maximum values of primary branches at harvest were 6.10 and 15.31, respectively with a mean of 7.16.

The phenotypic and genotypic coefficients of variation were 30.08 and 29.59 per cent, respectively. The heritability for the trait was 96.78 per cent with a genetic advance over mean of 59.96 per cent.

However, the primary branches at harvest under moisture stressed situation ranged from 6.20 to 11.62 with a mean of 7.32. The phenotypic and genotypic coefficients of variation were 12.83 and 11.50 per cent, respectively. The heritability for the trait was 80.27 per cent with a genetic advance over mean of 21.22 per cent.

The genotypes which recorded more primary branches at harvest under stress condition include ICGV 15154 (11.62), ICGV 15143 (9.78), Dh-86 (7.90), Dh-101 (7.70) and VB-11 (7.70).

4.2.2.8 Secondary branches at 60 days after sowing

Under normal condition, secondary branches at 60 days after sowing varied from 0.80 to 3.55 with a mean of 1.09. For this trait, the phenotypic coefficient variation (39.12 %), genotypic coefficient (35.86 %), heritability (84.04 %) coupled with genetic advance over mean 67.72 per cent were recorded.

However, under moisture stressed environment, the mean secondary branches at 60 days after sowing was 1.09 with a range of 0.80 to 2.15. The genotypic and phenotypic coefficients of variation were 22.56 and 25.53 per cent, respectively. The broad sense heritability of 78.06 per cent combined with genetic advance over mean of 41.05 per cent was recorded for this trait.

4.2.2.9 Secondary branches at 90 days after sowing

The secondary branches at 90 days after sowing under normal moisture condition were in the range of 2.70 to 10.05 with a mean of 3.19. The genotypic and phenotypic coefficients of variation were 34.76 and 35.38 per cent, respectively. The heritability estimate was 96.50 per cent with a genetic advance over mean of 70.34 per cent was recorded for this trait.

On the other hand, under moisture stress condition, the mean secondary branches at 90 days after sowing was 3.22 with a range of 2.80 to 8.00. The phenotypic and genotypic coefficients of variation were 25.28 and 24.82 per cent, respectively. The heritability estimate of 96.38 per cent with a genetic advance over mean of 50.19 per cent was recorded for this trait.

4.2.2.10 Secondary branches at harvest

The minimum and maximum number of secondary branches at harvest under stress free condition were 3.80 and 13.20, respectively with a mean 5.07. The phenotypic and genotypic coefficients of variation were 27.82 and 25.99 per cent, respectively. The heritability for the trait was 87.27 per cent combined with a genetic advance over mean of 50.02 per cent was observed.

On the contrary, the secondary branches at harvest under stress situation were ranged from 4.80 to 9.84 with a mean of 5.22. The phenotypic and genotypic coefficients of variation were 14.82 and 14.32 per cent, respectively. The heritability for the trait was 93.32 per cent with a genetic advance over mean of 28.50 per cent.

The genotypes which recorded more secondary branches at harvest under stress condition include VB-14 (9.84), GPBD-4 (5.30), Dh-86 (5.30), Dh-101 (5.20) and K-9 (5.20).

4.2.2.11 Number of days to fifty per cent flowering

In normal moisture condition, number of days to fifty per cent flowering was in the range of 29.50 to 42.50 with a mean of 34.34. The phenotypic and genotypic coefficients of variation were 9.50 and 9.07 per cent, respectively. The broad sense heritability for the trait was 91.23 per cent with a genetic advance over mean of 17.85 per cent.

Whereas, the mean number of days to fifty per cent flowering was 35.40 in moisture stressed situation and it ranged from 29.50 to 43.50. The phenotypic and genotypic coefficients of variation were 10.89 and 10.54 per cent, respectively. The heritability of 93.62 per cent with a genetic advance over mean of 21.00 per cent was noticed for this trait.

4.2.2.12 Number of days to maturity

Under normal moisture condition, number of days to maturity exhibited a range of variation from 111 to 120 days with an overall mean of 115.46 days. The phenotypic and genotypic coefficients of variation were 2.42 and 2.14 per cent, respectively. The heritability estimate of 78.34 per cent with a genetic advance over mean of 3.91 per cent was recorded for this trait.

However, under moisture stressed situation, a marked variation was observed for this trait ranging from 108.50 to 119.50 days with a mean 113.64 days. The phenotypic and genotypic coefficients of variation were 2.59 and 2.39 per cent, respectively. The heritability for the trait was 85.35 per cent combined with a genetic advance over mean of 4.55 per cent was observed.

The genotypes showing early maturity under moisture stress condition includes ICGV 15148 (108.00), ICGV 15151 (108.50), LOCAL-1 (108.50), ICGV 15141 (109.50) and TMV-2 (110.00).

4.2.2.13 Total seedling length (cm)

Under normal moisture condition, total seedling length varied from 31.80 to 41.91 cm with a mean of 36.42 cm. For this trait, the phenotypic coefficient variation (9.70 %), genotypic coefficient (8.38 %), heritability (74.50 %) coupled with genetic advance over mean 14.89 per cent were recorded. However, under moisture stress, the

mean total seedling length was 33.24 cm with a range of 27.84 to 40.67 cm. The genotypic and phenotypic coefficients of variation were 5.38 and 9.93 per cent, respectively. Heritability (h^2) of 29.35 per cent with genetic advance over mean of 6.00 per cent was exhibited by the genotypes for this trait.

The following genotypes showed higher seedling length under moisture stress condition- TMV-2 (40.67 cm), K-6 (39.23 cm), K-9 (37.71 cm), GPBD-5 (37.24 cm) and KCG-6 (36.53 cm).

4.2.2.14 Fresh weight of the seedling (g)

The minimum and maximum values for fresh weight of the seedling under normal moisture condition were 31.60 and 116.20 g, respectively with a mean of 77.23 g. The estimates of phenotypic coefficient of variation (42.62 %) and genotypic coefficients of variation (38.92 %) were recorded. While, the heritability for the trait was 83.39 per cent with a genetic advance over mean of 73.22 per cent.

On the contrary, the fresh weight of the seedling under stressed situation was ranging from 27.50 to 88.93 g with a mean of 62.61 g. The phenotypic and genotypic coefficients of variation were 21.88 and 20.90 per cent, respectively. The heritability for the trait was 91.26 per cent with a genetic advance over mean of 41.13 per cent. The genotypes *viz.*, ICGV 15151 (88.93 g), TMV-2 (87.50 g), SB-1 (84.15 g), K-6 (78.28 g) and ICGV 15161 (76.82 g) showed high fresh weight of seedling under moisture stress condition.

4.2.2.15 Harvest index

The mean value of harvest index was 0.42 with a range of 0.17 to 0.72 under normal moisture condition. The phenotypic and genotypic coefficients of variation values were 41.85 and 37.96 per cent, respectively. While, the heritability estimate for the trait was 82.27 per cent combined with a genetic advance over mean of 70.92 per cent.

In case of moisture stressed situation, the Harvest index was ranging from 0.11 to 0.31 with a mean of 0.22. The phenotypic and genotypic coefficients of variation were 24.36 per cent and 22.19 per cent, respectively. The heritability for the trait was 82.98 per cent coupled with a genetic advance over mean of 41.63 per cent.

Some genotypes which have recorded high harvest index under stress environment include ICGV 15122 (0.31), ICGV 15145 (0.30), Dh-101 (0.30), ICGV 15149 (0.30) and ICGV 15152 (0.29).

4.2.2.16 Shelling percentage (%)

Under normal moisture, the shelling percentage varied from 48.50 to 79.00 per cent with a mean of 63.43 per cent. For this trait, the phenotypic coefficient variation (17.03 %), genotypic coefficient (14.64 %) and heritability (73.90 %) coupled with genetic advance over mean (25.93 %) were recorded.

However, under moisture stress, the mean shelling percentage was 57.79 per cent with a range of 43 to 76 per cent. The genotypic and phenotypic coefficients of variation were 17.50 and 13.72 per cent, respectively. Heritability estimate of 61.43 per cent with a genetic advance over mean of 22.15 per cent was exhibited by the genotypes for this trait.

The genotypes which have exhibited high shelling percentage under moisture stress include ICGV 15159 (76.00 %), ICGV 15141 (72.50 %), ICGV 15158 (71.00 %), Dh-234 (69.00 %) and R-2001-3 (66.00 %).

4.2.2.17 Percentage of sound mature kernels (%)

A marked variation was observed for this trait ranging from 72.17 to 92.02 per cent with a mean of 84.27 per cent under normal moisture condition. The phenotypic and genotypic coefficients of variation were 7.57 and 4.10 per cent, respectively. The heritability for the trait was 29.25 per cent with a genetic advance over mean of 4.56 per cent.

However, in moisture stressed condition, sound mature kernels exhibited a range of variation from 70.01 to 92.39 per cent with an overall mean of 82.97 per cent. The phenotypic and genotypic coefficients of variation were 7.43 and 6.42 per cent, respectively. The heritability for the trait was 74.72 per cent with a genetic advance over mean of 11.44 per cent.

The genotypes viz., TMV-2 (92.39 %), ICGV 15120 (89.20 %), VB (89.70 %), LOCAL-1 (89.37 %) and SB-15 (88.49 %) showed high percentage of sound mature kernels under managed drought condition.

4.2.2.18 Test weight (g)

The test weight was in the range of 37 to 57 g with a mean of 43.68 g under normal moisture condition. The estimates of phenotypic and genotypic coefficients of variation were 10.38 and 7.61 per cent, respectively. The heritability for the trait was 53.77 per cent with a genetic advance over mean of 11.50 per cent.

On other hand, under moisture stress, the lowest and highest values for this trait were 35.00 and 57.00 g, respectively with an overall mean of 42.11 g. The phenotypic and genotypic coefficients of variation were 11.52 and 8.98 per cent, respectively. The heritability for the trait was 60.78 per cent with a genetic advance over mean of 14.43 per cent.

Some genotypes which have recorded high test weight under stress environment include VB-14 (57.00 g), Dh-86 (52.00 g), SB-14 (51.00 g), Dh-234 (49.00 g) and ICGV 15138 (49.00 g).

4.2.2.19 Number of pods per plant

In normal moisture condition, the mean number of pods per plant was 19.57 with a range of 8.00 to 35.50. The phenotypic and genotypic coefficients of variation

were 47.08 and 34.08 per cent, respectively. The heritability for the trait was 52.41 per cent with a genetic advance over mean of 50.83 per cent.

Number of pods per plant in moisture stress was in the range of 7.65 to 21.84 with a mean of 14.59. The phenotypic and genotypic coefficients of variation were 26.96 and 21.38 per cent, respectively. The heritability for this trait was 62.92 per cent with a genetic advance over mean of 34.94 per cent.

Genotypes that have recorded more number of pods per plant under moisture stress are ICGV 15151 (21.84), SB-14 (21.10), ICGV 15152 (20.20), ICGV 15145 (20.04) and ICGV 15146 (19.48).

4.2.2.20 Number of mature pods per plant

Number of mature pods per plant was in the range of 6.80 to 31.20 with a mean of 16.98. GCV (31.45 %), PCV (48.03 %) and heritability (42.87 %) with a genetic advance over mean of 42.41 per cent was recorded under normal moisture condition.

However, in moisture stressed condition, the mean number of mature pods per plant was 14.20 with a range of 9.11 to 23.35. The GCV (16.32 %), PCV (20.53 %), heritability (63.19 %) with a genetic advance over mean of 26.72 per cent were recorded.

Genotypes that have recorded more number of mature pods per plant under moisture stress are ICGV 15145 (23.35), ICGV 15152 (18.98), ICGV 15151 (17.98), ICGV 15148 (17.67) and ICGV 15141 (17.30).

4.2.2.21 Number of immature pods per plant

Under normal moisture condition, the number of immature pods per plant varied from 0.40 to 6.20 with a mean of 2.78 per cent. For this trait, GCV (44.06 %), PCV (61.12 %), and heritability (51.96 %) with a genetic advance over mean of 65.42 per cent was recorded.

While, in stressed environment, the mean number of immature pods per plant was 2.07 with a range of 0.70 to 4.50. The GCV (43.39 %), PCV (47.28 %), heritability (84.22 %) and genetic advance over mean of 82.02 per cent was exhibited by the genotypes for this trait.

Under moisture stress condition, the genotypes viz., VB-14 (0.70), K-6 (0.70), TMV-2 (0.90), ICGV 15141 (1.10) and ICGV 15159 (1.11) have recorded more number of immature pods per plant.

4.2.2.22 Pod yield per plant (g)

The minimum and maximum values of pod yield per plant under normal moisture condition were 6.40 g and 26.60 g, respectively with a mean of 16.32 g. The estimates of PCV (49.48 %) and GCV (44.95 %) were recorded. The heritability for this trait was 82.51 per cent with a genetic advance over mean of 84.11 per cent.

On the contrary, the pod yield per plant under moisture stressed situation was ranging from 5.40 to 19.38 g with a mean of 11.48 g. The phenotypic and genotypic coefficients of variation were 27.83 and 23.90 per cent, respectively. The heritability for the trait was 73.72 per cent with a genetic advance over mean of 42.27 per cent.

Some genotypes which have recorded high pod yield per plant under stress environment include SB-14 (19.38 g), ICGV 15151 (19.15 g), ICGV 15141 (17.45 g), ICGV 15138 (15.00 g) and ICGV 15145 (14.88 g).

4.2.2.23 Pod yield per hectare (kg/ha)

The minimum and maximum values of pod yield per hectare under normal moisture condition were 516.51 and 2919.58 kg/ha with a mean of 1540.49 kg/ha. The estimates of phenotypic coefficient of variation (61.17 %) and genotypic coefficients of variation (47.56 %) were recorded. The heritability for this trait was 60.46 per cent with a genetic advance over mean of 76.18 per cent.

However, the pod yield per hectare in stressed situation was ranging from 690.91 to 1919.89 kg/ha with a mean of 1321.03 kg/ha. The phenotypic and genotypic coefficients of variation were 26.41 and 23.46 per cent, respectively. The heritability for the trait was 78.91 per cent with a genetic advance over mean of 42.93 per cent.

Under moisture stress condition, ICGV 15141 (1546.79 kg/ha), ICGV 15146 (1919.89 kg/ha), ICGV 15145 (1178.61 kg/ha), ICGV 15138 (1148.66 kg/ha) and Dh-234 (1247.06 kg/ha) have recorded higher yield.

4.2.2.24 Number of kernels per plant

Under normal moisture condition, the number of kernels varied from 10.50 to 42.50 with a mean of 23.80. For this trait, the phenotypic coefficient variation (49.19 %), genotypic coefficient (43.74 %), heritability (79.08 %) coupled with a genetic advance over mean 80.13 per cent were recorded.

Whereas under stressed environment, the mean number of kernels per plant was 19.50 with a range of 10.50 to 34.00. The genotypic and phenotypic coefficients of variation were 24.54 and 27.64 per cent, respectively. The heritability of 78.79 per cent with a genetic advance over mean of 44.86 per cent was exhibited by the genotypes for this trait.

Genotypes that have recorded more number of kernels per plant under moisture stress are ICGV 15124 (34.00), ICGV 15151 (28.78), ICGV 15159 (27.00), ICGV 15145 (25.70) and ICGV 15148 (25.05)

4.2.2.25 Kernel yield per plant (g)

The kernel yield per plant under normal moisture condition was in the range of 4.20 to 15.80 g with a mean of 10.48 g. The genotypic and phenotypic coefficients of variation were 38.06 and 44.22 per cent, respectively. The heritability estimate was

74.07 per cent with a genetic advance over mean of 67.47 per cent was recorded for this trait.

On the other hand, under stress condition, the mean kernel yield per plant was 9.13 g with a range of 5.00 to 19.00 g. The phenotypic and genotypic coefficients of variation were 38.23 and 34.90 per cent, respectively. The heritability estimate of 83.36 per cent with a genetic advance over mean of 65.65 per cent was recorded for this trait.

Under moisture stress condition, the genotypes viz., ICGV 15148 (19.00 g), SB-1 (18.11 g), ICGV 15154 (13.60 g), ICGV 15124 (13.60 g) and ICGV 15141 (13.00 g) recorded high kernel yield per plant.

Comparative statement based on estimates of different genetic parameters for yield component characters in groundnut genotypes under stress condition is presented in the table 15. The comparative performance of forty genotypes for yield components under normal moisture and moisture stress condition is presented in the table 16. The comparative overall mean performance of the genotypes for drought related parameters under both the conditions is presented in the table 17.

The genotypes which recorded high yield under normal moisture condition along with their yield under moisture stress are presented in the table 30. Further, the genotypes which recorded high yield under moisture stress and their yield under normal condition is presented in the table 31. The drought tolerant genotypes identified in the field experiment are presented in table 32.

4.2.3 Drought tolerance indices

To assess the degree of susceptibility and tolerance to drought stress, the STI (DTI), DSI (SSI) indices for pod yield per plant (g), root length (cm), plant height (cm) and kernel yield per plant (g) were calculated for groundnut genotypes which were evaluated in the present study.

4.2.3.1 Drought tolerance index (DTI) for pod yield per plant

The drought tolerance index and drought susceptibility index and drought tolerance efficiency value for pod yield per plant of each of the forty genotypes is presented in the table 18.

The mean drought tolerance index for pod yield per plant was 1.14 with a range of 0.31 to 2.78.

4.2.3.2 Drought Susceptibility index (DSI) for pod yield per plant

Drought Susceptibility index (DSI) for pod yield per plant was ranging from -3.59 to 2.73 with a mean of 0.97.

Table 15: Comparative statement based on estimates of different genetic parameters for yield and yield attributes under moisture stress condition

Character	Genetic parameters				Gene effects	Effect of environment
	GCV (%)	PCV (%)	Heritability (%)	GAM (%)		
Plant height at 30 DAS (cm)	Moderate	Moderate	High	High	Additive	Low
Plant height at 60 DAS (cm)	Moderate	Moderate	High	High	Additive	Low
Plant height at 90 DAS (cm)	Low	Low	High	Moderate	Additive	Low
Plant height at harvest (cm)	Moderate	Moderate	High	Moderate	Additive	Low
Primary branches at 60 DAS	Moderate	Moderate	High	High	Additive	Low
Primary branches at 90 DAS	Moderate	Moderate	High	High	Additive	Low
Primary branches at harvest	Moderate	Moderate	High	High	Additive	Low
Secondary branches at 60 DAS	High	High	High	High	Additive	Low
Secondary branches at 90 DAS	High	High	High	High	Additive	Low
Secondary branches at harvest	Moderate	Moderate	High	High	Additive	Low
Number of days to 50% flowering	High	High	High	High	Additive	Low
Number of days to maturity	Low	Low	High	Low	Non-Additive	Low
Total seedling length (cm)	Low	Low	High	Low	No- Additive	Low
Fresh weight of seedling (g)	High	High	High	High	Additive	Low
Harvest index	High	High	High	High	Additive	Low
Root to shoot ratio	High	High	High	High	Additive	Low
Root length (cm)	High	High	High	High	Additive	Low
Shelling percentage (%)	Moderate	Moderate	High	High	Additive	Low

Table 15: Continued.,

Percentage of sound mature kernels (%)	Low	Low	High	Moderate	Moderate	Additive	Low
Test weight (g)	Low	Moderate	Moderate	Moderate	Moderate	Additive and Non-additive	Medium
Number of pods per plant	High	High	High	High	High	Additive	Low
Number of mature pods per plant	Moderate	High	High	High	High	Additive	Low
Number of immature pods per plant	High	High	High	High	High	Additive	Low
Pod yield per plant (g)	High	High	High	High	High	Additive	Low
Pod yield per hectare (kg)	High	High	High	High	High	Additive	Low
Number of kernels per plant	High	High	High	High	High	Additive	Low
Kernel yield per plant (g)	High	High	High	High	High	Additive	Low

Table 16: Comparative mean performance of forty groundnut genotypes under moisture stress and normal moisture conditions for yield and yield attributes

Sl. No.	Genotype	Plant height at harvest (cm)				Primary branches at harvest			
		Stress	Non stress	Mean reduction	Change in % mean	Stress	Non stress	Mean reduction	Change in % mean
1	ICGV 15114	21.37	21.89	-0.52	-2.40	7.20	6.60	0.60	9.09
2	ICGV 15119	22.45	23.56	-1.11	-4.71	6.80	6.90	-0.10	-1.45
3	ICGV 15120	24.08	25.70	-1.62	-6.30	7.40	6.90	0.50	7.25
4	ICGV 15122	24.45	25.20	-0.75	-2.98	7.00	6.90	0.10	1.45
5	ICGV 15123	22.83	24.20	-1.37	-5.67	7.30	6.80	0.50	7.35
6	ICGV 15124	21.33	23.96	-2.63	-10.98	7.00	6.80	0.20	2.94
7	ICGV 15138	22.47	22.85	-0.38	-1.66	7.50	6.80	0.70	10.29
8	ICGV 15141	23.94	26.48	-2.54	-9.59	7.40	7.00	0.40	5.71
9	ICGV 15143	21.42	22.04	-0.62	-2.81	9.78	11.30	-1.53	-13.50
10	ICGV 15145	21.34	21.99	-0.65	-2.96	7.20	6.60	0.60	9.09
11	ICGV 15146	22.19	22.48	-0.29	-1.29	7.00	7.40	-0.40	-5.41
12	ICGV 15148	21.58	23.33	-1.75	-7.50	7.35	6.90	0.45	6.52
13	ICGV 15149	21.44	22.97	-1.53	-6.66	6.90	7.50	-0.60	-8.00
14	ICGV 15151	21.97	22.25	-0.28	-1.26	6.20	7.00	-0.80	-11.43
15	ICGV 15152	21.54	21.66	-0.12	-0.55	6.70	7.00	-0.30	-4.29
16	ICGV 15153	19.15	21.85	-2.70	-12.36	7.10	6.50	0.60	9.23
17	ICGV 15154	20.88	21.55	-0.68	-3.13	11.62	15.31	-3.70	-24.13
18	ICGV 15158	21.54	22.99	-1.45	-6.31	6.60	7.40	-0.80	-10.81
19	ICGV 15159	21.96	23.37	-1.41	-6.03	7.00	6.90	0.10	1.45
20	ICGV 15161	21.66	22.08	-0.42	-1.90	7.20	7.00	0.20	2.86
21	SB-1	22.34	22.59	-0.25	-1.11	7.05	7.00	0.05	0.71
22	SB-14	23.92	24.82	-0.90	-3.63	7.40	6.70	0.70	10.45
23	SB-15	22.33	23.34	-1.01	-4.33	6.75	6.80	-0.05	-0.74
24	SB-17	23.04	23.10	-0.06	-0.26	7.60	6.70	0.90	13.43
25	VB	23.96	22.23	1.73	7.78	7.40	6.60	0.80	12.12
26	VB-11	22.94	23.04	-0.10	-0.43	7.70	6.80	0.90	13.24
27	VB-14	22.67	24.57	-1.90	-7.73	7.00	7.10	-0.10	-1.41
28	DH-86	21.76	22.14	-0.38	-1.72	7.90	6.70	1.20	17.91
29	DH-101	24.67	23.94	0.73	3.05	7.70	6.60	1.10	16.67
30	DH-234	25.42	25.87	-0.45	-1.74	7.00	6.70	0.30	4.48
31	K-9	27.10	29.49	-2.39	-8.10	7.70	6.60	1.10	16.67
32	K-6	28.27	28.48	-0.21	-0.74	6.70	7.00	-0.30	-4.29
33	GPBD-4	23.10	23.95	-0.85	-3.55	6.20	6.90	-0.70	-10.14
34	GPBD-5	26.26	26.49	-0.23	-0.87	7.20	6.70	0.50	7.46
35	KCG-6	25.74	26.38	-0.64	-2.43	7.10	6.50	0.60	9.23
36	KCG-2	25.72	27.84	-2.12	-7.61	6.90	7.00	-0.10	-1.43
37	TMV-2	28.53	28.81	-0.28	-0.97	7.20	6.60	0.60	9.09
38	LOCAL-1	21.93	28.52	-6.59	-23.11	7.30	6.10	1.20	19.67
39	R-2001-3	23.33	23.99	-0.66	-2.75	7.30	7.00	0.30	4.29
40	G2-52	21.91	22.04	-0.13	-0.59	7.50	6.60	0.90	13.64

Table 16: Continued.,

Sl. No.	Genotype	Secondary branches at harvest				Number of days to maturity			
		Stress	Non Stress	Mean Reduction	Change in % mean	Stress	Non Stress	Mean Reduction	Change in % mean
1	ICGV 15114	5.00	4.90	0.10	2.04	110.50	114.50	-4.00	-3.49
2	ICGV 15119	5.20	5.20	0.00	0.00	114.50	117.00	-2.50	-2.14
3	ICGV 15120	4.90	4.70	0.20	4.26	114.00	117.50	-3.50	-2.98
4	ICGV 15122	4.80	5.00	-0.20	-4.00	116.00	116.50	-0.50	-0.43
5	ICGV 15123	5.20	5.00	0.20	4.00	113.50	116.00	-2.50	-2.16
6	ICGV 15124	5.20	5.10	0.10	1.96	111.50	114.00	-2.50	-2.19
7	ICGV 15138	4.80	4.90	-0.10	-2.04	114.50	116.50	-2.00	-1.72
8	ICGV 15141	5.20	5.00	0.20	4.00	109.50	111.50	-2.00	-1.79
9	ICGV 15143	5.00	4.20	0.80	19.05	116.00	118.50	-2.50	-2.11
10	ICGV 15145	5.10	5.10	0.00	0.00	114.50	116.50	-2.00	-1.72
11	ICGV 15146	5.10	4.90	0.20	4.08	112.50	115.50	-3.00	-2.60
12	ICGV 15148	5.20	4.90	0.30	6.12	108.50	111.50	-3.00	-2.69
13	ICGV 15149	5.10	4.90	0.20	4.08	110.50	113.50	-3.00	-2.64
14	ICGV 15151	4.90	3.80	1.10	28.95	108.50	111.00	-2.50	-2.25
15	ICGV 15152	5.20	5.00	0.20	4.00	114.00	115.00	-1.00	-0.87
16	ICGV 15153	5.10	4.90	0.20	4.08	116.00	119.50	-3.50	-2.93
17	ICGV 15154	4.90	4.70	0.20	4.26	110.50	114.00	-3.50	-3.07
18	ICGV 15158	5.20	5.00	0.20	4.00	111.50	115.50	-4.00	-3.46
19	ICGV 15159	5.20	5.00	0.20	4.00	114.00	117.50	-3.50	-2.98
20	ICGV 15161	5.10	4.00	1.10	27.50	114.50	118.00	-3.50	-2.97
21	SB-1	5.10	5.00	0.10	2.00	115.00	119.50	-4.50	-3.77
22	SB-14	5.20	5.00	0.20	4.00	119.50	119.00	0.50	0.42
23	SB-15	5.10	4.80	0.30	6.25	114.00	113.50	0.50	0.44
24	SB-17	5.00	5.20	-0.20	-3.85	116.00	119.50	-3.50	-2.93
25	VB	5.10	5.20	-0.10	-1.92	118.50	118.50	0.00	0.00
26	VB-11	5.20	4.80	0.40	8.33	116.50	120.00	-3.50	-2.92
27	VB-14	9.84	13.20	-3.36	-25.45	119.50	119.50	0.00	0.00
28	DH-86	5.30	5.10	0.20	3.92	115.00	114.00	1.00	0.88
29	DH-101	5.20	5.00	0.20	4.00	114.00	113.00	1.00	0.88
30	DH-234	5.10	5.10	0.00	0.00	111.00	114.50	-3.50	-3.06
31	K-9	5.20	5.00	0.20	4.00	116.00	116.00	0.00	0.00
32	K-6	5.10	5.10	0.00	0.00	112.50	114.00	-1.50	-1.32
33	GPBD-4	5.30	5.10	0.20	3.92	111.50	113.00	-1.50	-1.33
34	GPBD-5	5.10	5.30	-0.20	-3.77	114.50	114.00	0.50	0.44
35	KCG-6	5.00	4.80	0.20	4.17	112.00	113.50	-1.50	-1.32
36	KCG-2	5.00	3.90	1.10	28.21	115.50	114.00	1.50	1.32
37	TMV-2	5.20	4.80	0.40	8.33	110.00	109.00	1.00	0.92
38	LOCAL-1	5.20	4.90	0.30	6.12	108.50	114.00	-5.50	-4.82
39	R-2001-3	4.90	4.20	0.70	16.67	115.00	115.00	0.00	0.00
40	G2-52	5.10	5.10	0.00	0.00	116.00	115.50	0.50	0.43

Table 16: Continued.,

Sl. No.	Genotype	Total seedling length (cm)				Fresh weight of seedlings (g)			
		Stress	Non stress	Mean reduction	Change in % mean	Stress	Non stress	Mean reduction	Change in % mean
1	ICGV 15114	29.26	31.80	-2.55	-8.00	43.00	46.00	-3.00	-6.52
2	ICGV 15119	32.00	36.03	-4.03	-11.19	63.35	84.10	-20.75	-24.67
3	ICGV 15120	33.96	36.96	-3.00	-8.11	57.60	53.80	3.80	7.06
4	ICGV 15122	34.08	37.41	-3.33	-8.90	63.09	79.00	-15.91	-20.14
5	ICGV 15123	32.64	36.12	-3.48	-9.64	41.70	83.80	-42.10	-50.24
6	ICGV 15124	31.93	36.42	-4.49	-12.34	62.70	74.70	-12.00	-16.06
7	ICGV 15138	32.18	34.66	-2.48	-7.14	69.75	101.20	-31.45	-31.08
8	ICGV 15141	35.52	39.33	-3.81	-9.70	70.80	85.00	-14.20	-16.71
9	ICGV 15143	30.12	34.65	-4.53	-13.07	62.29	110.40	-48.11	-43.58
10	ICGV 15145	30.83	33.61	-2.78	-8.27	67.68	95.70	-28.02	-29.28
11	ICGV 15146	32.20	34.89	-2.69	-7.71	59.79	116.20	-56.41	-48.55
12	ICGV 15148	31.71	35.90	-4.19	-11.67	50.18	102.10	-51.92	-50.85
13	ICGV 15149	31.66	35.45	-3.79	-10.69	65.04	111.70	-46.66	-41.77
14	ICGV 15151	31.57	35.08	-3.51	-10.02	88.93	87.60	1.33	1.52
15	ICGV 15152	30.96	34.43	-3.47	-10.07	53.59	81.40	-27.81	-34.16
16	ICGV 15153	27.84	34.75	-6.91	-19.89	50.28	108.20	-57.92	-53.53
17	ICGV 15154	30.89	33.16	-2.27	-6.86	72.27	97.20	-24.93	-25.65
18	ICGV 15158	30.97	35.20	-4.23	-12.03	74.37	110.60	-36.24	-32.76
19	ICGV 15159	31.56	35.61	-4.05	-11.36	71.14	101.20	-30.06	-29.70
20	ICGV 15161	29.89	34.46	-4.57	-13.26	76.82	97.00	-20.18	-20.80
21	SB-1	33.17	35.50	-2.33	-6.57	84.15	107.40	-23.26	-21.65
22	SB-14	34.04	37.64	-3.60	-9.55	62.96	102.40	-39.44	-38.52
23	SB-15	34.00	36.47	-2.47	-6.77	61.26	59.10	2.16	3.65
24	SB-17	33.95	36.57	-2.62	-7.17	70.69	73.00	-2.31	-3.16
25	VB	32.36	34.42	-2.06	-5.98	57.47	46.20	11.27	24.38
26	VB-11	33.07	34.18	-1.11	-3.24	42.39	67.60	-25.21	-37.29
27	VB-14	34.06	36.53	-2.47	-6.77	71.56	67.20	4.36	6.49
28	DH-86	33.27	32.96	0.31	0.93	48.74	31.60	17.14	54.24
29	DH-101	33.35	33.93	-0.58	-1.70	68.24	58.80	9.44	16.05
30	DH-234	35.40	37.37	-1.97	-5.28	75.02	73.60	1.42	1.93
31	K-9	37.71	40.36	-2.65	-6.57	70.20	63.10	7.10	11.25
32	K-6	39.23	41.51	-2.28	-5.48	78.28	58.80	19.48	33.13
33	GPBD-4	33.31	36.82	-3.51	-9.54	39.10	36.60	2.50	6.83
34	GPBD-5	37.24	38.46	-1.22	-3.16	56.70	54.20	2.50	4.61
35	KCG-6	36.53	40.20	-3.67	-9.13	49.56	73.40	-23.84	-32.48
36	KCG-2	36.31	39.85	-3.54	-8.88	69.68	48.00	21.68	45.16
37	TMV-2	40.67	41.56	-0.89	-2.14	87.50	59.60	27.90	46.81
38	LOCAL-1	32.19	41.91	-9.72	-23.20	59.45	67.70	-8.25	-12.19
39	R-2001-3	35.87	39.37	-3.50	-8.89	59.66	67.80	-8.15	-12.01
40	G2-52	32.15	35.08	-2.93	-8.35	27.50	46.00	-18.50	-40.22

Table 16: Continued.,

Sl. No.	Genotype	Harvest index				Shelling percentage (%)			
		Stress	Non stress	Mean reduction	Change in % mean	Stress	Non stress	Mean reduction	Change in % mean
1	ICGV 15114	0.11	0.31	-0.20	-65.20	61.00	64.00	-3.00	-4.69
2	ICGV 15119	0.21	0.32	-0.10	-33.03	63.50	64.00	-0.50	-0.78
3	ICGV 15120	0.23	0.21	0.02	7.63	64.00	70.00	-6.00	-8.57
4	ICGV 15122	0.31	0.50	-0.19	-38.23	56.50	53.50	3.00	5.61
5	ICGV 15123	0.28	0.32	-0.04	-12.01	61.00	57.00	4.00	7.02
6	ICGV 15124	0.19	0.49	-0.30	-61.57	65.50	48.50	17.00	35.05
7	ICGV 15138	0.27	0.51	-0.24	-46.23	63.50	62.00	1.50	2.42
8	ICGV 15141	0.27	0.32	-0.04	-13.56	72.50	64.00	8.50	13.28
9	ICGV 15143	0.24	0.31	-0.07	-22.03	43.00	50.00	-7.00	-14.00
10	ICGV 15145	0.30	0.57	-0.27	-47.02	59.00	65.00	-6.00	-9.23
11	ICGV 15146	0.24	0.66	-0.42	-63.83	65.00	69.00	-4.00	-5.80
12	ICGV 15148	0.25	0.71	-0.46	-64.43	52.00	60.00	-8.00	-13.33
13	ICGV 15149	0.30	0.18	0.11	62.35	64.00	58.00	6.00	10.34
14	ICGV 15151	0.26	0.62	-0.35	-57.35	51.00	57.50	-6.50	-11.30
15	ICGV 15152	0.29	0.70	-0.42	-59.22	45.50	49.00	-3.50	-7.14
16	ICGV 15153	0.18	0.72	-0.54	-74.38	47.00	50.50	-3.50	-6.93
17	ICGV 15154	0.23	0.57	-0.34	-59.72	46.00	61.00	-15.00	-24.59
18	ICGV 15158	0.25	0.68	-0.43	-63.77	71.00	74.00	-3.00	-4.05
19	ICGV 15159	0.19	0.59	-0.39	-67.00	76.00	65.00	11.00	16.92
20	ICGV 15161	0.15	0.40	-0.26	-63.60	63.00	67.00	-4.00	-5.97
21	SB-1	0.17	0.68	-0.51	-74.94	50.50	63.00	-12.50	-19.84
22	SB-14	0.19	0.70	-0.51	-72.39	46.00	60.00	-14.00	-23.33
23	SB-15	0.20	0.43	-0.23	-53.33	48.00	63.00	-15.00	-23.81
24	SB-17	0.17	0.49	-0.32	-65.31	49.00	67.00	-18.00	-26.87
25	VB	0.23	0.31	-0.08	-25.47	43.00	70.00	-27.00	-38.57
26	VB-11	0.15	0.34	-0.20	-56.80	48.50	64.00	-15.50	-24.22
27	VB-14	0.20	0.19	0.01	2.99	61.00	64.00	-3.00	-4.69
28	DH-86	0.23	0.30	-0.07	-23.46	56.50	57.00	-0.50	-0.88
29	DH-101	0.30	0.38	-0.09	-22.19	49.00	68.00	-19.00	-27.94
30	DH-234	0.23	0.48	-0.25	-52.83	69.00	69.00	0.00	0.00
31	K-9	0.19	0.34	-0.15	-43.98	60.00	73.00	-13.00	-17.81
32	K-6	0.13	0.29	-0.16	-53.85	46.00	64.00	-18.00	-28.13
33	GPBD-4	0.19	0.34	-0.16	-45.55	50.00	63.00	-13.00	-20.63
34	GPBD-5	0.15	0.24	-0.09	-36.84	62.00	66.00	-4.00	-6.06
35	KCG-6	0.23	0.32	-0.09	-29.17	65.00	70.00	-5.00	-7.14
36	KCG-2	0.23	0.24	-0.01	-3.07	57.50	74.00	-16.50	-22.30
37	TMV-2	0.16	0.35	-0.19	-54.70	66.00	79.00	-13.00	-16.46
38	LOCAL-1	0.24	0.31	-0.07	-22.77	62.00	73.00	-11.00	-15.07
39	R-2001-3	0.23	0.30	-0.07	-22.60	66.00	62.00	4.00	6.45
40	G2-52	0.15	0.17	-0.02	-10.40	57.00	59.00	-2.00	-3.39

Table 16: Continued.,

Sl. No.	Genotype	Percentage of sound mature kernels (%)				Test weight (g)			
		Stress	Non stress	Mean reduction	Change in % mean	Stress	Non Stress	Mean reduction	Change in % mean
1	ICGV 15114	80.91	84.69	-3.77	-4.46	40.50	40.50	0.00	0.00
2	ICGV 15119	78.54	74.60	3.94	5.29	40.00	39.50	0.50	1.27
3	ICGV 15120	89.88	91.12	-1.24	-1.36	35.00	42.50	-7.50	-17.65
4	ICGV 15122	81.64	77.32	4.32	5.59	43.00	42.00	1.00	2.38
5	ICGV 15123	78.98	83.38	-4.39	-5.27	42.00	43.00	-1.00	-2.33
6	ICGV 15124	87.91	87.35	0.56	0.64	41.00	44.00	-3.00	-6.82
7	ICGV 15138	84.24	84.19	0.05	0.06	49.00	50.00	-1.00	-2.00
8	ICGV 15141	81.29	83.71	-2.42	-2.89	41.00	51.00	-10.00	-19.61
9	ICGV 15143	82.06	87.37	-5.31	-6.07	43.00	44.00	-1.00	-2.27
10	ICGV 15145	86.47	90.05	-3.58	-3.97	39.00	41.00	-2.00	-4.88
11	ICGV 15146	82.44	86.76	-4.32	-4.98	44.00	42.00	2.00	4.76
12	ICGV 15148	75.29	80.31	-5.03	-6.26	44.50	42.00	2.50	5.95
13	ICGV 15149	83.88	85.23	-1.35	-1.58	37.00	39.50	-2.50	-6.33
14	ICGV 15151	85.94	78.04	7.90	10.12	41.50	44.00	-2.50	-5.68
15	ICGV 15152	81.61	85.98	-4.37	-5.08	38.00	45.00	-7.00	-15.56
16	ICGV 15153	84.93	89.74	-4.81	-5.36	38.00	46.00	-8.00	-17.39
17	ICGV 15154	83.41	86.36	-2.94	-3.41	39.00	40.00	-1.00	-2.50
18	ICGV 15158	86.45	86.03	0.42	0.49	39.50	40.00	-0.50	-1.25
19	ICGV 15159	70.01	72.17	-2.16	-2.99	42.50	37.00	5.50	14.86
20	ICGV 15161	83.74	76.85	6.89	8.96	41.00	39.00	2.00	5.13
21	SB-1	78.11	73.18	4.93	6.73	39.00	47.00	-8.00	-17.02
22	SB-14	84.58	88.72	-4.13	-4.66	51.00	57.00	-6.00	-10.53
23	SB-15	88.49	88.01	0.48	0.54	38.50	47.00	-8.50	-18.09
24	SB-17	81.56	82.37	-0.81	-0.99	38.00	42.00	-4.00	-9.52
25	VB	89.70	92.02	-2.31	-2.51	38.00	37.50	0.50	1.33
26	VB-11	83.58	84.12	-0.54	-0.64	41.00	43.50	-2.50	-5.75
27	VB-14	83.52	86.55	-3.03	-3.51	57.00	42.00	15.00	35.71
28	Dh-86	79.65	82.85	-3.20	-3.86	52.00	46.00	6.00	13.04
29	Dh-101	81.45	86.21	-4.77	-5.53	38.50	40.50	-2.00	-4.94
30	Dh-234	83.16	83.67	-0.52	-0.62	49.00	49.00	0.00	0.00
31	K-9	79.08	82.85	-3.77	-4.55	41.00	42.50	-1.50	-3.53
32	K-6	84.87	90.74	-5.87	-6.47	43.00	45.50	-2.50	-5.49
33	GPBD-4	78.66	80.29	-1.62	-2.02	42.00	44.00	-2.00	-4.55
34	GPBD-5	75.83	74.59	1.24	1.66	44.00	49.00	-5.00	-10.20
35	KCG-6	85.69	86.44	-0.76	-0.87	42.00	42.00	0.00	0.00
36	KCG-2	82.16	84.70	-2.54	-2.99	44.00	47.00	-3.00	-6.38
37	TMV-2	92.39	90.18	2.21	2.45	41.00	46.00	-5.00	-10.87
38	LOCAL-1	89.37	91.30	-1.93	-2.11	44.00	45.50	-1.50	-3.30
39	R-2001-3	82.85	83.75	-0.91	-1.08	42.00	40.00	2.00	5.00
40	G2-52	84.30	86.81	-2.51	-2.89	41.00	42.00	-1.00	-2.38

Table 16: Continued.,

Sl. No.	Genotype	Number of pods per plant				Number of mature pods per plant			
		Stress	Non stress	Mean reduction	Change in % mean	Stress	Non stress	Mean reduction	Change in % mean
1	ICGV 15114	12.40	23.60	-11.20	-47.46	9.11	13.50	-4.39	-32.52
2	ICGV 15119	18.30	18.90	-0.60	-3.17	16.20	16.10	0.10	0.62
3	ICGV 15120	13.78	11.70	2.08	17.78	12.13	9.00	3.13	34.78
4	ICGV 15122	12.65	22.40	-9.76	-43.55	12.93	20.40	-7.47	-36.62
5	ICGV 15123	16.80	22.70	-5.90	-25.99	13.80	21.10	-7.30	-34.60
6	ICGV 15124	7.65	22.50	-14.86	-66.02	13.85	20.30	-6.45	-31.77
7	ICGV 15138	15.89	19.40	-3.51	-18.09	15.23	17.50	-2.27	-12.97
8	ICGV 15141	18.40	17.00	1.40	8.24	17.30	15.60	1.70	10.90
9	ICGV 15143	14.10	20.50	-6.40	-31.22	13.00	16.80	-3.80	-22.62
10	ICGV 15145	20.04	31.50	-11.46	-36.38	23.35	27.10	-3.76	-13.86
11	ICGV 15146	19.48	34.60	-15.12	-43.70	16.30	31.20	-14.90	-47.76
12	ICGV 15148	16.98	35.50	-18.52	-52.17	17.67	30.40	-12.74	-41.89
13	ICGV 15149	18.52	24.20	-5.69	-23.49	12.78	20.70	-7.93	-38.29
14	ICGV 15151	21.84	31.90	-10.06	-31.54	17.98	27.70	-9.72	-35.09
15	ICGV 15152	20.20	29.30	-9.10	-31.06	18.98	26.00	-7.02	-27.00
16	ICGV 15153	16.98	23.70	-6.72	-28.35	14.15	19.20	-5.06	-26.33
17	ICGV 15154	13.55	26.60	-13.06	-49.08	14.58	25.00	-10.43	-41.70
18	ICGV 15158	16.69	33.70	-17.01	-50.47	13.95	27.50	-13.56	-49.29
19	ICGV 15159	11.35	31.50	-20.16	-63.98	15.45	27.20	-11.76	-43.22
20	ICGV 15161	14.50	10.40	4.10	39.42	11.60	20.20	-8.60	-42.57
21	SB-1	18.75	23.30	-4.56	-19.55	15.79	17.30	-1.51	-8.73
22	SB-14	21.10	23.60	-2.50	-10.59	15.95	19.20	-3.26	-16.95
23	SB-15	14.44	17.50	-3.06	-17.49	15.64	15.20	0.44	2.89
24	SB-17	14.80	26.90	-12.10	-44.98	13.45	21.90	-8.46	-38.61
25	VB	15.15	11.80	3.35	28.35	14.50	9.30	5.20	55.91
26	VB-11	12.85	16.00	-3.16	-19.72	15.13	12.30	2.83	22.97
27	VB-14	8.90	8.80	0.10	1.14	12.01	8.40	3.61	42.98
28	Dh-86	10.40	9.30	1.10	11.83	9.90	7.30	2.60	35.62
29	Dh-101	10.31	14.90	-4.59	-30.81	14.84	13.00	1.84	14.12
30	Dh-234	12.60	15.40	-2.80	-18.18	11.10	12.40	-1.30	-10.48
31	K-9	14.25	14.40	-0.15	-1.08	11.80	13.50	-1.70	-12.59
32	K-6	10.10	10.50	-0.40	-3.81	11.95	9.40	2.55	27.13
33	GPBD-4	14.90	8.00	6.90	86.25	13.10	6.80	6.30	92.65
34	GPBD-5	11.40	10.70	0.70	6.54	12.40	9.60	2.80	29.17
35	KCG-6	11.60	12.70	-1.10	-8.66	11.20	11.40	-0.20	-1.75
36	KCG-2	13.85	9.20	4.65	50.49	14.54	8.50	6.04	71.06
37	TMV-2	13.20	13.40	-0.20	-1.49	12.30	12.10	0.20	1.65
38	LOCAL-1	10.45	17.30	-6.86	-39.62	13.00	15.40	-2.40	-15.58
39	R-2001-3	14.90	16.40	-1.50	-9.15	15.70	15.00	0.70	4.67
40	G2-52	9.70	10.90	-1.20	-11.01	13.57	8.80	4.77	54.20

Table 16: Continued.,

Sl. No.	Genotype	Number of immature pods per plant				Pod yield per plant (g)			
		Stress	Non stress	Mean reduction	Change in % mean	Stress	Non stress	Mean reduction	Change in % mean
1	ICGV 15114	1.95	3.40	-1.45	-42.65	5.40	12.20	-6.80	-55.74
2	ICGV 15119	2.10	2.80	-0.70	-25.00	9.34	13.00	-3.66	-28.15
3	ICGV 15120	1.90	1.70	0.20	11.76	8.22	9.40	-1.18	-12.55
4	ICGV 15122	2.00	2.00	0.00	0.00	10.03	18.00	-7.97	-44.28
5	ICGV 15123	3.60	1.60	2.00	125.00	10.92	19.20	-8.29	-43.15
6	ICGV 15124	2.60	2.20	0.40	18.18	11.14	18.00	-6.86	-38.11
7	ICGV 15138	2.25	1.90	0.35	18.42	15.00	19.80	-4.80	-24.24
8	ICGV 15141	1.10	1.40	-0.30	-21.43	17.45	16.20	1.25	7.72
9	ICGV 15143	1.50	3.70	-2.20	-59.46	11.00	15.60	-4.60	-29.49
10	ICGV 15145	1.30	4.40	-3.10	-70.45	14.88	21.20	-6.32	-29.81
11	ICGV 15146	3.90	3.40	0.50	14.71	13.38	24.60	-11.22	-45.61
12	ICGV 15148	4.50	5.10	-0.60	-11.76	12.23	25.80	-13.57	-52.60
13	ICGV 15149	2.90	3.50	-0.60	-17.14	10.78	16.40	-5.62	-34.27
14	ICGV 15151	3.90	4.20	-0.30	-7.14	19.15	23.00	-3.86	-16.76
15	ICGV 15152	2.50	3.30	-0.80	-24.24	11.10	21.20	-10.11	-47.67
16	ICGV 15153	1.50	4.50	-3.00	-66.67	11.50	22.20	-10.71	-48.22
17	ICGV 15154	2.42	1.60	0.82	51.25	12.15	20.60	-8.46	-41.04
18	ICGV 15158	1.91	6.20	-4.30	-69.27	13.32	24.40	-11.09	-45.43
19	ICGV 15159	1.11	4.60	-3.50	-75.98	13.60	24.20	-10.60	-43.80
20	ICGV 15161	2.32	4.00	-1.69	-42.13	10.40	19.60	-9.20	-46.94
21	SB-1	3.10	6.00	-2.90	-48.33	13.58	26.60	-13.02	-48.95
22	SB-14	3.30	4.40	-1.10	-25.00	19.38	25.60	-6.22	-24.30
23	SB-15	2.30	2.30	0.00	0.00	10.60	16.40	-5.80	-35.37
24	SB-17	2.40	5.00	-2.60	-52.00	10.80	18.80	-8.00	-42.55
25	VB	3.20	2.50	0.70	28.00	11.20	8.80	2.40	27.27
26	VB-11	1.50	3.70	-2.20	-59.46	11.38	13.40	-2.02	-15.07
27	VB-14	0.70	0.40	0.30	75.00	7.88	10.40	-2.52	-24.23
28	Dh-86	1.40	2.00	-0.60	-30.00	9.80	7.20	2.60	36.11
29	Dh-101	1.80	1.90	-0.10	-5.26	10.25	13.40	-3.16	-23.54
30	Dh-234	1.50	3.00	-1.50	-50.00	14.60	16.00	-1.40	-8.75
31	K-9	2.95	2.50	0.45	18.00	7.89	12.20	-4.31	-35.33
32	K-6	0.70	1.10	-0.40	-36.36	13.38	12.00	1.38	11.50
33	GPBD-4	1.40	1.20	0.20	16.67	8.44	7.20	1.24	17.15
34	GPBD-5	1.20	1.10	0.10	9.09	7.75	10.20	-2.46	-24.07
35	KCG-6	1.40	1.30	0.10	7.69	9.17	13.00	-3.83	-29.46
36	KCG-2	2.20	0.70	1.50	214.29	10.28	9.20	1.08	11.74
37	TMV-2	0.90	1.30	-0.40	-30.77	10.81	14.00	-3.19	-22.79
38	LOCAL-1	1.20	1.90	-0.70	-36.84	11.48	14.00	-2.52	-18.00
39	R-2001-3	1.20	1.40	-0.20	-14.29	11.92	13.20	-1.29	-9.73
40	G2-52	1.25	2.10	-0.85	-40.48	7.52	6.40	1.12	17.42

Table 16: Continued.,

Sl. No.	Genotypes	Pod yield per hectare (Kg/ha)				Number of kernels per plant			
		Stress	Non stress	Mean reduction	Change in % mean	Stress	Non Stress	Mean Reduction	Change in % mean
1	ICGV 15114	1579.14	1217.11	362.03	29.75	11.20	17.60	-6.40	-36.36
2	ICGV 15119	1201.60	1316.50	-114.89	-8.73	18.80	19.00	-0.20	-1.05
3	ICGV 15120	1404.81	1086.12	318.70	29.34	12.30	24.40	-12.10	-49.59
4	ICGV 15122	1762.03	1659.71	102.33	6.17	23.90	24.20	-0.30	-1.24
5	ICGV 15123	1868.45	1520.01	348.44	22.92	20.70	23.30	-2.60	-11.16
6	ICGV 15124	1283.96	1521.65	-237.69	-15.62	34.00	24.00	10.00	41.67
7	ICGV 15138	1148.66	1902.37	-753.71	-39.62	17.85	25.90	-8.05	-31.08
8	ICGV 15141	1546.79	2002.00	-455.21	-22.74	24.00	24.20	-0.20	-0.83
9	ICGV 15143	1614.97	1531.57	83.40	5.45	17.50	17.00	0.50	2.94
10	ICGV 15145	1178.61	2126.53	-947.93	-44.58	25.70	33.40	-7.70	-23.05
11	ICGV 15146	1919.89	1961.18	-41.29	-2.11	24.00	35.10	-11.10	-31.62
12	ICGV 15148	1637.43	2624.94	-987.50	-37.62	25.05	38.10	-13.05	-34.25
13	ICGV 15149	1156.95	663.85	493.10	74.28	17.75	22.30	-4.55	-20.40
14	ICGV 15151	1116.58	1332.76	-216.19	-16.22	28.78	36.00	-7.22	-20.06
15	ICGV 15152	1666.04	1373.25	292.80	21.32	19.80	31.10	-11.30	-36.33
16	ICGV 15153	1521.39	1293.30	228.09	17.64	21.40	27.70	-6.30	-22.74
17	ICGV 15154	1129.41	1743.25	-613.83	-35.21	21.54	32.30	-10.76	-33.31
18	ICGV 15158	1190.91	2104.06	-913.15	-43.40	21.47	39.40	-17.93	-45.51
19	ICGV 15159	1066.31	1292.50	-226.19	-17.50	27.00	42.50	-15.50	-36.47
20	ICGV 15161	1530.48	1062.42	468.06	44.06	15.20	32.20	-17.00	-52.80
21	SB-1	1718.72	1377.57	341.15	24.76	15.00	32.70	-17.70	-54.13
22	SB-14	1219.52	2286.89	-1067.37	-46.67	23.70	26.70	-3.00	-11.24
23	SB-15	1652.41	1286.08	366.32	28.48	17.70	25.10	-7.41	-29.50
24	SB-17	1709.63	1386.24	323.38	23.33	17.02	23.60	-6.58	-27.88
25	VB	708.02	968.75	-260.73	-26.91	21.20	13.80	7.40	53.62
26	VB-11	1056.68	2276.04	-1219.36	-53.57	20.54	18.40	2.14	11.60
27	VB-14	1201.34	1088.39	112.95	10.38	13.10	12.30	0.80	6.50
28	Dh-86	863.10	564.13	298.97	53.00	13.50	10.50	3.00	28.57
29	Dh-101	721.39	1230.73	-509.33	-41.38	18.00	20.80	-2.80	-13.46
30	Dh-234	1247.06	1216.68	30.38	2.50	21.50	20.80	0.70	3.34
31	K-9	1388.77	970.88	417.89	43.04	20.92	13.10	7.82	59.66
32	K-6	1385.03	813.74	571.29	70.21	11.05	14.30	-3.26	-22.76
33	GPBD-4	1020.86	1016.51	4.35	0.43	16.00	11.70	4.30	36.75
34	GPBD-5	1190.91	1026.49	164.42	16.02	13.99	25.60	-11.62	-45.37
35	KCG-6	851.34	933.79	-82.45	-8.83	14.64	18.60	-3.96	-21.29
36	KCG-2	1302.14	1401.53	-99.39	-7.09	22.67	15.60	7.07	45.32
37	TMV-2	1698.93	2250.45	-551.51	-24.51	19.56	20.90	-1.34	-6.41
38	LOCAL-1	1483.96	1694.33	-210.37	-12.42	20.50	25.70	-5.20	-20.23
39	R-2001-3	846.79	921.68	-74.89	-8.13	20.81	21.20	-0.39	-1.84
40	G2-52	1550.00	1473.67	76.33	5.18	10.50	10.90	-0.40	-3.67

Table 16: Continued.,

Sl. No.	Genotypes	Kernel yield per plant (g)			
		Stress	Non stress	Mean reduction	Change in % mean
1	ICGV 15114	5.20	7.00	-1.80	-25.71
2	ICGV 15119	7.40	7.20	0.20	2.78
3	ICGV 15120	5.60	9.60	-4.00	-41.67
4	ICGV 15122	10.40	10.80	-0.40	-3.70
5	ICGV 15123	7.30	10.90	-3.60	-33.03
6	ICGV 15124	13.60	10.20	3.40	33.33
7	ICGV 15138	12.80	12.60	0.20	1.59
8	ICGV 15141	13.00	11.00	2.00	18.18
9	ICGV 15143	6.60	5.80	0.80	13.79
10	ICGV 15145	9.60	15.60	-6.00	-38.46
11	ICGV 15146	11.60	15.00	-3.40	-22.67
12	ICGV 15148	19.00	15.60	3.40	21.79
13	ICGV 15149	6.60	10.40	-3.80	-36.54
14	ICGV 15151	11.00	14.20	-3.20	-22.54
15	ICGV 15152	7.20	13.60	-6.40	-47.06
16	ICGV 15153	7.40	13.00	-5.60	-43.08
17	ICGV 15154	13.60	13.00	0.60	4.62
18	ICGV 15158	11.30	15.10	-3.80	-25.17
19	ICGV 15159	12.75	15.80	-3.05	-19.30
20	ICGV 15161	6.40	13.20	-6.80	-51.52
21	SB-1	18.11	14.80	3.31	22.36
22	SB-14	11.60	14.20	-2.60	-18.31
23	SB-15	7.00	10.80	-3.80	-35.19
24	SB-17	7.00	11.70	-4.70	-40.17
25	VB	8.20	12.20	-4.00	-32.79
26	VB-11	7.80	8.00	-0.20	-2.50
27	VB-14	6.40	6.80	-0.40	-5.88
28	Dh-86	6.20	6.80	-0.60	-8.82
29	Dh-101	10.20	8.20	2.00	24.39
30	Dh-234	9.40	8.20	1.20	14.63
31	K-9	8.70	5.40	3.30	61.11
32	K-6	7.40	8.20	-0.80	-9.76
33	GPBD-4	5.20	5.40	-0.20	-3.70
34	GPBD-5	5.00	11.60	-6.60	-56.90
35	KCG-6	7.10	8.20	-1.10	-13.41
36	KCG-2	9.65	6.80	2.85	41.91
37	TMV-2	6.60	9.60	-3.00	-31.25
38	LOCAL-1	10.20	9.80	0.40	4.08
39	R-2001-3	10.00	8.60	1.40	16.28
40	G2-52	5.20	4.20	1.00	23.81

Table 17: Comparative overall mean performance of forty groundnut genotypes for yield and yield attributes under moisture stress and normal moisture condition

Characters	Normal Moisture	Moisture stress	Changes in mean value under stress condition compared to non-stress condition	Change in per cent mean under moisture stress conditions compared to non-stress conditions
Plant height at harvest (cm)	24.10	23.11	-0.99	-4.28
Primary branches at harvest	7.16	7.32	0.16	2.19
Secondary branches at harvest	5.07	5.21	0.14	2.69
Number of days to maturity	115.46	113.63	-1.83	-1.61
Total seedling length (cm)	36.14	33.24	-2.90	-8.72
Fresh weight of seedling (g)	77.22	62.61	-14.61	-23.33
Harvest index	0.41	0.21	-0.20	-95.24
Shelling percentage (%)	63.42	57.55	-5.87	-10.20
Percentage of sound mature kernels (%)	84.26	82.96	-1.30	-1.57
Test weight (g)	43.67	42.11	-1.56	-3.70
Number of pods per plant	19.56	14.59	-4.97	-34.06
Number of mature pods per plant	16.98	14.20	-2.78	-19.58
Number of immature pods per plant	2.07	2.78	0.71	25.54
Pod yield per plant (grams)	16.31	11.46	-4.85	-42.32
Pod yield per hectare (kg)	1389.74	1321.03	-68.71	-5.20
Number of kernels per plant	23.80	19.49	-4.31	-22.11
Kernel yield per plant (g)	10.47	9.13	-1.34	-14.68

- + Sign indicates increase in mean value of the concerned trait in moisture stress condition over normal moisture
- Sign indicates decrease in mean value of the concerned trait in moisture stress condition over normal moisture

4.2.3.3 Drought tolerance efficiency (DTE) (%) for pod yield per plant

The drought tolerance efficiency for pod yield per plant exhibited by groundnut genotype in the present study was in a range of 71.09 to 237.63 per cent with a mean of 122.22 per cent.

4.2.3.4 Drought tolerance index (DTI) for kernel yield per plant

The drought tolerance index and drought susceptibility index values for kernel yield per plant of each of forty genotypes presented in the table 19.

The mean drought tolerance index for kernel yield per plant was 1.41 with a range of 0.33 to 4.22.

4.2.3.5 Drought Susceptibility index (DSI) for kernel yield per plant

Drought Susceptibility index (DSI) for kernel yield per plant was in the range of -5.83 to 6.77 with an overall mean of 0.42.

4.2.3.6 Drought tolerance index (DTI) for plant height

The drought tolerance index and drought susceptibility index values for plant height in forty genotypes were calculated and presented in the table 20.

The mean drought tolerance index for plant height was 1.45 with a range of 1.16 to 2.11.

4.2.3.7 Drought Susceptibility index (DSI) for plant height

Drought Susceptibility index (DSI) for plant height was in the range of -2.58 to 7.29 with an overall mean of 1.41.

4.2.3.8 Drought tolerance index (DTI) for root length

The drought tolerance index and drought susceptibility index values for root length in forty genotypes were calculated and presented in the table 21.

The drought tolerance index for root length was in the range of 0.88 to 1.98 with a mean of 1.36.

4.2.3.9 Drought Susceptibility index (DSI) for root length

Drought Susceptibility index (DSI) for root length was ranging from -3.86 to 4.59 with an overall mean of 1.37.

4.3. Assessment of correlations between drought, biochemical and yield parameters

4.3.1 Character Association

The phenotypic correlations of physiological, biochemical and root related traits with pod yield per plant under normal moisture condition and moisture stress condition presented in table 22 and table 23, respectively.

The phenotypic correlations of yield components with pod yield per plant under normal moisture condition and moisture stress condition presented in table 24 and table 25, respectively.

Table 18: The means of pod yield under stress (Yd) and normal moisture (Yp) conditions and drought tolerance indices for pod yield per plant

Sl. No.	Genotype	Yd	Yp	DSI	DTI	DTE (%)
1	ICGV 15114	7.60	16.40	2.73	0.33	72.38
2	ICGV 15119	14.48	18.20	0.75	0.66	125.77
3	ICGV 15120	13.04	13.60	-0.04	0.45	147.45
4	ICGV 15122	16.06	26.20	1.91	1.06	93.94
5	ICGV 15123	16.03	24.80	1.20	1.02	112.66
6	ICGV 15124	17.14	25.80	1.63	1.12	102.12
7	ICGV 15138	24.20	28.60	0.55	1.74	130.91
8	ICGV 15141	26.90	26.60	-0.23	1.89	159.83
9	ICGV 15143	17.00	21.20	0.49	0.89	132.14
10	ICGV 15145	22.56	33.00	1.68	1.92	103.38
11	ICGV 15146	20.56	38.40	2.47	2.05	80.73
12	ICGV 15148	18.86	39.80	2.80	1.94	71.09
13	ICGV 15149	16.96	19.20	-3.59	0.72	237.63
14	ICGV 15151	29.49	34.20	0.68	2.58	129.65
15	ICGV 15152	16.79	31.60	2.48	1.36	79.76
16	ICGV 15153	16.99	33.00	2.59	1.43	77.20
17	ICGV 15154	18.49	31.40	2.19	1.49	88.34
18	ICGV 15158	20.63	38.60	2.47	2.09	80.93
19	ICGV 15159	20.20	39.60	2.49	2.05	82.63
20	ICGV 15161	16.00	26.40	1.62	1.04	101.10
21	SB-1	20.76	39.40	2.49	2.09	79.28
22	SB-14	28.58	38.20	1.36	2.78	112.17
23	SB-15	15.80	23.60	1.69	0.95	101.57
24	SB-17	16.40	29.60	2.37	1.26	84.35
25	VB	17.20	14.20	-1.23	0.64	187.58
26	VB-11	16.58	19.80	0.89	0.84	125.39
27	VB-14	11.28	17.40	1.47	0.49	114.45
28	Dh-86	14.60	10.60	-2.05	0.39	206.97
29	Dh-101	15.05	20.00	1.34	0.77	112.76
30	Dh-234	21.80	22.80	0.07	1.26	146.10
31	K-9	11.29	17.80	1.98	0.51	94.73
32	K-6	20.58	18.20	-0.71	0.96	169.40
33	GPBD-4	12.64	9.80	-2.22	0.31	207.57
34	GPBD-5	11.55	15.80	1.44	0.47	110.74
35	KCG-6	13.57	18.20	1.18	0.63	115.19
36	KCG-2	14.88	13.00	-0.88	0.50	173.65
37	TMV-2	15.42	20.80	1.44	0.82	110.85
38	LOCAL-1	16.16	23.40	1.18	0.92	123.70
39	R-2001-3	17.03	20.40	0.90	0.88	127.71
40	G2-52	11.92	10.40	-0.83	0.33	174.90
	Mean	17.33	24.25	0.97	1.14	122.22

Table 19: The means of kernel yield under moisture stress (KYd) and normal moisture (KYp) conditions and drought tolerance indices for kernel yield per plant

Sl. No.	Genotype	KYd	KYp	DSI	DTI
1	ICGV 15114	7.6	9.8	2.41	0.46
2	ICGV 15119	11.4	10.2	-1.92	0.70
3	ICGV 15120	8.2	14.8	5.19	0.74
4	ICGV 15122	16.2	16	-0.24	1.58
5	ICGV 15123	10.4	15.2	3.61	0.99
6	ICGV 15124	20.2	14.8	-4.41	1.83
7	ICGV 15138	19.4	18	-1.24	2.12
8	ICGV 15141	20	18.6	-2.29	2.34
9	ICGV 15143	9.8	7.6	-5.61	0.46
10	ICGV 15145	14.6	23	4.26	2.05
11	ICGV 15146	18.6	24	2.66	2.83
12	ICGV 15148	29.2	23.6	-2.79	4.22
13	ICGV 15149	10.4	13.2	-0.43	0.78
14	ICGV 15151	16	21.2	2.91	2.07
15	ICGV 15152	11.2	20	5.10	1.36
16	ICGV 15153	10.2	19.2	5.60	1.20
17	ICGV 15154	21	19.6	-0.84	2.52
18	ICGV 15158	17.5	23.6	3.02	2.55
19	ICGV 15159	19.35	26	2.43	3.11
20	ICGV 15161	9.8	18	4.77	1.06
21	SB-1	26.91	21	-3.65	3.46
22	SB-14	17.8	21.2	1.86	2.30
23	SB-15	10.2	15.2	3.72	0.96
24	SB-17	10.6	20.6	3.92	1.36
25	VB	12.8	16	0.51	1.19
26	VB-11	11.2	12.8	0.89	0.86
27	VB-14	8.8	11.6	0.15	0.57
28	Dh-86	8.8	9.4	0.55	0.52
29	Dh-101	14.8	12.6	-2.17	1.13
30	Dh-234	13.6	12.8	-1.01	1.05
31	K-9	12.8	7	-13.23	0.56
32	K-6	11.6	12.6	0.96	0.90
33	GPBD-4	7.2	7.2	-0.46	0.34
34	GPBD-5	7.4	17.4	6.77	0.79
35	KCG-6	10.2	12	1.81	0.75
36	KCG-2	14.1	9.6	-5.83	0.83
37	TMV-2	8.8	14.4	4.62	0.77
38	LOCAL-1	15.6	16.4	-0.46	1.59
39	R-2001-3	15	13.8	-1.49	1.27
40	G2-52	7.8	7	-2.71	0.33
	Mean	13.67	15.67	0.42	1.41

Table 20: The means of plant height under moisture stress (PHd) and normal moisture (PHp) and drought tolerance indices for plant height

Sl.No.	Genotype	PHd	PHp	DSI	DTI
1	ICGV 15114	32.05	32.68	0.69	1.20
2	ICGV 15119	34.25	36.07	1.93	1.43
3	ICGV 15120	37.36	39.96	2.47	1.73
4	ICGV 15122	37.88	37.60	-0.68	1.64
5	ICGV 15123	34.37	37.04	2.80	1.47
6	ICGV 15124	32.17	36.50	4.56	1.35
7	ICGV 15138	34.39	35.12	0.80	1.40
8	ICGV 15141	38.47	41.54	2.91	1.88
9	ICGV 15143	32.08	32.39	0.08	1.19
10	ICGV 15145	32.50	33.03	0.49	1.24
11	ICGV 15146	33.78	33.76	-0.14	1.31
12	ICGV 15148	32.17	34.36	2.26	1.27
13	ICGV 15149	32.71	34.25	1.47	1.29
14	ICGV 15151	33.08	33.13	-0.07	1.26
15	ICGV 15152	32.09	32.39	0.39	1.20
16	ICGV 15153	30.10	33.24	3.45	1.16
17	ICGV 15154	31.82	32.38	0.54	1.19
18	ICGV 15158	32.74	34.66	2.05	1.31
19	ICGV 15159	32.91	35.11	2.41	1.33
20	ICGV 15161	32.44	32.97	0.58	1.23
21	SB-1	34.29	33.67	-1.03	1.33
22	SB-14	35.06	37.16	2.35	1.50
23	SB-15	32.73	34.59	2.18	1.30
24	SB-17	34.58	34.58	-0.03	1.38
25	VB	35.53	33.21	-2.58	1.36
26	VB-11	34.02	34.25	0.28	1.34
27	VB-14	33.34	36.93	3.87	1.42
28	Dh-86	32.24	33.07	1.04	1.23
29	Dh-101	36.50	35.90	-0.51	1.51
30	Dh-234	37.51	39.17	1.77	1.69
31	K-9	40.02	44.13	3.67	2.03
32	K-6	41.06	42.53	1.60	2.01
33	GPBD-4	34.31	35.89	1.76	1.42
34	GPBD-5	39.24	39.70	0.47	1.79
35	KCG-6	37.25	39.40	2.40	1.69
36	KCG-2	37.46	39.79	1.81	1.73
37	TMV-2	42.53	43.07	0.51	2.11
38	LOCAL-1	33.37	41.87	7.29	1.60
39	R-2001-3	33.91	34.73	0.82	1.37
40	G2-52	32.94	32.78	-0.31	1.24
	Mean	34.68	36.12	1.41	1.45

Table 21: The means of Root length under moisture stress (RLd) and normal moisture condition (RLp) and drought tolerance indices for plant height

Sl. No.	Genotype	RLd	RLp	DSI	DTI
1	ICGV 15114	13.75	15.07	1.86	0.88
2	ICGV 15119	16.30	19.15	2.61	1.32
3	ICGV 15120	16.45	14.56	-2.70	1.02
4	ICGV 15122	16.49	18.40	2.09	1.29
5	ICGV 15123	16.69	18.09	1.74	1.28
6	ICGV 15124	17.69	19.44	1.00	1.45
7	ICGV 15138	16.77	18.56	1.76	1.32
8	ICGV 15141	19.27	20.03	0.44	1.63
9	ICGV 15143	15.30	18.99	3.60	1.23
10	ICGV 15145	15.68	17.50	2.05	1.16
11	ICGV 15146	16.76	19.03	1.81	1.35
12	ICGV 15148	17.25	19.40	1.84	1.42
13	ICGV 15149	16.41	19.68	2.31	1.36
14	ICGV 15151	16.36	19.23	2.89	1.34
15	ICGV 15152	15.48	19.94	2.77	1.31
16	ICGV 15153	14.96	20.03	4.59	1.27
17	ICGV 15154	15.45	18.01	1.49	1.18
18	ICGV 15158	15.69	18.94	1.99	1.26
19	ICGV 15159	14.82	19.24	3.63	1.21
20	ICGV 15161	14.01	19.01	4.17	1.13
21	SB-1	18.13	19.71	1.38	1.52
22	SB-14	16.37	20.14	1.69	1.39
23	SB-15	18.46	19.93	0.34	1.58
24	SB-17	17.98	20.19	2.04	1.56
25	VB	17.07	18.40	0.99	1.34
26	VB-11	16.18	17.15	-0.02	1.19
27	VB-14	18.45	17.79	-0.75	1.42
28	Dh-86	18.34	17.12	-3.86	1.31
29	Dh-101	16.10	15.88	-1.74	1.08
30	Dh-234	16.45	18.28	1.09	1.28
31	K-9	18.48	17.24	-0.53	1.34
32	K-6	17.95	19.69	0.95	1.50
33	GPBD-4	17.10	19.32	1.65	1.40
34	GPBD-5	18.61	17.80	0.00	1.41
35	KCG-6	18.06	21.27	2.30	1.63
36	KCG-2	17.71	18.52	1.08	1.40
37	TMV-2	19.54	20.17	-0.40	1.67
38	LOCAL-1	16.71	19.23	2.27	1.40
39	R-2001-3	19.87	22.94	2.04	1.98
40	G2-52	17.22	19.06	2.20	1.41
	Mean	16.91	18.80	1.37	1.36

4.3.1.1 Correlation of pod yield per plant with physiological, biochemical and root related traits

Under normal moisture, the pod yield per plant recorded a positive and highly significant association with oil content of seeds (0.4347), root to shoot ratio (0.3268) and a negative significant association with membrane stability index (0.2795). It had a negative non-significant association with relative water content (0.0805), SCMR (0.2057), phenolic content of leaf (0.2004), phenolic content in seeds (0.0773), protein content of seed (0.0751) and protein content of leaf (0.0866) while exhibited a positive non-significant correlation with root length (0.0482).

However, under moisture stress, the pod yield per plant recorded a positively significant association with oil content of seeds (0.2138) and negative significant association with phenolic content of leaf (0.2883). But it had positive non-significant association with protein content of leaf (0.0294), SCMR (0.0607) and root length (0.1021). It also recorded negative non-significant association with relative water content (0.0634), membrane stability index (0.1034), percent of wilted plants (0.1579), phenolic content in seeds (0.1266), protein content of seed (0.0875) and root to shoot ratio (0.0250).

4.3.1.2 Association among component traits

4.3.1.2.1 Relative water content

This trait under normal moisture condition, recorded a positive significant association with membrane stability index (0.2371) and positive non-significant association with SCMR (0.1372), protein content of leaf (0.0580) but exhibited a negative non-significant relationship with phenolic content in seeds (0.0164), protein content of seeds (0.1231), phenolic content in leaves (0.1218), root to shoot ratio (0.2083), oil content of seeds (0.1333) and root length (0.0188).

Under moisture stress, the relative water content recorded a positive significant association with phenolic content of seeds (0.3243). It had a negative non-significant association with membrane stability index (0.1354), root to shoot ratio (0.0073), oil content of seeds (0.1495), phenolic content of leaves (0.0148) and root length (0.0339). Positive non-significant correlation of this trait was observed for SCMR (0.0078), percent of wilted plants (0.0035), protein content of seeds (0.0885) and protein content of leaves (0.0500).

Table 22: Phenotypic correlation of physiological, biochemical and root attributes with pod yield per plant (g) under normal moisture condition

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	1.0000	0.2371*	0.1372	0.0580	-0.1231	-0.0164	-0.1218	-0.1333	-0.2083	-0.0118	-0.0805
X2		1.0000	-0.0149	0.2203*	-0.1042	0.3267**	0.2730*	-0.4288**	-0.3277**	-0.0922	-0.2793*
X3			1.0000	-0.2420*	0.2320	0.2031	0.1210	-0.1187	0.0143	0.1708	-0.2057
X4				1.0000	-0.1901	0.0389	0.2112	-0.2178	-0.1220	-0.0691	-0.0866
X5					1.0000	-0.0391	0.0378	-0.0632	0.0043	0.1098	-0.0751
X6						1.0000	0.2995**	-0.2741*	-0.0749	0.1789	-0.0773
X7							1.0000	-0.2076	-0.0802	0.1168	-0.2004
X8								1.0000	0.5473**	0.1419	0.4347**
X9									1.0000	0.4593**	0.3268**
X10										1.0000	0.0482
X11											1.0000

Where,

X1 – Relative water content (%)

X2 – Membrane stability index (%)

X3 – SPAD Chlorophyll Meter Reading

X4 - Protein content of leaves (%)

X5 - Protein content of seeds (%)

X6 - Phenolic content of seeds (µg/g)

X7 - Phenolic content of leaves (µg/g)

X8 - Oil content of seeds (%)

X9 - Root to shoot ratio

X10 - Root length (cm)

X11 - Pod yield per plant (g)

Table 23: Phenotypic correlation of physiological, biochemical and root attributes with pod yield per plant (g) under moisture stress condition

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1.0000	-0.1354	0.0078	0.0035	0.0500	0.0885	0.3243**	-0.0148	-0.1495	-0.0073	-0.0339	-0.0648
X2		1.0000	-0.0559	0.1937	-0.0230	0.2896**	0.1484	0.0793	0.0755	0.2863*	0.1886	-0.1033
X3			1.0000	-0.0927	0.1016	0.4036**	0.2113	0.3166**	-0.2798*	0.0357	0.1470	0.0607
X4				1.0000	-0.1219	0.1089	-0.0592	0.0033	-0.1276	0.2293*	0.2820*	-0.1579
X5					1.0000	0.3161**	-0.0092	0.0318	0.1244	0.1887	-0.0103	0.0294
X6						1.0000	0.1579	0.2446*	-0.2670*	0.2951*	0.3815**	-0.0875
X7							1.0000	0.4687**	-0.3194**	0.0779	0.2624*	-0.1266
X8								1.0000	-0.4782**	0.1759	0.3498**	-0.2883**
X9									1.0000	-0.0459	-0.3874**	0.2138*
X10										1.0000	0.5843**	-0.0250
X11											1.0000	0.1021
X12												1.0000

Where,

X1 – Relative water content (%)

X2 – Membrane stability index (%)

X3 – SPAD Chlorophyll Meter Reading

X4 – Per cent of wilted plants (%)

X5 - Protein content of leaves (%)

X6 - Protein content of seeds (%)

X7 - Phenolic content of seeds (µg/g)

X8 - Phenolic content of leaves (µg/g)

X9 - Oil content of seeds (%)

X10 - Root to shoot ratio

X11 - Root length (cm)

X12 - Pod yield per plant (g)

Table 24: Phenotypic correlation of yield components with pod yield per plant (g) under normal moisture condition

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X1	1.0000	-0.2100	0.0976	0.4506**	0.1412	0.3260**	-0.3367**	-0.3367**	-0.3500**	-0.2178	-0.2124	-0.2406	-0.3338**	-0.2482*	0.8765**	-0.2580*
X2		1.0000	-0.0972	-0.2436*	0.0806	-0.2377*	0.1631	-0.0336	0.1633	0.1212	0.0250	0.2219	0.1015	-0.0679	-0.0921	0.0866
X3			1.0000	0.0401	0.0514	0.0043	-0.1562	-0.2130	-0.1693	-0.1878	-0.1048	-0.0827	-0.1776	0.2662*	0.0295	-0.1090
X4				1.0000	0.1106	0.0592	-0.1898	-0.1237	-0.2276*	-0.0423	-0.0483	-0.1551	-0.2175	-0.0550	0.3006**	-0.1589
X5					1.0000	0.1685	-0.1474	-0.2173	-0.1694	-0.1655	-0.1047	-0.1582	-0.0940	-0.0753	0.1535	-0.1803
X6						1.0000	-0.1829	-0.1244	-0.1855	-0.1031	0.0081	-0.0038	0.1141	0.0091	0.2320*	0.0646
X7							1.0000	0.5124**	0.9309**	0.8533**	0.7649**	0.6641**	0.7211**	0.0173	-0.2771*	0.8913**
X8								1.0000	0.6038**	0.5125**	0.5142**	0.5151**	0.6076**	0.2800*	-0.3405**	0.5849**
X9									1.0000	0.7818**	0.7155**	0.6336**	0.7320**	0.0228	-0.2848*	0.8404**
X10										1.0000	0.8594**	0.5985**	0.7092**	0.0245	-0.1510	0.8607**
X11											1.0000	0.5240**	0.6764**	0.0702	-0.1686	0.8194**
X12												1.0000	0.5643**	0.1959	-0.1663	0.7245**
X13													1.0000	0.0885	-0.2389*	0.8297**
X14														1.0000	-0.2714	0.1295
X15															1.0000	-0.2068
X16																1.0000

Where,

- X1- Plant height at harvest (cm)
- X2- Primary branches at harvest
- X3- Secondary branches at harvest
- X4- Shelling percentage (%)
- X5- Percentage of sound mature kernels (%)
- X6- Test weight (g)
- X7- Number of mature pods per plant
- X8- Number of immature pods per plant
- X9- Number of pods per plant
- X10- Number of kernels per plant
- X11- Kernel yield per plant (g)
- X12- Fresh weight of seedling (g)
- X13- Harvest index
- X14- Number of days to maturity
- X15- Total seedling length (cm)
- X16- Pod yield per plant (g)

Table 25: Phenotypic correlation of yield components with pod yield per plant (g) under moisture stress condition

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X1	1.0000	-0.1189	-0.0676	0.1643	0.1199	0.0710	-0.1186	-0.1758	-0.0880	-0.0787	-0.0951	0.2314*	-0.2251*	0.0039	0.8496**	0.0485
X2		1.0000	-0.0796	-0.2497**	-0.0135	-0.0012	-0.0664	-0.0421	-0.1524	-0.0535	0.1291	0.0076	0.0500	0.0612	-0.1247	-0.0420
X3			1.0000	0.0481	-0.0416	0.4846**	-0.1246	-0.2304*	-0.2339	-0.1701	-0.1244	0.0732	-0.0705	0.2870**	0.0088	-0.1890
X4				1.0000	-0.0750	0.1125	-0.0830	-0.2170*	-0.0328	0.1135	0.0589	0.1641	0.0272	-0.2756*	0.1964	0.0399
X5					1.0000	-0.1084	-0.0361	-0.0877	-0.0105	-0.0146	-0.1944	0.1557	-0.0285	-0.1201	0.1689	0.1101
X6						1.0000	-0.1129	-0.1176	-0.1517	-0.0440	0.0929	0.0434	-0.0192	0.1633	0.1783	0.1573
X7							1.0000	0.2505*	0.6345**	0.5076**	0.4488**	0.1813	0.3925**	-0.0827	0.0067	0.5822**
X8								1.0000	0.4954**	0.3528**	0.4343**	0.0277	0.2505**	-0.0919	-0.1956	0.2485*
X9									1.0000	0.3202**	0.2658**	0.1956	0.3092**	-0.1271	-0.0116	0.5882**
X10										1.0000	0.5798**	0.2336**	0.3721**	-0.1661	-0.0856	0.5464**
X11											1.0000	0.3396**	0.2729*	-0.0516	-0.0516	0.5680**
X12												1.0000	0.0861	-0.1993	0.3071**	0.4618**
X13													1.0000	-0.1260	-0.2044	0.2710*
X14														1.0000	-0.1442	-0.1749
X15															1.0000	0.1042
X16																1.0000

Where,

- | | | | |
|----|--|-----|------------------------------|
| X1 | Plant height at harvest (cm) | X9 | Number of pods per plant |
| X2 | Primary branches at harvest | X10 | Number of kernels per plant |
| X3 | Secondary branches at harvest | X11 | Kernelyield per plant (g) |
| X4 | Shelling percentage (%) | X12 | Fresh weight of seedling (g) |
| X5 | Percentage of sound mature kernels (%) | X13 | Harvest index |
| X6 | Test weight (g) | X14 | Number of days to maturity |
| X7 | Number of mature pods per plant | X15 | Total seedling length (cm) |
| X8 | Number of immature pods per plant | X16 | Pod yield per plant (g) |

4.3.1.2.2 Membrane stability index

Membrane stability index under normal moisture recorded positive significant association with phenolic content of seeds (0.3267), phenolic content of leaves (0.2730) and protein content of leaves (0.2203) whereas it had a negative significant correlation for root to shoot ratio (0.3277) and oil content of seeds (0.4288). Further, it also had a negative non-significant association with SCMR (0.0149), root length (0.0922) and protein content of seeds (0.1042).

Under moisture stress, this trait has shown a significant positive association with protein content of seed (0.2896) and root to shoot ratio (0.2863). A negative non-significant association was noticed for SCMR (0.0559) and protein content of leaves (0.0230). Further, it had a positive non-significant correlation with per cent of wilted plants (0.1937), phenolic content of seeds (0.1484), phenolic content of leaves (0.0793), oil content of seeds (0.0755) and root length (0.1886).

4.3.1.2.3 SPAD Chlorophyll Meter Reading (SCMR)

The SCMR under normal moisture condition exhibited a negative significant relation with protein content of leaves (0.2420). It had a positive non-significant relation with protein content of seeds (0.2320), phenolic content of leaves (0.1210), root to shoot ratio (0.0143) and root length (0.1780). It had a negative non-significant relation with Oil content of seeds (0.1187).

Contrary to this, under moisture stress situation, it recorded a positive significant relation with protein content of seeds (0.4036) and phenolic content of leaves (0.3166). It had a negative significant relation with oil content of seeds (0.2798). It recorded a positive non-significant relation with protein content of leaves (0.1016), phenolic content of seeds (0.2113), root to shoot ratio (0.0357) and root length (0.1470). It had negative non-significant relation for per cent of wilted plants (0.0927).

4.3.1.2.4 Per cent of wilted plants

In moisture stress condition, the per cent of wilted plants had a positive significant correlation with root to shoot ratio (0.2293) and root length (0.2820). It had positive non-significant association with protein content of seeds (0.1089) and phenolic content of leaf (0.0033). It had a negative non-significant association with protein content of leaves (0.1219), phenolic content of seeds (0.0592) and oil content of seeds (0.1276).

4.3.1.2.5 Protein content of leaves

Under normal moisture, the protein content in leaf had a positive non-significant correlation with phenolic content of seeds (0.0389), phenolic content of leaves (0.2112) while having a negative non-significant relation with protein

content of seeds (0.1901), oil content of seeds (0.2178), root to shoot ratio (0.1220) and root length (0.0691).

Under moisture stress, the protein content in leaf tissues had a positive significant relation with protein content of seeds (0.3161) besides having a positive non-significant association with phenolic content of leaves (0.0318), root to shoot ratio (0.0143) and oil content of seeds (0.1887). It had a negative non-significant relation with phenolic content of seeds (0.0092) and root length (0.0103).

4.3.1.2.6 Protein content of seeds

Protein content of seeds had a positive non-significant relation with phenolic content of leaves (0.0378) and root to shoot ratio (0.0143). Negative non-significant relation with oil content of seeds (0.1187), phenolic content of seeds (0.0391) and root length (0.1098) was observed under normal moisture condition.

Under moisture stress condition, the protein content of seeds recorded a positive significant relation with root length (0.3815) and phenolic content of leaves (0.2446) and root to shoot ratio (0.2591). It had a negative significant relation with oil content of seeds (0.2670) and also recorded a positive non-significant relation with phenolic content of seeds (0.1579).

4.3.1.2.7 Phenolic content of seeds

In normal moisture condition, phenolic content in seeds had a positive significant association with phenolic content of leaf (0.2995) and negative significant association with oil content of seeds (0.2741). Further, it had a negative non-significant relation with root to shoot ratio (0.0749) and positive non-significant relation with root length (0.1789).

However, in moisture stressed condition, phenolic content in seeds had a positive significant association with phenolic content of leaf (0.4687) and root length (0.2624) besides having negative significant correlation with oil content of seeds (0.3194). Further, it exhibited a positive non-significant relation with root to shoot ratio (0.0779).

4.3.1.2.8 Phenolic content of leaves

Under normal moisture condition, phenolic content in leaf had a negative non-significant association with oil content of seeds (0.2076) and root to shoot ratio (0.0802) but exhibited a positive non-significant correlation with root length (0.1168).

This trait had a negative significant association with oil content of seeds (0.4782), but positive significant relation with root length (0.3498) and positive non-significant association with root to shoot ration (0.1759) under moisture stress.

4.3.1.2.9 Oil content of seeds

In normal moisture condition, the oil content of seeds had a positive significant association with root to shoot ratio (0.5473) and positive non-significant correlation with root length (0.1419) whereas in moisture stress situation, this trait had a negative significant relationship with root length (0.3874) and negative non-significant association with root to shoot ratio (0.0459).

4.3.1.2.10 Root to shoot ratio

For root to shoot ratio, positive correlation was observed with root length under both normal moisture (0.4593) and moisture stress (0.5843).

4.3.1.3 Correlation of pod yield with yield component traits

In case of normal moisture condition, the pod yield per plant recorded a highly positive significant association with number of mature pods per plant (0.8913), number of immature pods per plant (0.5849), number of pods per plant (0.8404), number of kernels per plant (0.8607), kernel yield per plant (0.8194), fresh weight of seedling (0.7245) and harvest index (0.8297). It had negative significant relation with plant height at harvest (0.2580). Further, it had a positive non-significant association with primary branches at harvest (0.0866), test weight (0.0646) and number of days to maturity (0.1295). A negative non-significant correlation of this trait was observed for secondary branches at harvest (0.1090), shelling percentage (0.1589), percentage of sound mature kernels (0.1803) and total seedling length (0.2068).

However, under managed drought condition, it had highly positive significant association with number of mature pods per plant (0.5822), number of immature pods per plant (0.2485), number of pods per plant (0.5882), number of kernels per plant (0.5464), kernel yield per plant (0.5680), fresh weight of seedling (0.4618) and harvest index (0.2710). A negative non-significant correlation was observed for primary branches at harvest (0.0420), secondary branches at harvest (0.1890) and number of days to maturity (0.1749). It had a positive non-significant correlation with plant height at harvest (0.0485), shelling percentage (0.0399), percentage of sound mature kernels (0.1101), test weight (0.1573) and total seedling length (0.1042).

4.3.1.4 Association among the component traits

4.3.1.4.1 Plant height at harvest

Under normal moisture condition, the plant height at harvest had positive significant association with shelling percentage (0.4506), test weight (0.3260) and total seedling length (0.8765). It also had a negative significant association with number of mature pods (0.3367), number of immature pods (0.3367), number of pods per plant (0.3500), fresh weight of the seedling (0.2406), harvest index (0.3338) and number of days to mature. A positive non-significant association was observed for

secondary branches at harvest (0.0976) and percentage of sound mature kernels (0.1412). It also had a negative non-significant correlation with primary branches at harvest (0.2100), number of kernels per plant (0.2178) and kernel yield per plant (0.2124).

Under moisture stress condition, plant height at harvest recorded a positive significant correlation with total seedling length (0.8496) and fresh weight of the seedlings (0.2314). It had a negative significant correlation with harvest index (0.2251). It also had a positive non-significant correlation with shelling percentage (0.1643), percentage of sound mature kernels (0.1199), test weight (0.0710) and number of days to maturity (0.0039). It had a negative non-significant correlation with primary branches at harvest (0.1189), secondary branches at harvest (0.0676), number of matured pods per plant (0.1186), number of immature pods per plant (0.1758), number of pods per plant (0.0880), number of kernels per plant (0.0787) and kernel yield per plant (0.0951).

4.3.1.4.2 Primary branches per plant at harvest

Under normal moisture, primary branches per plant at harvest had a positive non-significant association with fresh weight of seedling (0.2219), percentage of sound mature kernels (0.0806), number of mature pods per plant (0.1631), number of pods per plant (0.1633), number of kernels per plant (0.1212), kernel yield per plant (0.0250) and harvest index (0.1015). A negative significant correlation was recorded with shelling percentage (0.2436) and test weight (0.2377) besides having a negative non-significant association with secondary branches per plant at harvest (0.0972), number of immature pods per plant (0.0336), total seedling length (0.0921) and number of days to maturity (0.0679).

However, in moisture stressed condition, primary branches per plant at harvest had a negative significant association with shelling percentage (0.2497). The negative non-significant association for this trait was observed with secondary branches per plant at harvest (0.0796), percentage of sound mature kernels (0.0135), test weight (0.0012), number of mature pods per plant (0.0664), number of pods per plant (0.1524), number of immature pods per plant (0.0421), number of kernels per plant (0.0535) and total seedling length (0.1247). It had a positive non-significant association with kernel yield per plant (0.1291), fresh weight of seedling (0.0076), harvest index (0.0500) and number of days to maturity (0.0612).

4.3.1.4.3 Secondary branches per plant at harvest

Under normal moisture condition, secondary branches per plant at harvest had a positive significant association with number of days to maturity (0.2662) besides having a positive non-significant association with shelling percentage (0.0401), percentage of sound mature kernels (0.0614), test weight (0.0043) and total seedling

length (0.0295). This trait had a negative non-significant association with number of mature pods per plant (0.1562), number of immature pods per plant (0.2130), number of pods per plant (0.1693), number of kernels per plant (0.1878), kernel yield per plant (0.1048), harvest index (0.1776) and fresh weight of seedling (0.0827).

However, in moisture stress condition, secondary branches per plant at harvest had a positive significant association with number of days to maturity (0.2877) and test weight (0.4862) but positive non-significant association with shelling percentage (0.0486), fresh weight of seedling (0.0732) and total seedling length (0.0097). It showed a negative significant correlation with number of immature pods per plant (0.2306) and number of pods per plant (0.2345) whereas negative non-significant correlation was observed with percentage of sound mature kernels (0.0411), number of kernels per plant (0.1705), kernel yield per plant (0.1247) and harvest index (0.0729).

4.3.1.4.4 Shelling percentage

Under normal moisture condition, the shelling percentage had a positive significant association with total seedling length (0.3006) and positively non-significant correlation with percentage of sound mature kernels (0.1106) and test weight (0.0592). Negative significant correlation with number of pods per plant (0.2276) and non-significant negative correlation with number of mature pods per plant (0.1898), number of immature pods per plant (0.1237), number of kernels per plant (0.0423), kernel yield per plant (0.0483), fresh weight of seedling (0.1551), number of days to maturity (0.0550) and harvest index (0.2175) was observed for this trait.

The shelling percentage under moisture stress exhibited a negative significant correlation with number of days to maturity (0.2766) whereas negative non-significant correlation was seen with percentage of sound mature kernels (0.0754), number of mature pods per plant (0.0843), number of immature pods per plant (0.2176) and number of pods per plant (0.0350). Positive non-significant correlation of this trait was observed with test weight (0.1129), number of kernels per plant (0.1141), kernel yield per plant (0.0590), fresh weight of seedling (0.1638), harvest index (0.0189) and total seedling length (0.1960).

4.3.1.4.5 Percentage of sound mature kernels

Under normal moisture condition, the percentage of sound mature kernels had positive non-significant relation with total seedling length (0.1535) and test weight (0.1685). This character had a negative non-significant correlation with number of pods per plant (0.1694), number of mature pods per plant (0.1474), number of immature pods per plant (0.2173), number of kernels per plant (0.1655), kernel yield

per plant (0.1047), fresh weight of seedling (0.1582), number of days to maturity (0.0753) and harvest index (0.0940).

In moisture stressed condition, this trait had negative non-significant association with traits like test weight (0.1096), number of pods per plant (0.0110), number of mature pods per plant (0.0362), number of immature pods per plant (0.0880), number of kernels per plant (0.0143), kernel yield per plant (0.1949), number of days to maturity (0.1191) and harvest index (0.0292) except for fresh weight of seedling (0.1556) and total seedling length (0.1678) which had a positive non-significant correlation.

4.3.1.4.6 Test weight

For test weight under normal moisture condition, positive significant correlation was observed with total seedling length (0.2320) and positive non-significant correlation with harvest index (0.1141), kernel yield per plant (0.0081) and number of days to maturity (0.0091). Negative non-significant correlation was observed with number of pods per plant (0.1855), number of mature pods per plant (0.1829), number of immature pods per plant (0.1244), number of kernels per plant (0.1031) and fresh weight of seedling (0.0038).

In moisture stressed condition, test weight has shown positive non-significant correlation with kernel yield per plant (0.0929), number of days to maturity (0.1633), fresh weight of seedling (0.0434) and total seedling length (0.1783). Negative non-significant association of this trait with number of pods per plant (0.1517), number of mature pods per plant (0.1129), number of immature pods per plant (0.1176), number of kernels per plant (0.0440) and harvest index (0.0912) was observed.

4.3.1.4.7 Number of mature pods per plant

Under normal moisture condition, a positive significant correlation of number of mature pods was observed with number of immature pods per plant (0.5124), number of pods per plant (0.9309), number of kernels per plant (0.8533), kernel yield per plant (0.7649), harvest index (0.7211) and fresh weight of seedling (0.6641). Further, it also recorded a positive non-significant correlation with number of days to maturity (0.0173) besides having a negative significant association with total seedling length (0.2771).

Number of mature pods per plant in moisture stressed condition exhibited a positive significant correlation with number of immature pods per plant (0.2505), number of pods per plant (0.6345), number of kernels per plant (0.5076), kernel yield per plant (0.4483) and harvest index (0.3925) besides having a positive non-significant association with fresh weight of seedling (0.1813) and total seedling

length (0.0067). A negative non-significant correlation of this trait was seen with number of days to maturity (0.0827).

4.3.1.4.8 Number of immature pods per plant

Under normal moisture condition, number of immature pods per plant indicated a positive significant correlation with number of pods per plant (0.6038), number of kernels per plant (0.5125), kernel yield per plant (0.5142), harvest index (0.6076), fresh weight of seedling (0.5151) and number of days to maturity (0.2800) in addition to having a negative non-significant correlation with total seedling length (0.3405).

For number of immature pods per plant in moisture stressed condition, positive significant correlation was observed with number of pods per plant (0.4954), number of kernels per plant (0.3528) and kernel yield per plant (0.4343) and positive non-significant correlation was recorded with harvest index (0.2505) and fresh weight of seedling (0.0277), respectively. It also had negative non-significant correlation with number of days to maturity (0.0919) and total seedling length (0.1972).

4.3.1.4.9 Number of pods per plant

Under normal moisture condition, number of pods per plant pointed a positive highly significant correlation with number of kernels per plant (0.7818), kernel yield per plant (0.7155), fresh weight of seedling (0.6536) and harvest index (0.7320) besides its non-significant positive correlation with number of days to maturity (0.0228). A negative significant association was observed with total seedling length (0.2848).

In moisture stressed condition, this trait had positive significant correlation with kernels per plant (0.3202), harvest index (0.3089) and kernel yield per plant (0.2658) in addition to its positive non-significant relation with fresh weight of seedling (0.1956). A negative non-significant correlation was observed with number of days to maturity (0.1271) and total seedling length (0.0116).

4.3.1.4.10 Number of kernels per plant

Under normal moisture condition, number of kernels per plant exhibited a positive significant correlation with kernel yield per plant (0.8594), fresh weight of seedling (0.5985) and harvest index (0.7092). A negative non-significant correlation was observed with number of days to maturity (0.0245) and total seedling length (0.1510).

For this trait under moisture stressed condition, positive significant correlation was observed with kernel yield per plant (0.5798), harvest index (0.3721) and fresh

weight of seedling (0.2336). Further, it had a negative non-significant correlation with number of days to maturity (0.1661) and total seedling length (0.0856).

4.3.1.4.11 Kernel yield per plant

Under normal moisture condition, kernel yield per plant had positive significant correlation with fresh weight of seedling (0.5240) and harvest index (0.6764) besides showing a non-significant positive correlation with number of days to maturity (0.0702). There was a negative non-significant correlation of this trait with total seedling length (0.1886).

In moisture stressed condition, kernel yield per plant exhibited a positive significant correlation with fresh weight of seedling (0.3396) and harvest index (0.2729). It had a negative significant relation with number of days to maturity (0.2226) and negative non-significant association with total seedling length (0.0516).

4.3.1.4.12 Fresh weight of seedling

Under normal moisture condition, the fresh weight of seedling recorded a positive significant correlation with harvest index (0.5643) and non-significant positive correlation with number of days to maturity (0.1959). But a negative non-significant correlation was observed for this trait with total seedling length (0.1663).

In moisture stressed condition, positive significant correlation of fresh weight of seedling was observed with total seedling length (0.3071) and positive non-significant association with harvest index (0.0861). A negative non-significant relation was seen with number of days to maturity (0.1993) for this trait.

4.3.1.4.13 Harvest index

Under normal moisture condition, the harvest index exhibited a non-significant positive correlation with number of days to maturity (0.0885) and negative significant correlation with total seedling length (0.2389).

In moisture stressed condition, negative non-significant correlation was observed for harvest index with total seedling length (0.2204) and number of days to maturity (0.1260).

4.3.1.4.14 Number of days to maturity

For number of days to maturity under normal moisture condition, negative significant correlation was observed with total seedling length (0.2714). However, in moisture stressed condition, number of days to maturity had a negative non-significant relationship with total seedling length (0.1442).

4.3.2 Phenotypic path analysis

The path analysis for pod yield per plant was performed with various independent characters viz., plant height, number of primary branches per plant, number of days to flower initiation, number of days to maturity, number of pods per plant, number of mature pods per plant, number of immature pods per plant, test weight, shelling out turn, oil content, kernel yield, root to shoot ratio, phenolic content of seeds, phenolic content of leaves, total seedling length, relative water content, membrane stability index, protein content of both seeds and leaves, harvest index and others .

The results of path coefficient analysis of pod yield with physiological, biochemical and root related traits are presented in the tables 26 and 27 for moisture stressed and normal (without moisture stress) condition, respectively.

Further, the results of path coefficient analysis of pod yield with yield components are presented in the tables 28 and 29 for moisture stressed and normal (without moisture stress) conditions, respectively.

4.3.2.1 Relative Water Content (%)

Under normal moisture condition, the relative water content (0.0386) has direct positive effect towards pod yield and also has positive indirect effect on pod yield through membrane stability index (0.0092), SCMR (0.0053) and protein content of leaves (0.0022). Further, the trait had a negative indirect effect towards yield through protein content of seeds (0.0048), phenolic content of leaves (0.0047), phenolic content of seeds (0.0006), oil content of seeds (0.0051), root to shoot ratio (0.0080) and root length (0.0005).

Under water stress condition, the relative water content (0.0062) has direct negative effect towards pod yield. Further negative indirect effect was observed towards yield through protein content of leaves (0.0003), protein content of seeds (0.0006) and phenolic content of seeds (0.0020). However, this trait exerts a positive indirect effect through membrane stability index (0.0008), phenolic content of leaves (0.0001), oil content of seeds (0.0009) and root length (0.0002).

4.3.2.2 Membrane Stability Index (%)

Under normal moisture condition, the membrane stability index (0.1374) has direct negative effect towards pod yield. Further, negative indirect effect was observed towards yield through protein content of leaves (0.0303), phenolic content of leaves (0.0375) and phenolic content of seeds (0.0449). Positive indirect effect was observed through SCMR (0.0020), protein content of seeds (0.0143), oil content (0.0589), root to shoot ratio (0.0450) and root length (0.0127).

Under water stress condition, the membrane stability index (0.0438) has direct negative effect towards pod yield. Further, negative indirect effect was observed

towards yield through per cent wilted plants (0.0085), protein content of seeds (0.0127), phenolic content of leaves (0.0035), phenolic content of seeds (0.0065), oil content of seeds (0.0033), root to shoot ratio (0.0125) and root length (0.0083).

Positive indirect effect was observed through SCMR (0.0024) and protein content of leaves (0.0010).

4.3.2.3 SPAD Chlorophyll Meter Reading

Under normal moisture condition, SCMR (0.1836) has direct negative effect towards pod yield. Further, negative indirect effect was observed towards yield through protein content of seeds (0.0426), phenolic content of leaves (0.0222), phenolic content of seeds (0.0373), root to shoot ratio (0.0026) and root length (0.0314). Positive indirect effect was observed through protein content of leaves (0.0444) and oil content of seeds (0.0218) and MSI (0.0027).

Under water stress condition, SCMR (0.2040) has direct positive effect towards pod yield. Further, positive indirect effect was observed towards yield through protein content in leaves (0.0207), protein content in seeds (0.0823), phenol content in leaves (0.0646), phenol content in seeds (0.0431), root to shoot ratio (0.0073) and root length (0.0300). Negative indirect effect was observed through per cent wilted plants (0.0189) and oil content of seeds (0.0571) and MSI (0.0114).

4.3.2.4 Per cent of wilted plants (%)

Under water stress condition, per cent of wilted plants (0.1847) has direct negative effect towards pod yield. Further, negative indirect effect was observed towards yield through protein content in seeds (0.0201), phenol content in leaves (0.0006), root to shoot ratio (0.0424), MSI (0.0358) and root length (0.0521). Positive indirect effect was observed through protein content in leaves (0.0225), phenol content in seeds (0.0109), SCMR (0.0171) and oil content of seeds (0.0236).

4.3.2.5 Protein content of leaves (%)

Under normal moisture situation, the protein content in leaves (0.0149) has direct negative effect towards pod yield. Further, negative indirect effect was observed towards yield through phenol content of leaves (0.0031) and phenol content of seeds (0.0006). Positive indirect effect was observed through protein content of seeds (0.0028), oil content of seeds (0.0032), root to shoot ratio (0.0018) and root length (0.0010).

Under water stress condition, the protein content in leaves (0.0514) has direct positive effect towards pod yield. Further, positive indirect effect was observed towards yield through protein content of seeds (0.0163), phenolic content of leaves (0.0016), oil content of seeds (0.0064), SCMR (0.0052), RWC (0.0026) and root to

Table 26: Estimates of direct (diagonal) and indirect effects (of diagonal) of physiological, biochemical and root attributes on pod yield per plant at phenotypic level in groundnut genotypes under normal moisture condition

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	0.0386	0.0092	0.0053	0.0022	-0.0048	-0.0006	-0.0047	-0.0051	-0.0080	-0.0005
X2	-0.0326	-0.1374	0.0020	-0.0303	0.0143	-0.0449	-0.0375	0.0589	0.0450	0.0127
X3	-0.0252	0.0027	-0.1836	0.0444	-0.0426	-0.0373	-0.0222	0.0218	-0.0026	-0.0314
X4	-0.0009	-0.0033	0.0036	-0.0149	0.0028	-0.0006	-0.0031	0.0032	0.0018	0.0010
X5	0.0032	0.0027	-0.0060	0.0049	-0.0257	0.0010	-0.0010	0.0016	-0.0001	0.0028
X6	-0.0022	0.0447	0.0278	0.0053	-0.0053	0.1369	0.0410	-0.0375	-0.0103	0.0245
X7	0.0111	-0.0249	-0.0110	-0.0192	-0.0034	-0.0273	-0.0911	0.0189	0.0073	-0.0106
X8	-0.0390	-0.1254	-0.0347	-0.0637	-0.0185	-0.0802	-0.0607	0.2924	0.1600	0.0415
X9	-0.0343	-0.0540	0.0024	-0.0201	0.0007	-0.0123	-0.0132	0.0901	0.1647	0.0756
X10	0.0008	0.0062	-0.0115	0.0047	0.0074	-0.0121	-0.0079	-0.0096	-0.0310	-0.0675
X11 (r value)	-0.0805	-0.2795	-0.2057	-0.0867	-0.0751	-0.0774	-0.2004	0.4347	0.3268	0.0481
Residual effect = 0.2614										

Where,

- | | | | |
|------|----------------------------------|-------|-----------------------------------|
| X1 - | Relative water content (%) | X7 - | Phenolic content of leaves (µg/g) |
| X2 - | Membrane stability index (%) | X8 - | Oil content of seeds (%) |
| X3 - | SPAD Chlorophyll Meter Reading | X9 - | Root to shoot ratio |
| X4 - | Protein content of leaves (%) | X10 - | Root length (cm) |
| X5 - | Protein content of seeds (%) | X11 - | Pod yield per plant (g) |
| X6 - | Phenolic content of seeds (µg/g) | | |

Table 27: Estimates of direct (diagonal) and indirect effects (of diagonal) of physiological, biochemical and root attributes on pod yield per plant at phenotypic level in groundnut genotypes under moisture stress condition

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	-0.0062	0.0008	0.0000	0.0000	-0.0003	-0.0006	-0.0020	0.0001	0.0009	0.0000	0.0002
X2	0.0059	-0.0438	0.0024	-0.0085	0.0010	-0.0127	-0.0065	-0.0035	-0.0033	-0.0125	-0.0083
X3	0.0016	-0.0114	0.2040	-0.0189	0.0207	0.0823	0.0431	0.0646	-0.0571	0.0073	0.0300
X4	-0.0007	-0.0358	0.0171	-0.1847	0.0225	-0.0201	0.0109	-0.0006	0.0236	-0.0424	-0.0521
X5	0.0026	-0.0012	0.0052	-0.0063	0.0514	0.0163	-0.0005	0.0016	0.0064	0.0097	-0.0005
X6	-0.0131	-0.0429	-0.0598	-0.0161	-0.0469	-0.1482	-0.0234	-0.0362	0.0396	-0.0437	-0.0565
X7	-0.0125	-0.0057	-0.0081	0.0023	0.0004	-0.0061	-0.0384	-0.0180	0.0123	-0.0030	-0.0101
X8	0.0050	-0.0269	-0.1073	-0.0011	-0.0108	-0.0829	-0.1589	-0.3389	0.1621	-0.0596	-0.1186
X9	-0.0319	0.0161	-0.0597	-0.0272	0.0265	-0.0570	-0.0682	-0.1020	0.2134	-0.0098	-0.0827
X10	0.0012	-0.0457	-0.0057	-0.0366	-0.0301	-0.0471	-0.0124	-0.0281	0.0073	-0.1595	-0.0932
X11	-0.0167	0.0931	0.0726	0.1393	-0.0051	0.1884	0.1296	0.1728	-0.1914	0.2886	0.4939
X12 (r value)	-0.0648	-0.1034	0.0607	-0.1578	0.0293	-0.0877	-0.1267	-0.2882	0.2138	-0.0249	0.1021
Residual effect = 0.3581											
X1 -	Relative water content (%)		X5 -	Protein content of leaves (%)		X9 -	Oil content of seeds (%)				
X2 -	Membrane stability index (%)		X6 -	Protein content of seeds (%)		X10 -	Root to shoot ratio				
X3 -	SPAD Chlorophyll Meter Reading		X7 -	Phenolic content of seeds (µg/g)		X11 -	Root length (cm)				
X4 -	per cent of wilted plants		X8 -	Phenolic content of leaves (µg/g)		X12 -	Pod yield per plant (g)				

Table 28: Estimates of direct (diagonal) and indirect effects (of diagonal) of yield components on pod yield at phenotypic level in groundnut genotypes under normal moisture condition

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X1	0.0555	-0.0117	0.0054	0.0250	0.0078	0.0181	-0.0187	-0.0210	-0.0194	-0.0121	-0.0118	-0.0134	-0.0185	-0.0138	0.0486
X2	0.0015	-0.0071	0.0007	0.0017	-0.0006	0.0017	-0.0012	0.0002	-0.0012	-0.0009	-0.0002	-0.0016	-0.0007	0.0005	0.0007
X3	0.0040	-0.0039	0.0405	0.0016	0.0021	0.0002	-0.0063	-0.0086	-0.0069	-0.0076	-0.0042	-0.0034	-0.0072	0.0108	0.0012
X4	-0.0074	0.0040	-0.0007	-0.0164	-0.0018	-0.0010	0.0031	0.002	0.0037	0.0007	0.0008	0.0025	0.0036	0.0009	-0.0049
X5	-0.0077	-0.0044	-0.0028	-0.006	-0.0543	-0.0092	0.0080	0.0118	0.0092	0.0090	0.0057	0.0086	0.0051	0.0041	-0.0083
X6	0.0412	-0.0301	0.0005	0.0075	0.0213	0.1265	-0.0231	-0.0157	-0.0235	-0.0130	0.0010	-0.0005	0.0144	0.0012	0.0293
X7	-0.1694	0.0820	-0.0786	-0.0955	-0.0742	-0.092	0.503	0.2577	0.4682	0.4292	0.3848	0.3340	0.3627	0.0087	-0.1394
X8	-0.0144	-0.0013	-0.0081	-0.0047	-0.0083	-0.0048	0.0196	0.0382	0.0231	0.0196	0.0196	0.0197	0.0232	0.0107	-0.0130
X9	0.0260	-0.0121	0.0126	0.0169	0.0126	0.0138	-0.0693	-0.0449	-0.0744	-0.0582	-0.0532	-0.0486	-0.0545	-0.0017	0.0212
X10	-0.0323	-0.0180	-0.0278	-0.0063	-0.0245	-0.0153	0.1264	0.0759	0.1159	0.1482	0.1273	0.0887	0.1051	-0.0036	-0.0224
X11	-0.0242	0.0028	-0.0120	-0.0055	-0.1200	0.0009	0.0873	0.0587	0.0817	0.0981	0.1142	0.0598	0.0772	0.0080	-0.0192
X12	-0.0318	0.0293	-0.0109	-0.0205	-0.0209	-0.0005	0.0878	0.0681	0.0864	0.0791	0.0692	0.1321	0.0746	0.0259	-0.022
X13	-0.0795	0.0242	-0.0423	-0.0518	-0.0224	0.0272	0.1718	0.1448	0.1744	0.1690	0.1612	0.1345	0.2383	0.0211	-0.0569
X14	-0.0136	-0.0037	0.0146	-0.0030	-0.0041	0.0005	0.0009	0.0154	0.0013	-0.0013	0.0039	0.0108	0.0049	0.0549	-0.0149
X15	-0.0059	0.0006	-0.0002	-0.0020	-0.0010	-0.0016	0.0019	0.0023	0.0019	0.0010	0.0011	0.0011	0.0016	0.0018	-0.0067
X16 (r)	-0.258	0.0506	-0.1091	-0.159	-0.2883	0.0645	0.8912	0.5849	0.8404	0.8608	0.8194	0.7243	0.8298	0.1295	-0.2067
Residual effect = 0.2601															

Where,

X1	Plant height at harvest (cm)	X9	Number of pods per plant
X2	Primary branches at harvest	X10	Number of kernels per plant
X3	Secondary branches at harvest	X11	Kernel yield per plant (g)
X4	Shelling percentage (%)	X12	Fresh weight of seedling (g)
X5	Percentage of sound mature kernels (%)	X13	Harvest index
X6	Test weight (g)	X14	Number of days to maturity
X7	Number of mature pods per plant	X15	Total seedling length (cm)
X8	Number of immature pods per plant	X16	Pod yield per plant (g)

Table 29: Estimates of direct (diagonal) and indirect effects (of diagonal) of yield components on pod yield at phenotypic level in groundnut genotypes under moisture stress condition

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X1	0.1643	-0.0197	-0.0110	0.0268	0.0196	0.0118	-0.0200	-0.0291	-0.0150	-0.0133	-0.0159	0.0382	-0.0370	0.0008	0.1398
X2	0.0048	-0.0401	0.0032	0.0101	0.0005	0.0001	0.0027	0.0017	0.0061	0.0021	-0.0052	-0.0003	-0.0023	-0.0025	0.0050
X3	0.0139	0.0167	-0.2083	-0.0101	0.0086	-0.1013	0.0260	0.0480	0.0489	0.0355	0.0260	-0.0152	0.0152	-0.0599	-0.0020
X4	-0.0128	0.0196	-0.0038	-0.0782	0.0059	-0.0088	0.0066	0.0170	0.0027	-0.0089	-0.0046	-0.0128	-0.0015	0.0216	-0.0153
X5	0.0190	-0.0022	-0.0065	-0.0120	0.1588	-0.0174	-0.0058	-0.0140	-0.0017	-0.0023	-0.0310	0.0247	-0.0046	-0.0189	0.0266
X6	0.0242	-0.0006	0.1637	0.0380	-0.0369	0.3366	-0.0387	-0.0398	-0.0517	-0.0149	0.0310	0.0145	-0.0072	0.0554	0.0601
X7	-0.0145	-0.0079	-0.0148	-0.0100	-0.0043	-0.0137	0.1187	0.0298	0.0753	0.0604	0.0533	0.0214	0.0466	-0.0097	0.0003
X8	0.0404	0.0095	0.0526	0.0496	0.0201	0.0270	-0.0574	-0.2281	-0.1133	-0.0807	-0.0991	-0.0063	-0.0574	0.0210	0.0450
X9	-0.0417	-0.0699	-0.1073	-0.0160	-0.0050	-0.0702	0.2906	0.2275	0.4577	0.1465	0.1217	0.0894	0.1413	-0.0576	-0.0073
X10	-0.0152	-0.0100	-0.0320	0.0214	-0.0027	-0.0083	0.0955	0.0664	0.0601	0.1878	0.1089	0.0440	0.0710	-0.0314	-0.0164
X11	-0.0294	0.0391	-0.0378	0.0179	-0.0591	0.0280	0.1363	0.1319	0.0807	0.1760	0.3035	0.1032	0.0829	-0.0678	-0.0160
X12	0.0515	0.0016	0.0162	0.0363	0.0345	0.0096	0.0400	0.0062	0.0433	0.0519	0.0754	0.2217	0.0191	-0.0439	0.0679
X13	0.0075	-0.0019	0.0024	-0.0006	0.0010	0.0007	-0.0130	-0.0083	-0.0102	-0.0125	-0.0091	-0.0029	-0.0331	0.0039	0.0070
X14	-0.0001	-0.0008	-0.0038	0.0037	0.0016	-0.0022	0.0011	0.0012	0.0017	0.0022	0.0030	0.0026	0.0016	-0.0133	0.0019
X15	-0.1660	0.0244	-0.0019	-0.0382	-0.0327	-0.0348	-0.0005	0.0385	0.0031	0.0170	0.0103	-0.0598	0.0411	0.0276	-0.1950
X16(r value)	0.0459	-0.0422	-0.1891	0.0387	0.1099	0.1571	0.5821	0.2489	0.5877	0.5468	0.5682	0.4624	0.2757	-0.1747	0.1016
Residual effect = 0.3016															

Where,

X1	Plant height at harvest (cm)	X9	Number of pods per plant
X2	Primary branches at harvest	X10	Number of kernels per plant
X3	Secondary branches at harvest	X11	Kernel yield per plant (g)
X4	Shelling percentage (%)	X12	Fresh weight of seedling (g)
X5	Percentage of sound mature kernels (%)	X13	Harvest index
X6	Test weight (g)	X14	Number of days to maturity
X7	Number of mature pods per plant	X15	Total seedling length (cm)
X8	Number of immature pods per plant	X16	Pod yield per plant (g)

shoot ratio (0.0097). Negative indirect effect was observed through phenolic content of seeds (0.0005), root length (0.0005), MSI (0.0012) and PWP (0.0063).

4.3.2.6 Protein content of seeds (%)

Under normal moisture condition, the protein content of seeds (0.0257) has direct negative effect towards pod yield. Further, negative indirect effect was observed towards yield through phenolic content of leaves (0.0010) and root to shoot ratio (0.0001). Positive indirect effect was observed through phenolic content of seeds (0.0010), oil content of seeds (0.0016) and root length (0.0028).

Under water stress condition, the protein content of seeds (0.1482) has direct negative effect towards pod yield. Further, negative indirect effect was observed towards yield through phenolic content of seeds (0.0234), phenolic content of leaves (0.0362), root to shoot ratio (0.0437) and root length (0.0565). Positive indirect effect was observed through oil content of seeds (0.0396).

4.3.2.7 Phenol content of seeds (%)

Under normal moisture condition, the phenolic content of seeds (0.1369) has direct positive effect towards pod yield. Further, positive indirect effect was observed towards yield through phenolic content of leaves (0.0410) and root length (0.0245). Negative indirect effect was observed through oil content of seeds (0.0375) and root to shoot ratio (0.0103).

Under water stress condition, phenolic content of seeds (0.0384) has direct negative effect towards pod yield. Further, negative indirect effect was observed towards yield through phenolic content of leaves (0.0180), root to shoot ratio (0.0030) and root length (0.0101). Positive indirect effect was observed through oil content of seeds (0.0123).

4.3.2.8 Phenolic content of leaves (%)

Under normal moisture condition, phenolic content of leaves (0.0911) has direct negative effect towards pod yield. Further, negative indirect effect was observed towards yield through root length (0.0106). Positive indirect effect was observed through oil content of seeds (0.0189) and root to shoot ratio (0.0073).

Under water stress condition, the phenolic content of leaves (0.3389) has direct negative effect towards pod yield. Further, negative indirect effect was observed towards yield through root to shoot ratio (0.0596) and root length (0.1186). Positive indirect effect was observed through oil content of seeds (0.1621).

4.3.2.9 Oil content of seeds (%)

Under normal moisture condition, the oil content of seeds (0.2924) has direct positive effect towards pod yield. Further, positive indirect effect was observed

towards yield through root to shoot ratio (0.1600) and root length (0.0415). However, under water stress condition, the oil content of seeds (0.2134) has direct positive effect towards pod yield. Further, negative indirect effect was observed towards yield through root to shoot ratio (0.0098) and root length (0.0827).

4.3.2.10 Root to shoot ratio

Under moisture condition, root to shoot ratio (0.1647) has direct positive effect towards pod yield. Further, positive indirect effect was observed towards yield through root length (0.0756). However, under water stress, root to shoot ratio (0.1595) has direct negative effect towards pod yield. Further, negative indirect effect was observed towards yield through root length (0.0932).

4.3.2.11 Root length (cm)

Under normal moisture situation, the root length (0.0675) has direct negative effect towards pod yield in comparison to its direct positive effect (0.4939) towards pod yield.

4.3.2.12 Plant height (cm) at harvest

Under normal moisture condition, plant height (0.5555) has direct positive effect towards pod yield. Further, it has recorded indirect positive effect through secondary branches per plant (0.0054), shelling percentage (0.0250), percentage of sound mature kernels (0.0078), test weight (0.0181) and total seedling length (0.0486) and indirect negative effect through primary branches (0.0117), number of mature pods per plant (0.0187), number of immature pods per plant (0.0210), number of pods per plant (0.0194), number of kernels per plant (0.0121), kernel yield per plant (0.0118), fresh weight of seedling (0.0134), harvest index (0.0185) and number of days to maturity (0.0138).

In moisture stress condition, plant height (0.1643) has direct positive effect towards pod yield. Positive indirect effect was observed through shelling percentage (0.0268), percentage of sound mature kernels (0.0196), test weight (0.0118), fresh weight of seedling (0.0382), number of days to maturity (0.0008) and total seedling length (0.1398). Negative indirect effect was observed through primary branches per plant (0.0197), secondary branches per plant (0.0110), number of mature pods per plant (0.0200), number of immature pods per plant (0.0291), number of pods per plant (0.0150), number of kernels per plant (0.0133), kernel yield per plant (0.0159) and harvest index (0.0370).

4.3.2.13 Primary branches per plant at harvest

Under normal moisture situation, primary branches per plant (0.0071) has direct negative effect towards pod yield. Negative indirect effect was observed through percentage of sound mature kernels (0.0006), number of mature pods per

plant (0.0012), number of pods per plant (0.0012), number of kernels per plant (0.0009), kernel yield per plant (0.0002), harvest index (0.0007) and fresh weight of seedling (0.0016). Positive indirect effect was observed through secondary branches per plant (0.0007), shelling percentage (0.0017), test weight (0.0017), number of immature pods per plant (0.0002), number of days to maturity (0.0005) and total seedling length (0.0007).

Under moisture stress condition, primary branches per plant (0.0401) has direct negative effect towards pod yield. Negative indirect effect was observed through kernel yield per plant (0.0052), harvest index (0.0023), fresh weight of seedling (0.0003) and number of days to maturity (0.0025). Positive indirect effect was observed through secondary branches per plant (0.0032), shelling percentage (0.0101), sound mature kernels (0.0005), test weight (0.0001), number of mature pods per plant (0.0027), number of immature pods per plant (0.0017), total number of pods per plant (0.0061), number of kernels per plant (0.0021) and total seedling length (0.0050).

4.3.2.14 Secondary branches per plant at harvest

Under normal moisture condition, number of secondary branches per plant (0.0405) has direct positive effect towards pod yield. Further, it has recorded indirect positive effect through shelling percentage (0.0016), percentage of sound mature kernels (0.0021), test weight (0.0002), number of days to maturity (0.0108) and total seedling length (0.0012) besides its indirect negative effect through number of mature pods per plant (0.0063), number of immature pods per plant (0.0086), number of pods per plant (0.0069), number of kernels per plant (0.0076), kernel yield per plant (0.0042), fresh weight of seedling (0.0034) and harvest index (0.0072).

In moisture stress condition, number of secondary branches per plant (0.2083) has direct negative effect towards pod yield. Negative indirect effect was observed through shelling percentage (0.0101), test weight (0.1013), fresh weight of seedling (0.0152), number of days to maturity (0.0599) and total seedling length (0.0020). Positive indirect effect was observed through percentage of sound mature kernels (0.0086), number of mature pods per plant (0.0260), number of immature pods per plant (0.0480), number of pods per plant (0.0489), number of kernels per plant (0.0355), kernel yield per plant (0.0260) and harvest index (0.0152).

4.3.2.15 Shelling percentage

Under normal moisture, the shelling percentage (0.0164) has direct negative effect towards pod yield. Negative indirect effect was observed through percentage of sound mature kernels (0.0018), test weight (0.0010), and total seedling length (0.0049). Positive indirect effect was observed through number of mature pods per plant (0.0031), number of immature pods per plant (0.0020), number of pods per plant

(0.0037), number of kernels per plant (0.0007), kernel yield per plant (0.0008), fresh weight of seedling (0.0025), harvest index (0.0036) and number of days to maturity (0.0009). However, under moisture stress condition, the shelling percentage (0.0782) has direct negative effect towards pod yield. Further, it has recorded indirect negative effect through test weight (0.0088), number of kernels per plant (0.0089), kernel yield per plant (0.0046), fresh weight of seedling (0.0128), harvest index (0.0015) and total seedling length (0.0153) whereas indirect positive effect was observed through percentage of sound mature kernels (0.0059), number of mature pods per plant (0.0066), number of immature pods per plant (0.0170), number of pods per plant (0.0027) and number of days to maturity (0.0216).

4.3.2.16 Percentage of sound mature kernels

Under normal moisture condition, the percentage of sound mature kernels (0.0543) has direct negative effect towards pod yield and an indirect negative effect through test weight (0.0092) and total seedling length (0.0083). Further, it has recorded indirect positive effect through number of mature pods per plant (0.0080), number of immature pods per plant (0.0118), number of pods per plant (0.0092), number of kernels per plant (0.0090), kernel yield per plant (0.0057), fresh weight of seedling (0.0086), harvest index (0.0051) and days to maturity (0.0041).

In moisture stress condition, the percentage of sound mature kernels (0.1588) has direct positive effect towards pod yield and also an indirect positive effect through total seedling length (0.0266) and fresh weight of seedling (0.0247). Further, it recorded an indirect negative effect through test weight (0.0174), number of mature pods per plant (0.0058), number of immature pods per plant (0.0140), number of pods per plant (0.0017), number of kernels per plant (0.0023), kernel yield per plant (0.0310), harvest index (0.0046) and number of days to maturity (0.0189).

4.3.2.17 Test weight

Under normal moisture condition, test weight (0.1265) has direct positive effect towards pod yield. Further, it recorded an indirect positive effect towards yield through kernel yield per plant (0.0010), harvest index (0.0144), number of days to maturity (0.0012) and total seedling length (0.0293). It exhibited an indirect negative effect towards yield through number of mature pods per plant (0.0231), number of immature pods per plant (0.0157), number of pods per plant (0.0235), number of kernels per plant (0.0130) and fresh weight of seedling (0.0005).

In moisture stress condition, test weight (0.3366) has direct positive effect towards pod yield and indirect positive effect towards yield through kernel yield per plant (0.0310), days to maturity (0.0554), fresh weight of seedling (0.0145) and total seedling length (0.0601). Further, an indirect negative effect was observed towards yield through number of mature pods per plant (0.0387), number of immature pods

per plant (0.0398), number of pods per plant (0.0517) number of kernel per plant (0.0149) and harvest index (0.0072).

4.3.2.18 Number of matured pods per plant

Under normal moisture, number of matured pods per plant (0.5030) has direct positive effect towards pod yield and indirect positive effect towards yield through number of immature pods per plant (0.2577), number of pods per plant (0.4682), number of kernels per plant (0.4292), kernel yield per plant (0.3848), days to maturity (0.0087), fresh weight of seedling (0.3340) and harvest index (0.3627). Further, an indirect negative effect was observed towards yield only through total seedling length (0.1394).

In moisture stress condition, number of matured pods per plant (0.1187) has direct positive effect towards pod yield and indirect positive effect towards yield through number of immature pods per plant (0.0298), number of pods per plant (0.0753), number of kernels per plant (0.0604), kernel yield per plant (0.0533), fresh weight of seedling (0.0214), harvest index (0.0466) and total seedling length (0.0003). Further, it had an indirect negative effect towards yield through days to maturity (0.0097).

4.3.2.19 Number of immature pods per plant

Under normal moisture status, the number of immature pods per plant (0.0382) has direct positive effect towards pod yield and indirect positive effect towards yield through number of pods per plant (0.0231), number of kernels per plant (0.0196), kernel yield per plant (0.0196), days to maturity (0.0107), fresh weight of seedling (0.0197) and harvest index (0.0232). Further, an indirect negative effect was observed towards yield through total seedling length (0.0130).

In moisture stress condition, number of immature pods per plant (0.2281) has direct negative effect towards pod yield and indirect negative effect towards yield through number of pods per plant (0.1133), number of kernels per plant (0.0807), kernel yield per plant (0.0991), fresh weight of seedling (0.0063) and harvest index (0.0574). Further, an indirect positive effect was seen towards yield through number of days to maturity (0.0210) and total seedling length (0.0450).

4.3.2.20 Number of pods per plant

Under normal moisture condition, number of pods per plant (0.0744) has direct negative effect towards pod yield and also it recorded an indirect negative effect towards yield through number of kernels per plant (0.0582), kernel yield per plant (0.0532), days to maturity (0.0017), fresh weight of seedling (0.0486) and harvest index (0.0545). Further, it exerts an indirect positive effect towards yield through total seedling length (0.0212).

In moisture stress condition, number of pods per plant (0.4577) has direct positive effect towards pod yield besides it exerts an indirect positive effect towards yield through number of kernels per plant (0.1465), kernel yield per plant (0.1217), fresh weight of seedling (0.0894) and harvest index (0.1413). Further, it has shown an indirect negative effect towards yield through number of days to maturity (0.0576) and total seedling length (0.0073).

4.3.2.21 Number of kernels per plant

Under normal moisture condition, number of kernels per plant (0.1482) has direct positive effect towards pod yield and also recorded an indirect negative effect towards yield through kernel yield per plant (0.1273), fresh weight of seedling (0.0887) and harvest index (0.1051). Further, it exerts an indirect negative effect towards yield through days to maturity (0.0036) and total seedling length (0.0224).

In moisture stress condition, number of kernels per plant (0.1878) has direct positive effect towards pod yield and also exerts an indirect positive effect towards yield through kernel yield per plant (0.1089), fresh weight of seedling (0.0440) and harvest index (0.0710). Further, it has shown an indirect negative effect towards yield through days to maturity (0.0314) and total seedling length (0.0164).

4.3.2.22 Kernel yield per plant (g)

Under normal moisture condition, kernel yield per plant (0.1142) has direct positive effect towards pod yield. Further, it recorded an indirect positive effect towards yield through fresh weight of seedling (0.0598), number of days to maturity (0.0080), harvest index (0.0772) and also exerts an indirect negative effect towards yield through total seedling length (0.0192).

In moisture stress condition, kernel yield per plant (0.3035) has direct positive effect towards pod yield. Further, it recorded an indirect positive effect towards yield through fresh weight of seedling (0.1032), harvest index (0.0829) and also shown an indirect negative effect towards yield through number of days to maturity (0.0678) and total seedling length (0.0160).

4.3.2.23 Fresh weight of seedling (g)

Under normal moisture condition, fresh weight of seedling (0.1321) has direct positive effect towards pod yield. Further, it recorded an indirect positive effect towards yield through number of days to maturity (0.0259) and harvest index (0.0746) and also recorded an indirect negative effect towards yield through total seedling length (-0.022).

In moisture stress condition, fresh weight of seedling (0.2217) has direct positive effect towards pod yield. Further, it recorded an indirect positive effect towards yield through harvest index (0.0191) and total seedling length (0.0679)

besides exerting an indirect negative effect towards yield through days to maturity (-0.0439).

4.3.2.24 Harvest index

Under normal moisture condition, harvest index (0.2383) has direct positive effect towards pod yield. Further, it recorded an indirect positive effect towards yield through number of days to maturity (0.0211) and also exerts an indirect negative effect towards yield through total seedling length (0.0569).

In moisture stress condition, harvest index (0.0331) has direct negative effect towards pod yield and indirect positive effect towards yield through days to maturity (0.0039) and total seedling length (0.0070).

4.3.2.25 Number of days to maturity

Under normal moisture condition, number of days to maturity (0.0549) has direct positive effect towards pod yield and indirect negative effect towards yield through total seedling length (0.0149).

In moisture stress condition, number of days to maturity (0.0133) has direct negative effect towards pod yield and indirect positive effect towards yield through total seedling length (0.0019).

4.3.2.26 Total seedling length

Under normal moisture condition, total seedling length (0.0067) has direct negative effect towards pod yield. In moisture stress condition, total seedling length (0.1950) has direct negative effect towards pod yield.

Table 30: Highest yielding genotypes in normal moisture condition and their performance under moisture stress condition

Sl. No.	Genotype	Yield/ plant (g) (Normal Moisture)	Yield /plant (g) (Moisture stress)	Yield reduction / plant (g)	Per cent yield reduction /plant (%)
1	SB - 1	26.60	13.58	-13.02	-48.95
2	ICGV 15148	25.80	12.23	-13.57	-52.60
3	SB - 14	25.60	19.38	-6.22	-24.30
4	ICGV 15146	24.60	13.38	-11.22	-45.61
5	ICGV 15158	24.40	13.31	-11.09	-45.45
6	ICGV 15159	24.20	13.60	-10.60	-43.80
7	ICGV 15151	23.00	19.19	-3.81	-16.57
8	ICGV 15153	22.20	11.49	-10.71	-48.24
9	ICGV 15145	21.20	14.88	-6.32	-29.81
10	ICGV 15152	21.20	11.09	-10.11	-47.69
11	ICGV 15154	20.30	12.14	-8.16	-40.20
12	ICGV 15138	19.80	15.00	-4.80	-24.24
13	ICGV 15161	19.60	10.40	-9.20	-46.94
14	ICGV 15123	19.20	10.91	-8.29	-43.18
15	SB - 17	18.80	10.80	-8.00	-42.55

Table 31: Highest yielding genotypes in moisture stress condition and their performance under normal moisture condition

Sl. No.	Genotype	Yield/ plant(g) (Normal moisture)	Yield/ plant(g) (Moisture stressed)	Yield reduction / plant (g)	Per cent yield reduction /plant (%)
1	SB -14	25.60	19.38	-6.22	-24.30
2	ICGV 15151	23.00	19.14	-3.86	-16.78
3	ICGV 15141	16.20	17.45	1.25	7.72
4	ICGV 15138	19.80	15.00	-4.80	-24.24
5	ICGV 15145	21.20	14.88	-6.32	-29.81
6	Dh -234	16.00	14.60	-1.40	-8.75
7	ICGV 15159	24.20	13.60	-10.60	-43.80
8	SB -1	26.60	13.58	-13.02	-48.95
9	ICGV 15146	24.60	13.88	-10.72	-43.58
10	K - 6	12.00	13.38	1.38	11.50
11	ICGV 15158	24.40	13.31	-11.09	-45.45
12	ICGV 15148	25.80	12.23	-13.57	-52.60
13	ICGV 15154	20.60	12.14	-8.46	-41.07
14	R -2001 - 3	13.20	11.91	-1.29	-9.77
15	ICGV 15153	22.20	11.49	-10.71	-48.24

Table 32: Drought tolerant genotypes identified in the present investigation based on extent of yield reduction under moisture stress over normal moisture condition

SL. No.	Genotype	Yield/ plant(g) (Normal moisture)	Yield/ plant (g) (Moisture stress)	Yield reduction / plant (g)	Per cent yield reduction / plant (%)
1	Dh -234	16	14.6	-1.4	-8.75
2	R -2001 - 3	13.2	11.91	-1.29	-9.7727
3	ICGV 15151	23	19.14	-3.86	-16.783
4	ICGV 15138	19.8	15	-4.8	-24.242
5	SB -14	25.6	19.38	-6.22	-24.297
6	ICGV 15145	21.2	14.88	-6.32	-29.811
7	ICGV 15154	20.6	12.14	-8.46	-41.068
8	ICGV 15146	24.6	13.88	-10.72	-43.577
9	ICGV 15159	24.2	13.6	-10.6	-43.802
10	ICGV 15158	24.4	13.31	-11.09	-45.451
11	TMV -2	14	10.81	-3.19	-22.786

Discussion

V DISCUSSION

Groundnut is a leading oilseed crop in India and primarily cultivated in the *kharif* season. It suffers from various biotic and abiotic constraints, which reduces its productivity in the *Kharif* season. Drought is the most significant constraint that affects groundnut productivity in rainfed agriculture. Drought resistance breeding in most crops is based on empirical approach, which has given limited success. Recently various physiological traits such as relative water content, specific leaf weight (John *et al.* 2012) and SPAD chlorophyll meter reading have been associated with drought tolerance in groundnut (Puangbut *et al.* 2011 and, Nigam and Aruna, 2008). Instead of empirical approach, if the selection for drought tolerance is trait based, the success in developing tolerance genotype will be high and more assured.

The knowledge of the extent and nature of genetic variability present in genetic resources for the desired traits is essential for successful planning of a breeding programme. Further, how these traits are associated with each other and with yield decide the selection strategy, which a breeder should follow.

The present investigation was conducted with an aim to evaluate the groundnut genotypes for drought tolerance and yield. The results obtained in the course of investigation were discussed under the following headings.

5.1 Analysis of variance

5.2 Screening of groundnut genotypes for drought tolerance and yield, and assessment of genetic variability parameters

5.3 Association analysis

5.4 Path coefficient analysis

5.5 Conclusion

5.6 Future line of work

5.1 Analysis of variance

The results of the present study indicated that, the analysis of variance for the biochemical, physiological and root related traits (Table 2 and 3) and, yield and component traits (Table 10 and 11) under both normal moisture and moisture stress situation was found to be highly significant under both moisture stressed and non-stressed field conditions when analyzed separately for each environment. This indicates that, variation exists among the genotypes for drought tolerance through various traits. Previous studies also reported significant genotypic differences for RWC (Clavel *et al.*, 2006), Bootnang *et al.* 2010), SCMR (Babita *et al.*, 2006, Nigam *et al.*, 2005, Nigam and Aruna, 2008, and Sheshshayee *et al.*, 2006), pod yield

(Puangbut *et al.*, 2009, 2010 and Jongrunklang *et al.*, 2008) and MSI (Pranusha, 2011).

The magnitude of genotypic variation was found to be high for fifty per cent flowering, days to maturity, number branches per plant, number of mature pods per plant, pod yield per plant, shelling per cent, hundred kernel weight, sound matured kernel percentage and oil content. The presence of high variability for these characters is in agreement with the results obtained by Suvarna *et al.* (2004) and Gopinath *et al.* (2008).

The Analysis of variance for interaction (genotype x environment) of physiological, biochemical and root attributes (Table 4) is indicated that the effect of environments (moisture stress and normal moisture) was significant on all the traits except oil content. Further, the genotype x environment (G x E) interaction was highly significant for almost all the traits except for oil content. This clearly indicates that, the performance of the genotypes differed significantly for most of the traits across environments (moisture stress and normal moisture condition).

Similarly the mean sum of squares for interaction (genotype x environment) of yield and component characters (Table 12) is indicated that the effect of environments (moisture stress and normal moisture) was significant on all the traits except plant height at 30 DAS and number of days to flower initiation. Further, the genotype x environment (G x E) interaction was highly significant for almost all the traits except for plant height at 60 DAS, number of primary branches per plant at 30 DAS, number of primary branches per plant at 60 DAS and number of days to 50 per cent flowering. This clearly indicates that, the performance of the genotypes differed significantly for most of the traits across environments (moisture stress and normal moisture condition). Similar results are in relation with the reports of Arunyanark *et al.* (2008), Wright *et al.* (1996) and Girdthai *et al.* (2010).

5.2 Screening of groundnut genotypes for drought tolerance and yield, and assessment of genetic variability parameters

The goal of plant breeder is to increase the yield potential of a crop, coupled with desirable quality of grain. Improvement in yield can be achieved by genetically manipulating the morpho-genetic architecture of the plant applying recombination breeding or other crop improvement methods for creation of new variability. The extent of genetic variability available in the plant population largely determines the opportunity for selection. Thus, an insight into the magnitude of genetic variability is of paramount importance to the plant breeder for starting judicious breeding programme. The simple measure of genetic variability is the coefficient of variation which partitions the total variation into phenotypic, genotypic and environmental components. The genotypic coefficient of variation measures the extent of genetic

variability present in the crop species for particular trait. The phenotypic coefficient of variation of characters is the manifestation of genotype, environment and interaction between the genotypes and environment. Therefore, the total variance needs to be partitioned into heritable and non-heritable components to assess the true breeding behavior of a particular trait. The results obtained from quantitative characters studied in the present investigation are being discussed in this chapter.

Genetic advance is the measure of genetic gain under selection. Genetic advance under selection depends on three main factors like genetic variability, heritability and selection intensity. Therefore, a high genetic advance may be attributed either due to high genetic variability or heritability or due to both. If a character shows high genetic advance, selection will be rewarding for improvement of such trait.

Groundnut has emerged as an economically important crop due to its significant share in vegetable oil production of India. Abiotic stress has been reported as a major constrain for groundnut production and recent abrupt climate change is making the abiotic stresses more common in the country. Water stress severely affects growth and development at all growth stages of plant.

Agronomic interventions poses their own importance in abiotic stress tolerance, since genetic solutions are unlikely to close more than 30 per cent of the gap between potential and realized yield under water stress (Edmeades *et al.*, 2004). However, improved genetics can be conveniently packaged in a seed and therefore more easily and completely adopted than improved agronomic practices that depend more heavily on input availability, infrastructure, and skills in crop and soil management (Campos *et al.*, 2004). So, the use of genetics and plant breeding aspects to improve drought tolerance and provide yield stability is an important part of the solution to stabilizing global groundnut production. However, the crop improvement for water stress requires incessant efforts chiefly, through the knowledge of genetic mechanism governing heritable character. Genetic effects of heritable character lead a plant breeder to an obvious understanding of inheritance patterns of various plant characters as their relative contribution to the absolute yield.

Efficient improvement of any crop depends chiefly on the information on genetic variability and diversity which outlines the basis for any crop breeding programme. Further, the triumph of any crop improvement programme depends on the amount of genetic variability present in the population for the character for which the improvement is designed at. So, screening the germplasm lines and cultivated varieties for drought tolerance is the initial step in developing cultivars with both high yield and drought tolerance. However, drought tolerance screening under field conditions needs lot of resources like land, labour, rain-free environment and planning

of the experiment. Further, it also depends on the environmental influences that change phenotypic expression of a genotype.

Comparative statement based on estimates of different genetic parameters for biochemical, physiological and root related characters in groundnut genotypes under stress condition were presented in table 7. The comparative performance of forty genotypes for physiological, biochemical and root related traits under control and stress condition is presented in the table 8. Similarly the comparative overall mean performance of the genotypes for physiological, biochemical and root related attributes under both stress and stress free condition is presented in the table 9.

Relative water content in moisture stressed plants has shown 25.77 per cent decrease when compared to normal plants. This may be because of less moisture content in root zone of moisture stressed plant when compared to normal moisture plant. This trait showed high genotypic and phenotypic coefficients of variation in moisture stressed condition and low genotypic and phenotypic coefficients of variation under normal condition. It showed high heritability and high genetic advance over mean in moisture stressed condition as against their lower values under normal moisture condition. This reflects that, this trait can be used to select drought tolerant genotypes only under stress environments (imposed or natural moisture stress) but not under normal environments. It also indicates the presence of additive gene action for this trait. Similar observations were reported by Suvarna *et al.* (2004) and Songsri *et al.* (2008a).

The groundnut plants under moisture stressed condition showed 2.49 per cent decrease in the mean membrane stability index (MSI) as against the plants in normal moisture condition. The ability of plants to maintain membrane integrity under drought is what determines tolerance towards drought (Vieira *et al.*, 1974). Further, Dhindsa *et al.* (1981), Chen *et al.* (1991) have linked increased electrolyte leakage to reductions in chlorophyll concentrations (due to leaf senescence) while Premachandra *et al.* (1992), Mc Donald and Archbold (1998) have shown that reduced water application affected the electrolyte leakage. This trait exhibited high genotypic and phenotypic coefficients of variation in both stressed and non-stressed condition. It also had high heritability with high genetic advance over mean in both the conditions indicating its utility as a parameter for selecting genotypes for drought tolerance. Such genotypic variations in relative membrane injury were also reported in different crops (Sullivan and Ross, 1979 and Sudhakar *et al.*, 2006a) including groundnut (Pranusha *et al.*, 2012).

SPAD chlorophyll reading in moisture stressed plants was increased to about 2.54 per cent when compared to plants which were exposed to normal moisture. This is in line with the results obtained by Beeflink *et al.* (1985), Mensah *et al.* (2006) and Geravandi *et al.* (2009). But many researchers (Ahmadi, 1985,

Kulshreshta *et al.*, 1987, Majumdar *et al.*, 1991 and El-Tayeb, 2006) have also reported decrease in chlorophyll content under drought stress condition. While some reports (Rensburg and Kruger, 1994, and Kyparissis *et al.*, 1995) indicated no change in chlorophyll content under drought stress. This clearly shows the need for detailed and systematic research on the fate of chlorophyll content under moisture stress in different crops. This trait showed lower genotypic and phenotypic coefficients of variation in both stressed and normal condition. It also exhibited high heritability with moderate genetic advance over mean indicating the possibility to improve this trait by proper selection methods. Similar findings were reported by Songsri *et al.* 2009 wherein it was suggested that, peanut genotypes having ability to maintain higher SCMR and low SLA (Specific Leaf Area) under drought stress condition should be more drought tolerant and hence, maintain higher water use efficiency under severe drought condition. However, Painawadee *et al.* (2009) reported low to intermediate heritability estimates for this trait. Venkateswarlu *et al.* (2007) reported predominance of additive gene effects for expression of SCMR and SLA in a few groundnut crosses. SCMR is an indication of the light transmittance characteristics of the leaf which is dependent on the leaf chlorophyll content (Richardson *et al.* 2002). Madhava *et al.* (2003) suggested that SCMR might be useful for screening peanut genotypes in early segregating populations as it is much simpler than SLW and SLW might be suitable for screening the advance generation material.

Chlorophyll measurement in groundnut using SPAD Chlorophyll Meter is shown in plate 3.

Per cent of wilted plants in moisture stressed condition was in the range of 12.55 to 56.32 per cent with a mean of 29.89 per cent which indicates that, half of the genotypes under study have poor drought tolerance ability. The high phenotypic and genotypic coefficients of variation, high heritability coupled with high genetic advance over mean for per cent of wilted plants further shows the importance of this trait and selection based on this character will be more useful in identifying genotypes for drought tolerance as this trait is also under the influence of additive gene action (Gobu *et al.*, 2014).

Oil content in moisture stressed field condition was increased by 4.61 per cent as compared to normal moisture. This trait exhibited low genotypic and phenotypic coefficients of variation in both moisture stressed and normal condition. It exhibited higher heritability with high genetic advance over mean in both the conditions. Although the trait appears to be under the influence of additive gene action, improvement of oil content through simple selection is ineffective in view of narrow genetic variation for this trait. These results are in relation with the reports of Gopinath *et al.* (2008). Shivakumar and Sharma (1986) reported that oil content of kernels significantly decreased with increased moisture stress due to imposed



Plate 3: Chlorophyll measurement in groundnut using SPAD Chlorophyll Meter

moisture stress at all the growth stages of the groundnut. However, Venkataravana *et al.* (2001) observed high coefficient of variability at phenotypic and genotypic level and high heritability with high genetic advance for oil percentage indicating the presence of additive gene action. Prakash *et al.*, (2000) reported low variability and high heritability, indicated the least influence of environment on oil content.

Phenolic content of leaves in moisture stressed field condition increased by 1.81 per cent as compared to normal moisture. This trait exhibited high genotypic and phenotypic coefficients of variation in both moisture stressed and normal condition. It exhibited higher heritability with high genetic advance over mean in both the conditions. These results are in agreement with that of Aninbon *et al.*, (2016).

Phenolic content of seeds in moisture stressed field condition decreased by 3.89 per cent as compared to normal moisture. This trait exhibited high genotypic and phenotypic coefficients of variation in both moisture stressed and normal condition. It exhibited higher heritability with high genetic advance over mean in both the conditions. These results are in agreement with that of Aninbon *et al.* (2016), Kro *et al.* (2014) and HuiHui *et al.* (2015).

Protein content of both leaves and seeds in moisture stressed field condition increased by 6.81 and 12.60 per cent, respectively as compared to normal moisture. Protein content of leaf showed moderate GCV and PCV estimates in both situations. It showed high heritability with high genetic advance over mean indicating selection based on this trait will be helpful for breeder. The similar results were reported by Kulshreshta *et al.* (1987). They reported that the drought tolerant genotypes of mungbean had comparatively higher protein content than the drought sensitive mungbean genotypes. A similar report was also made by Botha and Botha (1979) in drought-sensitive maize lines. The above reports clearly indicate that the protein content was altered in plants during water deficits.

Root to shoot ratio in moisture stressed condition was increased by 4.26 per cent as compared to the plants grown with normal watering. This trait exhibited moderate genotypic and phenotypic coefficients of variability in both moisture stressed and normal condition. It also exhibited high heritability with high genetic advance over mean. Since root to shoot ratio depends on the root length, it also followed the similar trend with respect to heritability and genetic advance over per cent mean. These finding were in line with that of Gobu *et al.* (2014). In addition to root length, the root to shoot ratio can also be utilized for selection in early generation as this trait can also be fixed because of its additive nature of genetic variance.

In moisture stressed plots, root length showed 9.06 per cent decrease as compared to plants in controlled condition. The results are in agreement with the reports of Madhusudhan and Sudhakar (2014), and Girdthai *et al.* (2010). Usually root length in plants will be increased in search of water and it is supported by stem reservoirs. Tap root length increases under moisture stress condition which is compensated by root volume. Root volume, secondary and tertiary branches of root decreases due to moisture stress. Several authors reported that longer root length helps explore water as well as nutrients from deeper layers of soil profile (Sheshaiah *et al.*, 2014). This trait showed moderate genotypic and phenotypic coefficients of variability in both moisture stressed and non-stressed condition. It also exhibited high heritability with high genetic advance over mean indicating the additive nature of genetic variation for this trait and the trait can be easily fixed in the genotypes by selection in the early generations which helps the breeder developing improved drought tolerant genotypes in groundnut.

Comparative statement based on estimates of different genetic parameters for yield component characters in groundnut genotypes under stress condition is presented in the table 15. The comparative performance of forty genotypes for yield components under normal moisture and moisture stress condition is presented in the table 16. The comparative overall mean performance of the genotypes for drought related parameters under both the conditions is presented in the table 17.

Plant height at 30, 60 and 90 days after sowing, primary branches at 60 and 90 days after sowing, secondary branches at 60 and 90 days after sowing and days to fifty per cent flowering under moisture stress showed a minor decrease over normal condition. Since moisture stress was not imposed before or around these stages, this variation was probably due to environmental factors. These traits showed variable genotypic and phenotypic coefficients of variation besides having variable heritability with high genetic advance over mean.

Generally, it has been documented that, plants show different levels of tolerance to drought stress at different crop stages. In case of groundnut, flowering, pegging, pod formation and pod development stages are regarded as critical stages of irrigation (Wright and Nageswara, 1994). It is reported that highest yield reduction takes place when groundnut experienced moisture stress during flowering, pegging, pod formation and pod development stages (Nautiyal *et al.*, 1999, Rucker *et al.*, 1995, and, Wright and Nageswara, 1994). Majority of studies supported that, pod development stage is the most critical stage for irrigation because developing pod acts as an active sink for photosynthetic product (Meisner, 1991 and Ramachandrappa *et al.*, 1992). So, the present study was undertaken for studying the moisture stress tolerance of genotypes pod development stages. The recommended

package of practice for groundnut crop was followed in both the plots except irrigation schedule for moisture stressed plots.

Plant height at harvest under moisture stressed field condition showed a marginal reduction of 4.28 per cent compared to normal condition. Reduction in plant height may be due to limited availability of water, limited availability of stem reservoirs, reduced cell division and low water potential. Reduction in plant height due to stress at stem elongation stage was due to loss of turgor resulting in reduction in cell division and elongation as report by Rauf *et al.* (2012). Similar results were reported by Ayub *et al.* (2012) and, Arunachalam and Kannan (2013). This trait showed moderate phenotypic and moderate genotypic coefficients of variation both under moisture stressed and normal condition. This trait exhibited a high heritability coupled with high genetic advance over mean in both moisture stressed and normal condition. Similar results were reported by Zaman *et al.* (2011), Savaliya *et al.* (2009), Ashutosh and Prashant, (2014), Nandini *et al.* (2011) and Kadam *et al.* (2016).

There was a non-significant increase in the number of days to fifty per cent flowering in moisture stressed field condition as compared to normal field condition. All the genotypes started flowering before inducing the drought stress. Since moisture stress was imposed 90 days after sowing, this negligible variation was just due to environmental factors. It is well established that, generally early flowering occurs under moisture stress, only the cultivars with drought tolerance ability tend to exhibit early flowering. This trait showed lower genotypic and moderate phenotypic coefficient of variation. Further, it also exhibited high heritability with moderate genetic advance over mean indicating a possibility of improving this trait through selection procedures. The results are on par with the results of Ashutosh and Prashant (2014), Padmaja *et al.*, (2013), Nandini and Savithamma (2012), John *et al.* (2005) and Patil *et al.* (2014).

Number of days to maturity in moisture stressed plants was reduced by 1.61 per cent as compared to normally watered plants. Similar trend was obtained by Suriharan *et al.* (2008). Although, it is well established that, drought stress accelerates maturation in groundnut and only the cultivars with drought tolerance ability tend to mature early than susceptible cultivar. Early maturity is an important vehicle for drought escape, especially to the late-season drought. This trait showed lower genotypic and phenotypic coefficients of variation in both the field conditions. Similar results were obtained by Ashutosh and Prashant, (2014), Patil *et al.* (2014) and Satyanarayan *et al.* (2014). Early maturity is an important character in groundnut as it enables escape from drought (Janila *et al.* 2013). However, a high heritability accompanied by a lower genetic advance over mean (in both the field conditions) is an indicative of the possible non-additive gene action. Hence, selection based on this

trait will be ineffective in identifying a drought tolerant genotype. The results are on par with Ashutosh and Prashant, (2014), Padmaja *et al.* (2013), Patil *et al.* (2014) and Satyanarayan *et al.* (2014).

Total number of pods per plant in moisture stressed condition showed 34.06 per cent decreased as compared to non-moisture stressed field. Number pods are the summation of mature and immature pods per plant. This trait exhibited high genotypic and phenotypic co-efficient of variation. Similar findings were obtained by Nandini *et al.* (2011), Parameshwarappa and Girish (2007), John *et al.* (2007), Veeramani *et al.* (2005) and Makhan *et al.* (2003). High heritability coupled with high genetic advance over mean in both moisture stressed and normal condition is a clear indication of the presence of additive nature of genetic variation which can be fixed in the early generations by simple selection procedures. Similar results were reported by Khote *et al.* (2009), Nandini *et al.* (2011), Parameshwarappa and Girish (2007), John *et al.* (2007), Veeramani *et al.* (2005), Makhan *et al.* (2003), Gowda *et al.* (1996), Satish (2014) and Satyanarayan *et al.* (2014). However, total number of pods also includes immature pods, it is very important to consider number of mature pods per plant rather than their total number for improving drought tolerance in groundnut and also for yield improvement of groundnut in general.

The average number of mature pods per plant in moisture stressed condition showed 19.58 per cent decline as compared to normal condition. This trait exhibited high genotypic and phenotypic coefficients of variation, high heritability coupled with high genetic advance over mean in both moisture stressed and normal condition. Similar results were reported by Zaman *et al.* (2011). These genetic parameters provide clear evidence for predominance of additive nature of genetic variation in the germplasm for this trait and selection for this trait is effective in both moisture stress and normal conditions even in early generations to fix its performance.

The average number of immature pods per plant in moisture stressed condition showed 25.54 per cent increase as compared to normal condition. Groundnut is considered as an unpredictable crop. Due to moisture stress, the soil crust becomes hard, so that pegs are unable penetrate into the soil and develop into a pod. Further, the pegs that have already penetrated into soil may not develop into full sized mature pods. This will increase the number of immature pods under drought stress as evident in the present study. This trait has exhibited high genotypic and phenotypic coefficients of variation and high heritability coupled with high genetic advance over mean in both moisture stressed and normal condition. Similar trend was reported by Zaman *et al.* (2011) and Sanjeevakumar *et al.* (2015).

Pod yield per plant in moisture stressed condition showed 42.32 per cent reduction as compared to normal moisture condition in the field. This trait exhibited high genotypic and phenotypic coefficients of variation and high heritability coupled

with high genetic advance over mean in both moisture stressed and normal condition. This clearly indicates that, pod yield under drought is a very important trait in groundnut which is under the influence of additive gene action which can be fixed or improved through selection. The current findings are in conformation with the findings of Khote *et al.* (2009), Nandini *et al.* (2011), Parameshwarappa and Girish (2007), John *et al.* (2007), Veeramani *et al.* (2005), Makhan *et al.* (2003), Gowda *et al.* (1996), Narasimhulu *et al.* (2012), Satyanarayan *et al.* (2014) and Thirumala *et al.* (2014).

Pod yield per hectare in moisture stressed condition showed 5.20 per cent decrease as compared to normal moisture condition. This trait exhibited high genotypic and phenotypic coefficients of variation and high heritability coupled with high genetic advance over mean in both moisture stressed and normal moisture condition. These results are indicative of the predominance of fixable component of genetic variation (additive variance) and hence there is possibility of improving this trait by simple selection even in early segregating generations. Similar results obtained by Ashutosh and Prashant (2014) and Satish (2014). The current findings are in conformation with the findings of Khote *et al.* (2009) and Nandini *et al.* (2011).

Test weight or 100-seed weight in moisture stressed condition showed 3.70 per cent reduction as compared to normal moisture. This trait exhibited moderate genotypic and phenotypic coefficients of variation and high heritability coupled with high genetic advance over mean in both moisture stressed and normal condition. Similar findings were obtained by Ashutosh and Prashant, (2014), Savaliya *et al.* (2009), John *et al.* (2007), Narasimhulu *et al.* (2012), Khote *et al.* (2009), Satish, (2014) and Patil *et al.* (2014). It can be understood that, test weight, an important yield contributing trait may also be under the influence of additive genetic variance whose improvement can be done by selection methods.

Shelling out turn (%) in moisture stressed condition declined by 10.20 per cent compared to normal moisture condition. This trait exhibited moderate genotypic and phenotypic coefficients of variation in moisture stressed condition. It exhibit lower genotypic and moderate phenotypic coefficients of variation in normal moisture condition. Similar results were obtained by Parameshwarappa *et al.* (2005), Satyanarayan *et al.* (2014), John *et al.* (2011) and Padmaja *et al.* (2013). It exhibited high heritability with high genetic advance over mean in both moisture stressed and normal condition. Since shelling out turn is an important yield contributing parameter in groundnut, the trait can be improved through selection methods in view of high heritability coupled with high genetic advance values despite their narrow variation in the present germplasm. Similar results were reported by Ashutosh and Prashant, (2014), Nandini *et al.* (2011), John *et al.* (2007), Narasimhulu *et al.* (2012), Khote *et al.* (2009) and Thirumala *et al.* (2014).

The kernel yield per plant under moisture stress was declined by 14.68 per cent compared to normal moisture which is having a significant impact on oil yield. This trait has shown high genotypic and phenotypic coefficients of variation in both moisture stressed and normal moisture conditions. This trait has recorded high heritability with high genetic advance over mean in both the conditions indicating the possibility of additive gene action governing this trait and selection for this trait can be done in early segregating generations so that the performance can be fixed by simple selection schemes. The Kernels of drought tolerant genotypes are shown in plate 4.

Harvest index in moisture stressed field condition decreased by 95.24 per cent as compared to normal condition. This trait exhibited high genotypic and phenotypic coefficients of variation in both moisture stressed and normal conditions. It exhibited high heritability with high genetic advance over mean in moisture stressed condition. But, it has shown higher heritability with high genetic advance over mean in normal condition. Similar findings were obtained by Patil *et al.* (2014) and, Nath and Alam, (2002). This trait can be improved by selection schemes provided there is a wide genetic variation for this trait. Since the germplasm used in the present study has moderate genetic variation for this trait, the trait can still be improved by selecting under normal moisture instead of under moisture stress.

Number of primary and secondary branches per plant at harvest in moisture stressed field increased marginally by 2.19 and 2.69 per cent, respectively, as compared to normal condition. Lenka and Misra (1973) reported that the plants were shorter in drought year than the normal year but less plant height was compensated by more number of branches. For this trait, GCV and PCV values were high in moisture stressed and moderate in normal condition. Similar results were obtained by Satyanarayan *et al.* (2014). This trait also had high heritability with higher genetic advance over mean in both the conditions. Similar results were reported by Ashutosh and Prashant (2014), Satish (2014), and Satyanarayan *et al.* (2014). These results indicate that, the trait cannot be improved by simple selection methods but demand careful assessment of the performance of the genotypes before making selection as there could be a possibility of non-additive gene action controlling this trait.

The results of sound mature kernels, there was 1.57 per cent decrease in stress condition compared to normal situation. This character also showed high heritability coupled with high GAM and low GCV and PCV values which indicated the substantial influence of environment on these characters and prevalence of narrow range of variability, high G x E interaction or non-additive gene action. Yogendra *et al.* (2002) reported low variability for shelling per cent while Nandini *et al.* (2011) reported moderate PCV and GCV for this trait.

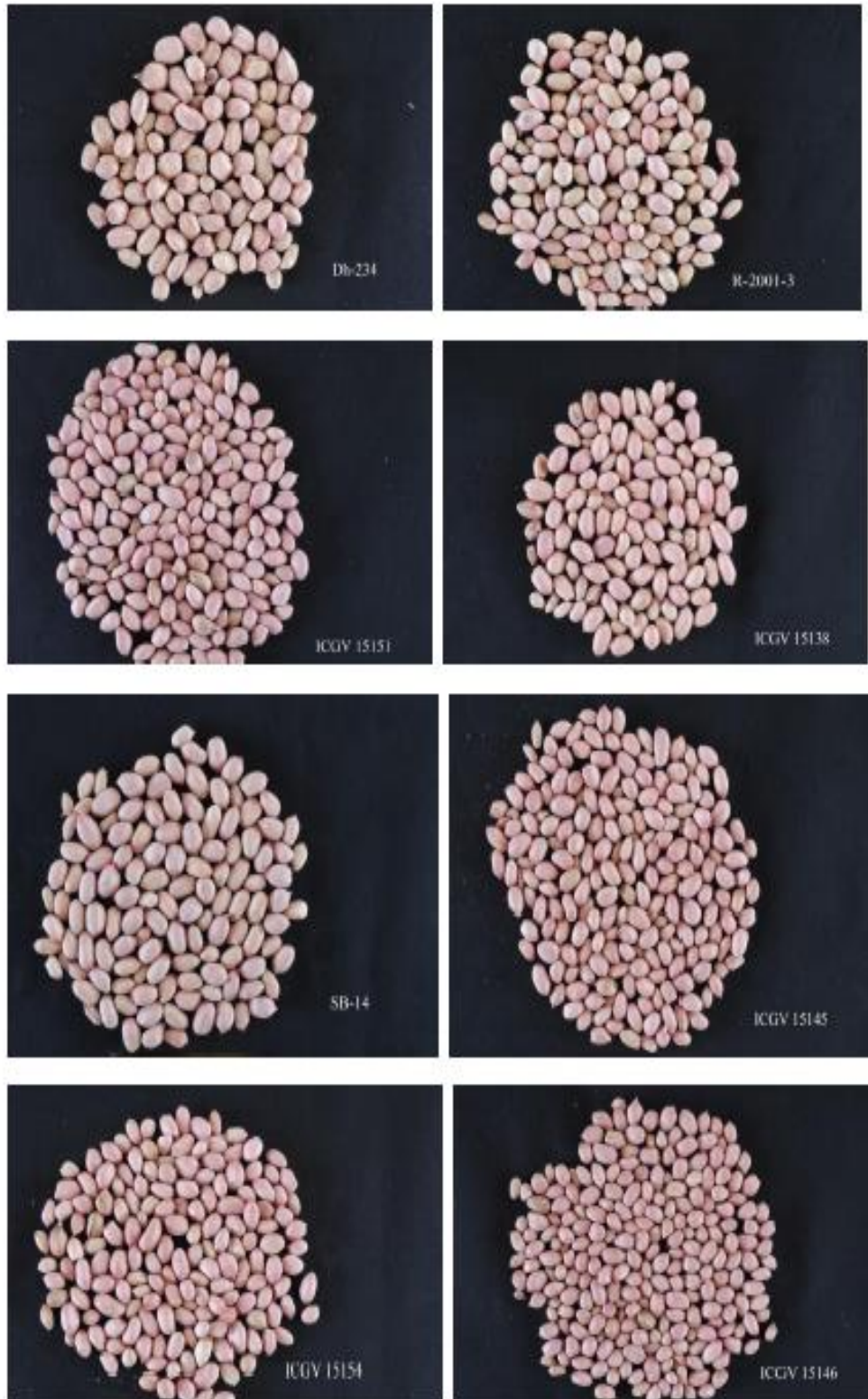


Plate 4: Kernels of drought tolerant genotypes

Venkataramana, (2001) and Yogendra *et al.* (2002) reported low variability for SMK per cent and oil content whereas, Parameswarappa and Girish (2007) reported high PCV and GCV for SMK per cent. Gopinath *et al.* (2008) reported high heritability for shelling per cent and oil content but moderate heritability observed for SMK per cent. Suvarna *et al.* (2004) reported low GAM for oil content, SMK per cent and shelling per cent. Similar results were reported by John *et al.* (2006) for shelling per cent.

The fresh weight of seedlings in stressed condition showed 23.33 per cent reduction when compared to control. However, the fresh weight of the seedlings in both stressed and control condition showed high genotypic and phenotypic coefficients of variability in the present investigation. It also showed high heritability along with high genetic advance over mean. Hence, selection based on fresh weight of seedlings managed moisture stress may facilitate the groundnut breeder to identify potential drought tolerant lines.

The number of kernels per plant in stressed condition showed 22.11 per cent reduction when compared to normal moisture. This trait exhibited high GCV and PCV values under both stress and stress free conditions. It also showed high heritability coupled with high genetic advance over mean in both conditions indicating that selection based on this trait may help breeder to identify drought tolerant genotypes.

The total length of seedlings in stressed condition showed 8.72 per cent reduction when compared to normal moisture. However, the total length of the seedling in both stressed and control condition showed low genotypic and phenotypic coefficients of variability in the present investigation. Further, it also showed high heritability along with moderate genetic advance over mean in stressed condition. Hence, selection based on fresh weight of seedlings under managed moisture stress may facilitate the groundnut breeder to identify potential drought tolerant lines.

Based on stress tolerance index (STI) and drought susceptibility index (DSI) for pod yield of genotypes, the genotypes like SB -14 and ICGV 15151 had the highest STI values of 2.78 and 2.58, respectively (DSI values 1.36 and 0.68). Genotypes like GPBD-4 and ICGV 15114 were ranked with the minimum STI values of 0.31 and 0.33 (DSI values 2.73 and -2.22), respectively showing high sensitivity to moisture stress than other genotypes. STI is better than the other indices for evaluating genotypes under drought stress condition and the higher rates of STI show the higher tolerance of the genotype to drought and therefore higher yield.

Guttieri *et al.* (2001) proposed that, the genotype with a value of SSI more than 1 of showed greater susceptibility to drought. Selection based on SSI is led to the selection of drought tolerant genotypes (Clarke and McCaig, 1982).

The genotypes which recorded high yield under normal moisture condition and their comparative yield under moisture stress condition is indicated in table 30 while the genotypes which recorded high yield under moisture stress and their comparative yield under normal condition is presented in table 31. But the real drought tolerant genotype is one which showed minimum yield reduction under moisture stress condition when compared to their yield in normal condition. Such drought tolerant genotypes identified in the present investigation include Dh -234, R-200-3, ICGV 15151, ICGV 15138, SB-14, ICGV 15145, ICGV 15154, ICGV 15146, ICGV 15159, ICGV 15158 which have recorded significantly higher yield (Table 32).

5.3 Association analysis

Information on the phenotypic and genotypic interrelationship of the pod yield with its components and physiological characters and also among the component characters themselves would be useful to the breeder in developing an appropriate selection strategy. Yield is a complex trait and through selection for this attribute based on heritability estimates only will not be rewarding for yield improvement. Pod yield is dependent on various other component traits like plant height, test weight, shelling out turn, harvest index, *etc.* Pod yield is the effect of complex interrelationships between various component characters. Hence, path coefficient analysis was employed to partition the correlation into measures of direct and indirect effects. Therefore, understanding the relationship between these traits helps in achieving the improved yield. In crop improvement, phenotypic correlation coefficient is a useful tool for the breeder which helps in selection of a complex character through the selection of simpler characters. In groundnut lot of work has been done in path analysis and scientists achieved their goals and many such success reports include John and Reddy (2015), Jayalakshmi and Nirmala (2015), Thakur *et al.* (2013b), Babariya and Dobariya (2012), Ravi and Sekhar (2012), Dandu *et al.* (2012), Zaman *et al.* (2011), Korat *et al.* (2010), Vaithiyalingan *et al.* (2010), Giri *et al.* (2009), Mane *et al.* (2008), Sirisha (2005), Lakshmiddevamma *et al.* (2004), Chishti *et al.* (2000), Venkataravana *et al.* (2000) and, Islam and Rasul (1998).

In this respect, numerous studies reported significant relationships among the different pairs of various characters of groundnut. In view of this, phenotypic correlation analysis was carried out for physiological, biochemical and root related traits (Table 22 and 23) and also for yield component traits in 40 groundnut genotypes (Table 24 and 25) under both normal moisture and moisture stress environments. It was evident from the results that, there exists a significant association among many of these traits.

In normal moisture field condition, pod yield per plant recorded a positive and highly significant association with oil content of seeds, root to shoot ratio and a negative significant association with membrane stability index. It had a negative non-significant association with RWC, SCMR, phenolic content of leaf, phenolic content of seeds, protein content of seed and protein content of leaf and positive non-significant correlation with root length.

However, in moisture stress field condition, pod yield per plant recorded a positive significant association with oil content of seeds and negative high significant association with phenolic content in leaf. But it had positive non-significant association with protein content of leaf, SCMR and root length. It also recorded negative non-significant association with RWC, membrane stability index, per cent of wilted plants, phenolic content in seeds, protein content of seed and root to shoot ratio. These results are in agreement with Songsri *et al.* (2009). Further, the results are in agreement with that of Sudhakar *et al.* (2006b) wherein they have reported significant positive correlation between SCMR and yield under terminal moisture stress conditions in green gram and black gram. Positive correlation between SCMR and seed yield has been reported in groundnut (Rao *et al.*, 2014).

Among the component biochemical, physiological and root related characters, different types of correlations were observed and are discussed hereunder:

Relative water content in normal moisture condition had a positive significant association with membrane stability index and positive non-significant association with SCMR and protein content of leaf but negative non-significant relationship with phenolic content of seeds, protein content of seeds, phenolic content of leaves, root to shoot ratio, oil content of seeds and root length. However, under moisture stress condition, relative water content recorded a highly positive significant association with phenolic content of seeds. It had a negative non-significant association with membrane stability index, root to shoot ratio, oil content of seeds, phenolic content of leaves and root length. Positive non-significant correlation was observed for SCMR, per cent of wilted plants, protein content of seeds and protein content of leaves.

In normal moisture situation, the membrane stability index recorded positive significant association with protein content of leaves, phenolic content of leaves and phenolic content of seeds. Negative high significant correlation was observed for root to shoot ratio and oil content of seeds. In addition, it also had a negative non-significant association with SCMR, root length and protein content of seeds. Whereas, in moisture stress situation, it had positive high significant association with protein content of seeds and root to shoot ratio. A negative non-significant association was noticed for SCMR and protein content of leaves. Further, it had a positive

non-significant correlation with per cent of wilted plants, phenolic content of seeds, phenolic content of leaves, oil content of seeds and root length.

The SCMR, under normal moisture condition has shown positive significant relation with protein content of seeds besides having a negative significant relation with protein content of leaves. It had a positive non-significant relation with phenolic content of leaves, root to shoot ratio and root length. Further, it had a negative non-significant relation with oil content of seeds. However, under moisture stress situation, SCMR recorded a positive highly significant relation with protein content of seeds and phenolic content of leaves besides its negative significant relation with oil content of seeds. It recorded a positive non-significant relation with protein content of leaves, phenolic content of seeds, root to shoot ratio and root length. Further, it had negative non-significant relation for per cent of wilted plants.

In moisture stress condition, the per cent of wilted plants had a positive significant correlation with root to shoot ratio and root length in addition to its positive non-significant association with protein content of seeds and phenolic content of leaves. It had a negative non-significant association with protein content of leaves, phenolic content of seeds and oil content of seeds.

Under normal moisture condition, the protein content of leaves had a positive non-significant correlation with phenolic content of seeds as well as leaves. In addition, it also had a negative non-significant relation with protein content of seeds, oil content of seeds, root to shoot ratio and root length. However, under moisture stressed condition, the protein content in leaf tissue had a positive highly significant relation with protein content of seeds besides a positive non-significant association with phenolic content of leaves, root to shoot ratio and oil content of seeds. It had negative non-significant relation with phenolic content of seeds and root length.

Protein content of seeds had a positive non-significant relation with phenolic content of leaves and root to shoot ratio apart from having a negative non-significant relation with oil content of seeds, phenolic content of seeds and root length under normal moisture condition. Nevertheless, under moisture stress condition, the protein content of seeds recorded a positive highly significant relation with root length, phenolic content of leaves and root to shoot ratio. It had a negative significant relation with oil content of seeds and a positive non-significant relation with phenolic content of seeds.

In normal moisture condition, the phenolic content of seeds had a highly positive significant association with phenolic content of leaves, negative significant association with oil content of seeds and negative non-significant relation with root to shoot ratio and positive non-significant relation with root length. However in moisture stressed condition, this trait had a highly positive significant association with phenolic

content of leaves and root length, and negative highly significant correlation with oil content of seeds in addition to exhibiting a positive non-significant relation with root to shoot ratio.

In normal moisture condition, the phenolic content of leaves had a negative non-significant association with oil content of seeds and root to shoot ratio besides having a positive non-significant correlation with root length. This trait had a highly negative significant association with oil content of seeds but it exhibited a positive significant relation with root length and positive non-significant association with root to shoot ratio under moisture stress condition.

In normal moisture condition, the oil content of seeds had a positive highly significant association with root to shoot ratio and positive non-significant correlation with root length. However, in moisture stress situation, this trait had negative non-significant association with root to shoot ratio besides having a highly negative significant relationship with root length.

For root to shoot ratio, highly positive correlation was observed with root length in both case of normal moisture and moisture stress conditions. Similar results were reported by Painawadee *et al.* (2009) and Pirdasthi *et al.* (2009).

In normal moisture condition, the pod yield per plant recorded a highly positive significant association with number of mature pods per plant, number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant, fresh weight of seedling and harvest index. It had negative significant relation with plant height at harvest. It had positive non-significant association with primary branches at harvest, test weight and number of days to maturity. A negative non-significant correlation was observed for secondary branches at harvest, shelling percentage, percentage of sound mature kernels and total seedling length. Similar trend was reported by Roy *et al.* (2003). However, in managed drought condition it had highly positive significant association with number of mature pods per plant, number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant, fresh weight of seedling and harvest index. A negative non-significant correlation was observed for primary branches at harvest, secondary branches at harvest and number of days to maturity. It had positive non-significant correlation with plant height at harvest, shelling percentage, percentage of sound mature kernels, test weight and total seedling length. Similar results were reported by Lakshmiddevamma *et al.* (2004), Suneetha *et al.* (2005), Venkateswarlu *et al.* (2007), Vasanthi *et al.* (1998), Vaithiyalingan *et al.* (2010) and John and Reddy, (2015).

Among the yield component traits, different types of correlations were observed and are discussed briefly here under:

Under normal moisture, number of primary branches per plant at harvest had a positive significant association with fresh weight of seedling while it had a negative significant correlation with shelling percentage and test weight. It has recorded a positive non-significant association with percentage of sound mature kernels, number of mature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant and harvest index. Also this trait had a negative non-significant association with secondary branches per plant at harvest, number of immature pods per plant, total seedling length and number of days to maturity. However, in moisture stress condition, number of primary branches per plant at harvest had a negative significant association with shelling percentage. The negative non-significant association for this trait was observed with secondary branches per plant at harvest, percentage of sound mature kernels, test weight, number of mature pods per plant, number of pods per plant, number of immature pods per plant, number of kernels per plant and total seedling length. It had a positive non-significant association with kernel yield per plant, fresh weight of seedling, harvest index and number of days to maturity. Similar findings were reported by Venkataravana *et al.* (2000).

Under normal moisture condition, number of secondary branches per plant at harvest had a positive significant association with number of days to maturity and also positive non-significant association with shelling percentage, percentage of sound mature kernels, test weight and total seedling length. This trait had a negative non-significant association with number of mature pods per plant, number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant, harvest index and fresh weight of seedling. However, in moisture stress condition, number of secondary branches per plant at harvest had a positive significant association with number of days to maturity and test weight but positive non-significant association with shelling percentage, fresh weight of seedling and total seedling length. It showed negative significant correlation with number of immature pods per plant and number of pods per plant whereas negative non-significant correlation was observed with percentage of sound mature kernels, number of kernels per plant, kernel yield per plant and harvest index.

The shelling percentage under normal moisture had a positive significant association with total seedling length and positively non-significant correlation with percentage of sound mature kernels and test weight. Negative significant correlation of this trait was observed with number of pods per plant and non-significant negative correlation with number of mature pods per plant, number of immature pods per plant, number of kernels per plant, kernel yield per plant, fresh weight of seedling, number of days to maturity and harvest index. However, under moisture stress condition, negative significant correlation was observed with number of days to maturity whereas negative non-significant correlation was seen with percentage of sound

mature kernels, number of mature pods per plant, number of immature pods per plant and number of pods per plant. Positive non-significant correlation was observed with test weight, number of kernels per plant, kernel yield per plant, fresh weight of seedling, harvest index and total seedling length. Similar results of significant association of shelling per cent with pod yield per plant was reported by Nagda *et al.* (2001), Abhay *et al.* (2002), Venkataravana *et al.* (2000) and John *et al.* (2009).

Under normal moisture condition, the percentage of sound mature kernels had positive non-significant relation with total seedling length and test weight. This character had a negative non-significant correlation with number of pods per plant, number of mature pods per plant, number of immature pods per plant, number of kernels per plant, kernel yield per plant, fresh weight of seedling, number of days to maturity and harvest index. In moisture stressed condition, this trait has negative non-significant association with all the traits like test weight, number of pods per plant, number of mature pods per plant, number of immature pods per plant, number of kernels per plant, kernel yield per plant, number of days to maturity and harvest index except fresh weight of seedling and total seedling length which had positive non-significant correlation. Similar results of positive significant association of pod yield per plant and test weight with SMK per cent was reported by Francis and Ramalingam (1999) and Roy *et al.* (2003).

The test weight under normal moisture condition recorded positive significant correlation with total seedling length and positive non-significant association with harvest index, kernel yield per plant and number of days to maturity. Negative non-significant correlation was observed with number of pods per plant, number of mature pods per plant, number of immature pods per plant, number of kernels per plant and fresh weight of seedling. In moisture stress condition, the test weight shown positive non-significant correlation with kernel yield per plant, number of days to maturity, fresh weight of seedling and total seedling length in addition to negative non-significant correlation with number of pods per plant, number of mature pods per plant, number of immature pods per plant, number of kernels per plant and harvest index. Similar trend of association of hundred kernel weight with pod yield per plant and seedling length in positive direction was also reported by Sarala and Gowda (1998) and Nagda *et al.* (2001).

Under normal moisture condition, the number of mature pods per plant had positive highly significant correlation with number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant, harvest index and fresh weight of seedling also a positive non-significant association with number of days to maturity. It had a negative significant association with total seedling length. However, this trait under moisture stress condition, exhibited a

positive significant correlation with number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant and harvest index in addition it had a positive non-significant correlation with fresh weight of seedling and total seedling length. Negative non-significant correlation was seen with number of days to maturity. Songsri *et al.* (2008a) reported significant correlation for number of mature pods per plant. Number of matured pods per plant seemed to play an important role in maintaining high pod yield under drought especially under severe stressed condition. Patil *et al.* (2004) reported that number of mature pods were positively significantly associated with pod yield per plant. Similar results were also reported by Francis and Ramalingam (1997) and Sarala and Gowda (1998).

Under normal moisture condition, the number of immature pods per plant indicated a positive highly significant correlation with number of pods per plant, number of kernels per plant, kernel yield per plant, harvest index, fresh weight of seedling and number of days to maturity. It also had a negative non-significant correlation with total seedling length. For number of immature pods per plant in moisture stress condition, positive highly significant correlation was observed with number of pods per plant, number of kernels per plant and kernel yield per plant. Positive significant and positive non-significant correlation was recorded with harvest index and fresh weight of seedling, respectively. It also had negative non-significant correlation with number of days to maturity and total seedling length. Similar results were reported by Lakshmidamma *et al.* (2004), Suneetha *et al.* (2005), Venkateswarlu *et al.* (2007) and Ravi and Sekhar (2012).

Under the conditions of no moisture stress, the number of pods per plant pointed a positive highly significant correlation with number of kernels per plant, kernel yield per plant, fresh weight of seedling and harvest index. Non-significant positive correlation was found with number of days to maturity and negative significant association was observed with total seedling length. Nevertheless, this trait under moisture stress condition exhibited a positive significant correlation with number of kernels per plant and harvest index. A positive significant association was recorded with kernel yield per plant in addition to positive non-significant relation with fresh weight of seedling. Negative non-significant correlation was observed with number of days to maturity and total seedling length. Similar findings were reported by Babariya and Dobariya, (2012), Hamidou *et al.* (2012), Nandini and Savithamma (2012) and Ravi and Sekhar, (2012).

Under normal moisture condition, the number of kernels per plant exhibited a positive highly significant correlation with kernel yield per plant, fresh weight of seedling and harvest index. There exists a negative non-significant correlation of this trait with number of days to maturity and total seedling length. For this trait under moisture stress condition, positive highly significant correlation was observed with

kernel yield per plant and harvest index. It had a positive significant relation with fresh weight of seedling. A negative non-significant correlation was observed for number of days to maturity and total seedling length. Similar observations were reported Seyyed and Seyyed, (2012).

Under no moisture stress condition, the kernel yield per plant has shown positive highly significant correlation with fresh weight of seedling and harvest index, and also a non-significant positive correlation with number of days to maturity. There was a negative non-significant correlation was recorded with total seedling length. However, under moisture stress condition, positive highly significant correlation was exhibited by kernel yield per plant with fresh weight of seedling besides it also had positive significant association with harvest index. It had negative significant relation with number of days to maturity and also negative non-significant association with total seedling length. Similar results were reported by Jayalakshmi and Nirmala (2015) and John and Reddy (2015).

Under normal moisture condition, the fresh weight of seedlings recorded a positive highly significant correlation with harvest index and non-significant positive correlation with number of days to maturity. Further, a negative non-significant correlation was observed with total seedling length. However, in moisture stress condition, positive significant correlation was observed for fresh weight of seedling with total seedling length and positive non-significant association with harvest index. Further, the trait had a negative non-significant relation with number of days to maturity.

Under normal moisture condition, the harvest index exhibited a non-significant positive correlation with number of days to maturity and had negative significant correlation with total seedling length. In moisture stress condition, negative non-significant correlation was observed for harvest index with total seedling length and number of days to maturity. Similar results were cited by Kalmeshwer *et al.* (2006) and Nagda *et al.* (2001).

For number of days to maturity under normal moisture, negative significant correlation was observed with total seedling length. However, under moisture stress condition, number of days to maturity had a negative non-significant relationship with total seedling length.

Correlation coefficient analysis just facilitates us to know the nature and degree of relationship among characters. Still, direct contribution of every component towards yield and their indirect contributions through other components are unknown. In this context, the path analysis facilitate in partitioning the correlation coefficient into direct and indirect effects of the component characters on the yield which would helpful for accurate selection. If the correlation between yield and any of its

component traits is due to the direct effect, it reveals a true relation between them and selection for that character will be effective in order to improve yield. But if the correlation is mainly due to indirect effect of another component character, the breeder has to select the latter character through which the indirect effect is used.

5.4 Path coefficient analysis

In the present study, the results of path analysis (Table 27 and 29) for moisture stress field condition reflected that, the yield related traits *viz.*, relative water content, phenolic content of leaves, oil content of seeds, root to shoot ratio, plant height at harvest, number of secondary branches per plant, number of mature pods per plant, number of immature pods per plant, number of kernels per plant, test weight, kernel yield per plant, fresh weight of seedling, harvest index and number of days to maturity had direct positive effect on pod yield.

The results of path analysis (Table 26 and 28) for normal moisture condition reflected that, SCMR, protein content of leaves, oil content of seeds, root length, plant height at harvest, percentage of sound mature kernels, test weight, number of mature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant and fresh weight of seedling had direct positive effect on pod yield.

Under normal moisture condition, the relative water content has direct positive effect (0.0386) towards pod yield and the indirect effect on pod yield through other component traits was found to be negligible (< 0.1). However, under water stress condition, the relative water content has direct negative effect towards pod yield (-0.0062). Further, the negative indirect effects were negligible (Table 30 and 31).

According to Lenka and Mishra (1973), if the direct or indirect effects were < 0.1 , they were considered to be negligible. Hence, the indirect effects which have < 0.1 for other component traits were not considered for discussion in this chapter in view of their negligible influence on pod yield.

The membrane stability index has direct negative effect both under normal moisture (0.1374) and moisture stress (0.0438) towards pod yield which is considered to be low (Lenka and Mishra, 1973). However, the indirect effect of different component traits through this trait was found to be negligible both under normal moisture and moisture stress.

Under normal moisture condition, SCMR has direct negative effect towards pod yield (0.1836) whereas in water stressed conditions, it has direct positive effect towards pod yield (0.2040). However, the indirect effects were negligible under both the situations.

Under moisture stress, the per cent wilted plant has direct negative effect towards pod yield (0.1847). The indirect effects on pod yield through other component traits were negligible.

Under normal moisture condition, the protein content in leaves has direct negative effect towards pod yield (0.0149) while it recorded a positive direct effect under moisture stress (0.0514). Nevertheless, the indirect effects were negligible.

Under both normal moisture and moisture stress, the protein content in seeds has direct negative effect towards pod yield (0.0257 and 0.1482, respectively). The indirect effects on pod yield through other component traits were negligible.

Under normal moisture condition, the phenol content in seeds has direct positive effect towards pod yield (0.1369) while it recorded a negative direct effect under moisture stress (-0.0384). Nevertheless, the indirect effects were negligible.

Under both normal moisture and moisture stress, the phenol content in leaves has direct negative effect towards pod yield (0.0911 and 0.3389, respectively). The indirect effects on pod yield through other component traits were negligible.

Under normal moisture condition, oil content of seeds has direct positive effect towards pod yield (0.2924). Further, positive and negative indirect effect was observed towards yield through root to shoot ratio (0.1600) and MSI (0.1254), respectively. However, under moisture deficit condition oil content of seeds has direct positive effect towards pod yield (0.2134). The indirect effects on pod yield through other component traits were negligible. Similar results were reported by Varman and Raveendran (1996).

Under normal moisture condition, the root to shoot ratio has direct positive effect towards pod yield (0.1647) while it recorded a negative direct effect under moisture stress (0.1595). Nevertheless, the indirect effects were negligible.

Under normal moisture condition, the root length has direct negative effect towards pod yield (0.0675). The indirect effects on pod yield through other component traits were negligible. However in water stress condition, root length has direct high positive effect towards pod yield (0.4939). The indirect positive effect on pod yield was observed through root to shoot ratio (0.2886) which is considered to be medium and through other component traits were negligible.

Under both normal moisture and moisture stress, the plant height has direct positive effect towards pod yield (0.0555 and 0.1643, respectively). The indirect effects on pod yield through other component traits were negligible. Similar positive direct effect of plant height on pod yield had been reported by Babariya and Dobariya (2012) and Raut *et al.* (2010).

Under both normal moisture and moisture stress, the primary branches per plant have direct negative effect towards pod yield (0.0071 and 0.0401, respectively). The indirect effects on pod yield through other component traits were negligible.

Under normal moisture condition, the secondary branches per plant have direct positive effect towards pod yield (0.0405) while it recorded a negative direct effect under moisture stress (0.2083). Nevertheless, the indirect effects were negligible.

Under both normal moisture and moisture stress, the shelling percentage has direct negative effect towards pod yield (0.0164 and 0.0782, respectively). The indirect effects on pod yield through other component traits were negligible. Similar results were reported by Trivikrama Reddy, (2003), Chaitanya (2004) and Lakshmiddevamma *et al.* (2004).

Under normal moisture condition, the percentage of sound mature kernels has direct negative effect towards pod yield (0.0543) while it recorded a positive direct effect under moisture stress (0.1588). Nevertheless, the indirect effects were negligible.

Under both normal moisture and moisture stress, the test weight has direct positive effect towards pod yield (0.1265 and 0.3366, respectively). The indirect effects on pod yield through other component traits were negligible. Similar trend of effect of test weight towards pod yield per plant in positive direction was also reported by Kalmeshwer *et al.* (2006), Suneetha *et al.* (2005), Chaitanya (2004), Trivikram Reddy (2003) and Nagda *et al.* (2001).

Under normal moisture condition, the number of matured pods per plant has direct positive effect towards pod yield (0.5030). Further it recorded indirect positive effect towards yield through number of immature pods per plant (0.2577), number of pods per plant (0.4682), number of kernels per plant (0.4292), kernel yield per plant (0.3848), fresh weight of seedling (0.3340) and harvest index (0.3627) which were considered to be medium to high. In moisture stress condition, number of matured pods per plant has direct positive effect towards pod yield (0.1187). The indirect effects on number of matured pods per plant through other component traits were negligible. Similar results were reported by Trivikram Reddy, (2003) and Venkataravana *et al.* (2000).

Under normal moisture condition, the number of immature pods per plant has direct positive effect towards pod yield (0.0382). The indirect effects on pod yield through other component traits were negligible. However in water stress condition, it has direct negative effect towards pod yield (0.2281). The indirect positive effect on pod yield was observed through number of pods per plant (0.2275) which is considered to be medium.

The number of pods per plant has direct negative effect under normal moisture (0.0744) and direct high positive effect under moisture stress (0.4577) on pod yield per plant. However, the indirect effect of different component traits through this trait was found to be negligible both under normal moisture and moisture stress. Positive direct effect of number of pods per plant had been reported by Babariya and Dobariya (2012), Raut *et al.* (2010), Vekariya *et al.* (2010), Awatade *et al.* (2009) and, Azad and Hamid, (2000).

Under both normal moisture and moisture stress, the number of kernels per plant has direct positive effect towards pod yield (0.1482 and 0.1878, respectively). The indirect effects on pod yield through other component traits were negligible.

The kernel yield per plant has direct positive effect under both normal moisture (0.1142) and direct high positive effect under moisture stress (0.3035) on pod yield per plant. However, the indirect effect of different component traits through this trait was found to be negligible both under normal moisture and moisture stress. Similar results were reported by Venkateswarlu *et al.* (2007), Lakshmidevamma *et al.* (2004), Venkataravana *et al.* (2000) and, Azad and Hamid, (2000).

Under both normal moisture and moisture stress, the fresh weight of seedling has direct positive effect towards pod yield (0.1321 and 0.2217, respectively). The indirect effects on pod yield through other component traits were negligible.

Under normal moisture condition, the harvest index has direct positive effect towards pod yield (0.2383) while it recorded a negative direct effect under moisture stress (0.0331). Nevertheless, the indirect effects were negligible. Harvest index had a positive direct effect on pod yield per plant as reported by Suneetha *et al.* (2005), Nagda and Joshi, (2004), Trivikram Reddy, (2003) and, Bera and Das, (2000).

Under normal moisture condition, the number of days to maturity has direct positive effect towards pod yield (0.0549) while it recorded a negative direct effect under moisture stress (0.0133). Nevertheless, the indirect effects were negligible. Positive direct effect of days to maturity on pod yield had been reported by Babariya and Dobariya (2012), Raut *et al.* (2010), Vekariya *et al.* (2010) and Awatade *et al.* (2009).

Under both normal moisture and moisture stress, the total seedling length has direct negative effect towards pod yield (0.0067 and 0.1950, respectively). The indirect effects on pod yield through other component traits were negligible.

The low residual effect shows that the important yield components have been included in the present investigation for path analysis.

5.5. Conclusion

From this study, it may be concluded that, for groundnut improvement programme, number of pods per plant, kernel yield per plant, test weight, harvest index, number of primary branches per plant and number of days to fifty per cent flowering, relative water content, membrane stability index, per cent of wilted plants, phenolic content of seeds and leaves, protein content of leaves and root length can be pyramided in the breeding material for overall pod yield improvement in groundnut. Groundnut being a highly self pollinated crop, selection and hybridization followed by selection are the only means to improve the desired traits.

5.6 Future line of work

1. Drought tolerant genotypes (Dh -234, R -2001 - 3, ICGV 15151, ICGV 15138, SB -14, ICGV 15145, ICGV 15154, ICGV 15146, ICGV 15159 and ICGV 15158) identified in present investigation have recorded significantly higher yield per plant under moisture stress. Hence, these genotypes can be evaluated in different environments and under varying levels of moisture stress to compare their potentiality and to confirm their stable performance.
2. In the present study, the traits *viz.*, relative water content, membrane stability index, phenolic content of leaves and seeds, root length, number of pods per plant, pod yield per plant and hectare, number of kernels per plant and kernel yield plant exhibited high heritability coupled with high genetic advance over mean. Selection based on these traits will be more useful in identifying genotypes for drought tolerance.
3. Comprehensive study on the morpho-physiological and biochemical aspect of drought adaptation mechanism prevailing in the identified drought tolerant genotypes can be carried out.
4. The drought tolerant genotypes identified in the present investigation can be studied at molecular level to identify the genes or QTL responsible for drought tolerant ability and
5. The identified drought tolerant genotypes may be used as source of parents in breeding programmes for developing varieties suitable of climate change in future.

Summary

VI SUMMARY

Groundnut (*Arachis hypogaea* L.) is one of the important oil seed and cash crops grown in India accounting for 36 per cent of total oil seed production. Drought stress is a globally widespread and ever growing environmental phenomenon encountered by groundnut crop and long duration of water deficit lead to severe reduction in overall production. Drought stress can be determined by three factors *viz.*, intensity, time of incidence and duration. Under drought stress conditions changeable nature of these factors make it complicated for plant breeder to decide which plant trait should be improved first to improve plant production.

Recent research advances associated with crop responses to numerous biotic and abiotic stresses especially water deficit stress is gaining significant emphasis, as global environment fluctuations situation prognosticates water deficit conditions. Better critical knowledge about drought stress tolerance related to physiological and morphological characters helps in the screening of germplasm to evaluate genotypes against drought. One of the superior goals of plant breeders is to make peanut genotypes suitable to drought stress condition which ensures higher pod yield. Several efforts have been address to enhance the productivity of groundnut crop under water deficit situation by improving the attributes damaged by drought stress. Thus, there is a need to identify drought tolerant traits and cultivates to minimize the reduction in production and productivity of crops.

In this context, the present investigation entitled with “Genetic investigation on end-of season drought stress in advanced breeding lines of Groundnut (*Arachis hypogaea* L.)” was carried out to elucidate the information on drought tolerance of genotypes and nature of association of physiological, biochemical and yield component characters on pod yield per plant and to assess the genetic variability and heritability and genetic advance over mean and their path among the groundnut genotypes for drought tolerance and yield to identify the drought tolerant genotypes. The present study was conducted in a randomized complete block design with two replications at College of Horticulture, Hiriyur during 2016. The experimental material consisted of 40 advanced breeding lines (ICRISAT and other SAUs).

The observations were recorded for sixteen characters including physiological and yield traits *viz.*, relative water content, days to fifty per cent flowering, days to maturity, number of primary and secondary branches per plant, number of immature pods per plant, number of mature pods per plant, shelling per cent, sound mature kernel per cent, oil content (%) and pod yield per plant. The results obtained in the present study are summarized below.

The analysis of variation revealed the existence of highly significant differences among the genetic materials for all the traits recorded. A wide range of variation and high heritability coupled with high genetic advance was recorded for

most of the traits. It indicates the broad genetic base and less environmental influence which specifies the predominance of genetic factors controlling variability in these traits. Hence, simple and early generation selection schemes would be effective for improvement and there is an ample scope for isolation of promising lines from present gene pool for drought tolerance and yield.

High heritability and high genetic advance was observed in many quantitative and morphological traits under drought stress. The high genetic advance under moisture stress conditions was because of higher phenotypic variance, although heritability was low or remained same as that under non stress condition. These finding revealed the importance of such traits giving more response under stress for crop improvement in groundnut.

In the present investigation, higher values of GCV, heritability and GAM were observed for relative water content, per cent of wilted plants, membrane stability index, phenolic content of leaves, phenolic content of seeds, fresh weight of seedling, number of primary branches per plant, harvest index and root length. It is clearly indicates that these traits were governed by additive gene action. Hence, selection would be rewarding.

The association studies revealed that, pod yield per plant showed significant positive correlation with number of mature pods per plant, number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant, fresh weight of seedling, harvest index, oil content and root to shoot ratio. It can be concluded that, these traits should be given due importance while practicing selection for increasing yield.

In the present study, the results of path analysis for moisture stressed field condition reflected that, the physiological and yield related traits *viz.*, relative water content, phenolic content of leaves, oil content of seeds, root to shoot ratio, plant height at harvest, number of secondary branches per plant, number of mature pods per plant, number of immature pods per plant, number of kernels per plant, test weight, kernel yield per plant, fresh weight of seedling, harvest index and number of days to maturity had direct positive effect on pod yield. This indicates that, if other characters are kept constant, an increase in matured pods per plant and total number of pods per plant will increase the yield significantly.

When the moisture stress was imposed at pod development stage under field conditions, the genotypes *viz.*, SB-14, ICGV 15151, ICGV 15141 ICGV 15138, ICGV 15145, Dh -234, ICGV 15159, SB-1, ICGV 15146, K-6, ICGV 15158, ICGV 15148, ICGV 15154, R-2001-3 and ICGV 15153 produced high yield indicating their tolerance to drought and they seem to be suitable genotypes for rainfed cultivation of groundnut particularly where drought is expected at the pod development stage. The yield of these genotypes ranged from 11.49 g/plant to 19.38 g/plant under moisture stress condition.

While under normal field conditions (without moisture stress), the genotypes like SB-1, ICGV 15148, SB-14, ICGV 15146, ICGV 15158, ICGV 15159, ICGV 15151, ICGV 15153, ICGV 15145, ICGV 15152, ICGV 15154, ICGV 15138, ICGV 15161 ICGV 15123 and SB-17 recorded higher yield and hence, can be recommended for cultivation in those regions where drought is not a common problem. The yield of these genotypes ranged from 22.20 g/plant to 25.60 g/plant under normal condition.

But the real drought tolerant cultivar is one which shows minimum yield reduction under moisture stress when compared to their yield under non-moisture stress condition. Such drought tolerant genotypes identified in present investigation were Dh-234 and R-2001-3 and ICGV 15151. These genotypes recorded significantly higher yield under moisture stress and hence they can be suggested for cultivation in drought prone areas. These genotypes under moisture stress recorded less than 20 per cent yield reduction.

These drought tolerant genotypes can be studied at further biochemical level to find out the various mechanisms involved and also at molecular level to identify the genes/Quantitative trait loci (QTLs) responsible for drought tolerance. They can also be utilized in recombination breeding for transferring this trait to other cultivated varieties having local farmers and vegetable oil industries preference.

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Appendix

VIII APPENDIX

Appendix-I

Meteorological data from October -2016 to march 2017, College of Horticulture, Hiriyr.

Month	Temperature		Relative humidity (%)		Rainfall (mm)	Rainy days
	Minimum	Maximum	RH-1	RH-2		
Oct-16	21.00	30.00	87.10	68.10	89.00	8
Nov-16	20.00	29.00	71.60	73.00	65.00	6
Dec-16	22.00	27.70	82.60	48.90	0.80	0
Jan-17	20.00	30.20	80.00	48.00	4.60	1
Feb-17	23.00	35.60	75.00	31.00	0.00	0
Mar-17	26.00	36.80	70.00	32.00	0.00	0