YIELD AND TRAITS ASSOCIATED WITH DROUGHT TOLERANCE IN EXOTIC GROUNDNUT (*Arachis hypogaea* L.) GENOTYPES UNDER DIFFERENT WATERING REGIMES

MASHAMBA PHILIPO

A DISSERTATION SUBMITTED IN PARRTIAL FULLFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2014

ABSTRACT

Groundnut (*Arachis hypogaea* L.) production in rain fed regions of Africa is mostly affected by intermittent drought of different duration and intensity. Improvement of groundnuts for drought tolerance could increase production in drought areas. Therefore, this study aimed at identifying drought tolerant genotypes as source material for breeding. Pot experiment was conducted to evaluate 30 groundnut genotypes for drought tolerance, under well watered and water stress condition. A split plot experiment in completely randomized design with four replications was conducted in screen house at Sokoine University of Agriculture (SUA), Tanzania. Data were recorded for plant height, number of pod/plant and pod yield/plant. Harvest Index (HI), SCMR at 40, 60 and 80 DAS and DTI of pod yield and number of pods/plant were measured and calculated as drought tolerant traits. Broad-sense heritability was calculated for HI, pod yield, number of pod/plant and SCMR. Results showed that drought significantly reduced pod yield, number of pods/plant and plant height but significantly increased SCMR. Number of pods/plant, SCMR at 60 DAS and HI were significantly related to pod yield in all watering condition. Heritability of the traits ranged from 0.22 to 0.59 with HI having highest value and number of pods lowest in WW while in WS condition heritability was generally lower from 0.04 to 0.45. Due to SCMR at 60 DAS, number of pods/plant and HI having moderate heritability and significant correlation with pod yield under water stress condition, these could be useful criteria in drought tolerance selection. In this study 11 genotypes namely, ICG 2106, ICR 48, ICGS 44, ICG 3053, ICG 11088, ICGV-SM 87003, ICG 12235, ICG 13723, ICGV 02271, ICGV 97182 and ICGV 91114 were identified as possible drought tolerant based on high pod yield, HI, SCMR at 60 DAS and number of pods/plants in water stress condition.

ABSTRACT

Groundnut (*Arachis hypogaea* L.) production in rain fed regions of Africa is mostly affected by intermittent drought of different duration and intensity. Improvement of groundnuts for drought tolerance could increase production in drought areas. Therefore, this study aimed at identifying drought tolerant genotypes as source material for breeding. Pot experiment was conducted to evaluate 30 groundnut genotypes for drought tolerance, under well watered and water stress condition. A split plot experiment in completely randomized design with four replications was conducted in screen house at Sokoine University of Agriculture (SUA), Tanzania. Data were recorded for plant height, number of pod/plant and pod yield/plant. Harvest Index (HI), SCMR at 40, 60 and 80 DAS and DTI of pod yield and number of pods/plant were measured and calculated as drought tolerant traits. Broad-sense heritability was calculated for HI, pod yield, number of pod/plant and SCMR. Results showed that drought significantly reduced pod yield, number of pods/plant and plant height but significantly increased SCMR. Number of pods/plant, SCMR at 60 DAS and HI were significantly related to pod yield in all watering condition. Heritability of the traits ranged from 0.22 to 0.59 with HI having highest value and number of pods lowest in WW while in WS condition heritability was generally lower from 0.04 to 0.45. Due to SCMR at 60 DAS, number of pods/plant and HI having moderate heritability and significant correlation with pod yield under water stress condition, these could be useful criteria in drought tolerance selection. In this study 11 genotypes namely, ICG 2106, ICR 48, ICGS 44, ICG 3053, ICG 11088, ICGV-SM 87003, ICG 12235, ICG 13723, ICGV 02271, ICGV 97182 and ICGV 91114 were identified as possible drought tolerant based on high pod yield, HI, SCMR at 60 DAS and number of pods/plants in water stress condition.

DECLARATION

I Mashamba Philipo, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

02/06/2014

Mashamba Philipo — Date

(MSc. Candidate)

The above declaration is confirmed

02/06/2014

Prof. Susan Nchimbi-Msolla — Date

(Supervisor)

COPYRIGHT

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to the Lord Almighty for His Mercies and Grace before and during my studies period. Many people and organizations deserve to be thanked for their priceless contributions to the success of my studies.

My special gratitude goes to International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Tropical Legume Projects management team for granting me scholarship. My sincere gratitude goes to my employer, the Ministry of Agriculture, Food and Cooperatives for their permission to pursue this higher degree.

I am deeply thankful to my supervisor, Prof. Susan Nchimbi-Msolla for her constant technical assistance, guidance, encouragement and advice since the development of the proposal up to completion of this study. Special thanks should be extended to Dr. Omari Mponda and Dr. Elly Kafiriti for nominating and giving me permission to pursue this higher degree.

I am greatly thankful to the office of Faculty of Agriculture and the Department of Crop Science and Production for their administrative support during the study period. I would like to thank the staff and classmates of the Department of Crop Science and Production, especially those in the Crop Improvement section for their various assistance during the whole period of study at Sokoine University of Agriculture (SUA). God bless all of you for the kindness.

DEDICATION

To Almighty God my creator; to my wife Grace K. Philipo, my children Philipo and Princes Philipo, my mother Mija Mondesta and my father Lugendo Philipo, my brothers and sisters whose sacrifice laid the foundation for my education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of Variance
CV	Coefficient of variation
DAS	Days after sowing
DTI	Drought tolerance index
EC	Emulsifiable Concentration
FAO	Food and Agriculture Organization of the United Nations
Fig	Figure
Fpr	F probability
GxE	Genotype by environment interaction
h^2	Heritability in broad sense
HI	Harvest index
ICRISAT	International Crops Research Institute for the semi-Arid Tropics
m ha	Metric hactare
MAFC	Ministry of Agriculture, Food and Cooperatives
MT	Metric tons
NP	Number of pods/plant
PY	Pod yield
R	Correlation coefficient
R^2	Coefficient of determination
s.e	Standard error
SCMR	SPAD Chlorophyll Meter Reading Semi-Arid Tropics
SPAD	Soil Plant Analysis Development
SUA	Sokoine University of Agriculture

TE	Transpiration Efficiency
WS	Water stress condition
WW	Well watered condition
σ^2E	Residual mean square
σ^2G	Genotypic variance

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Groundnut (*Arachis hypogaea* L.) is the world's fourth most important source of edible oils, third most important source of vegetable protein and thirteenth most important crop. It has 44 to 50 % edible oil, 25 % easily digestible protein and 20 % carbohydrate (FAO, 2008). Developing countries account for over 97.6% of world groundnut area (21.7 m ha) and about 95.5% of total production (33.0 MT) with average yield of 1522 kg ha^{-1}. Production is concentrated in Asia and Africa, where the crop is grown mostly by smallholder farmers under rain fed conditions with limited inputs. Asia accounts for 56% of global groundnut area and 67% of production. Africa accounts for 40% of global groundnut area and 26% of production (ICRISAT, 2008). In Tanzania, the total groundnuts production is 293 870 tons produced within the area of 409 320 ha, this gives a yield of 718 kg ha^{-1} (MAFC, 2005).

Groundnut is mostly cultivated as a rain fed crop by the resource poor farmers, hence affected by intermittent drought stress of different duration and intensities. Drought contributes to over 6.7 million metric tons loss in annual world groundnut production (Devi *et al.*, 2010). Despite the importance of groundnut in Tanzania its productivity is still low. For the past five years, that is from 2000 to 2005, the average groundnuts productivity in Tanzania was 718 kg ha^{-1} (MAFC, 2005) while the potential groundnuts production in Tanzania is 1500 kg/ha (Mponda and Kafiriti, 2008). Low yield per ha in groundnut production is caused mostly by drought among the limiting factors.

Most of the groundnut growing areas in Tanzania are affected by intermittent drought of different duration and intensity. Naturland (2000) reported that, groundnut require 500-1000 mm of rainfall which is well distributed during the growth period to produce optimum yields for the varieties which take more than 100 days to attain physiological maturity. A yield loss in groundnut caused by drought was estimated to be 56 – 85% depending on the stage of growth in groundnut that is affected by drought (Painawadee *et al.*, 2009).

Breeding and selection of groundnut tolerant to drought have been conducted for a long time based on pod yield, but it has been unsuccessful in getting drought tolerant genotypes (Wunna *et al.*, 2009), the genotypes which could maximize groundnut yield in drought prone areas where groundnut is grown under rain fed condition.

Long and severe drought experienced in Dodoma, Tanzania in the year 2007/08, resulted into total crop failure in most groundnut growing areas of Chamwino, Bahi and Kongwa (Monyo, 2009). In Southern Tanzania, the poorly distributed rainfall and prolonged dry spells encouraged outbreak of rosette leading to reduction in yield.

Therefore, breeding and selection of drought tolerant genotypes may help to improve the risky groundnut production in drought prone environments. Since breeding approach utilizing selection for pod yield been unsuccessful for a long time (Jongrungklang *et al.*, 2008), recently, other surrogate traits such as Soil Plant Analysis Development (SPAD) Chlorophyll Meter Reading (SCMR), Harvest Index (HI) and Drought Tolerance Index (DTI) have been used during drought tolerance selection in breeding programme. Songsri *et al.* (2008) reported low genotype x environment interaction estimates for Specific Leaf

Area (SLA) and SCMR. Wunna *et al.* (2009) reported the use of HI and DTI for yield and yield components in drought tolerance selection.

This study is aimed at determining the status and heritability estimates of HI, DTI, SCMR, pod yield and number of pods per plant from 30 groundnut genotypes developed by ICRISAT, India under different watering regimes, so as to speed up the selection and breeding of groundnut genotypes tolerant to drought.

1.2 Objectives

1.2.1 Overall objective

To identify drought tolerant genotypes as source material for breeding so as to improve groundnut yield in drought prone areas.

1.2.2 Specific objectives

i. To identify high pod yielding groundnut genotypes under different water regimes.
ii. To determine the levels of drought tolerance traits (HI, DTI and SCMR) among 30 groundnut genotypes
iii. To determine heritability estimates and relationship between yield and yield components with drought tolerance traits (HI and SCMR).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Groundnut Origin and Botany

Groundnut is native to the Western Hemisphere. It probably originated in South America, the centre of origin most likely being Brazil, where about 15 wild species are found. The Spanish introduced it to Europe from where traders spread it to Asia and Africa. Groundnut reached North America via the slave trade (Acquaah, 2007).

Groundnut (*Arachis hypogaea* L.) belong to the leguminosae family and to the subfamily of papilionoideae. It is a herbaceous, annual type of plant that grows to a height of 20 to 60 cm. Depending on the species, the plants may grow upright and sideways with their side wards shoots to a breadth of 30 to 80 cm. The main stem usually remains upright. The taproots penetrate to a depth of 90 to 120 cm, creating branches within the upper soil levels that are then populated by rhizobia and mycorhiza. *Arachis hypogaea* does not grow in the wild, the wild species are perennial. The blossoms open up in the morning time, usually after self-pollination has taken place. The blossoming period usually begins 3-4 weeks after sowing, and can last for up to 2 months. All of the species are geocarpy reproducers, i.e. they sink a stalk-like structure called a peg into the ground after fertilization, in order to grow the groundnut seeds there (Naturland, 2000).

2.2 Drought Effects on Groundnut Pod Yield and Number of Pods per Plant

Drought denotes a prolonged period without considerable precipitation that may result in reduction in soil water content and, thus, cause plant water deficit. It can be defined in terms of either the external water status at the boundaries of the plant (soil, air) or the internal plant water status within the tissue (Amede *et al.*, 2004).

The duration of drought is variable, sometimes lasting for a short time and without severe adverse physiological impact, sometimes lasting throughout an entire growing season or even years, resulting in complete devastation of crops. The efforts of breeders are directed at short duration drought that often is experienced when crop production is rain fed. Under rain fed condition, rainfall is often erratic in frequency, quantity, and distribution. To avoid disruption in growth and development processes, and consequently in crop performance (yield), plants need to maintain a certain level of physiological activity during the adverse period. The effect of drought varies among species and also depends on the stage of plant growth and development at which the moisture stress occurs. Drought at flowering may cause significant flower drop and low fruit set. Similarly, when drought occurs at fruiting, there will be fruit drop and/or partially filled or shrivelled fruits. At the end, both quality and product yield will be decreased (Acquaah, 2007).

In groundnut, drought stress during flowering and pod filling stage is critical for yield and agronomic characters. This would result in drastic reduction in crop yield, and magnitude of reduction would depend on groundnut varieties. Not only the yield of groundnut but also the qualities of products decreases under drought stress (Shinde *et al.*, 2010). Smartt (1994) reported that water deficits during flowering can result in a decrease in flower number and a delay in time to flower. However, since only 15-20% of flowers result in pods that contribute to yield, reduction in flowers number arising from water deficits do not directly influence pod yield. Also groundnut can compensate for reduced flower numbers resulting from water deficits by producing a flush of flowers once the stress has been relieved.

Water deficits during pegging and pod set decrease yield primarily by reducing pod number. A reduction in soil water content can have a dual effect on peg and pod development owing to the subterranean fruiting habit of groundnut. On the other hand, root zone water content can directly affect plant water status, photosynthesis and hence assimilate supply to developing pegs and pods. Groundnut cultivars differ in their pegging and pod set response to soil water deficits, some maintain a peg production efficiency (ratio of pod number to peg number) of about 0.8 irrespective of a drought applied during the early reproductive phase (17 – 72 days after planting) while other genotypes had an efficiency of only 0.15 during drought. Therefore, soil water deficits during the pegging and pod set phase severely inhibit reproductive efficiency and reduce HI and pod yield in groundnut.

2.3 Drought Tolerance Traits

2.3.1 SPAD chlorophyll meter reading

The photo-synthetically active light transmittance characteristics of the leaf expressed as SCMR is dependent on the unit amount of chlorophyll/unit leaf area (Chlorophyll density). In general, the thicker leaves usually have a higher density of chlorophyll/unit leaf area and hence have a greater photosythetic capacity compared with thiner leaves. Groundnut genotypes with high chlorophyll density have more photosythetic machinery (Jongrungklang *et al.*, 2008).

Extracted leaf chlorophyll content is highly positively correlated with SCMR with R^2 values ranging between 0.83 and 0.93 (Glynn, 2008). Traditional methods of extracting chlorophyll from leaves using chemical solvents require laboratory conditions and are time-consuming, labor-intensive, and expensive. Due to this fact, SPAD chlorophyll meter can be used to measure greenness based on optical responses when a leaf is exposed to light that in turn is used to accurately estimate foliar chlorophyll concentrations.

Drought stress causes wilting to groundnut genotypes, hence reduce the green leaf area and water uptake from soil profile to some extent. Early studies reported that drought stress increases SPAD chlorophyll meter reading (SCMR) in groundnut. Groundnut genotypes with high SCMR under drought condition could maintain higher rate of photosynthesis per unit leaf area. SCMR is strongly correlated with Transpiration Efficiency (TE) and pod yield in groundnut under water limited conditions (Bootang *et al.*, 2010).

2.3.2 Harvest index

Harvest index (HI) implies the relative distribution of photosynthesis products between economical sinks and other existing sinks in the plant. In groundnut harvest index is the proportion of pod weight to total biomass and it can vary depending on the timing and severity of water deficit relative to pod set. Smartt (1994) reported that groundnut cultivars differences in pod yield during a terminal drought were due to variation in harvest index which was associated with differences in pods and the effective duration of pod filling phase. Water deficit is one of the limiting factors of plant growth and development that not only reduces production of dry matter but also causes a disorder to the partitioning of carbohydrates to grain thus reducing the harvest index, the reason for harvest index reduction at severe drought stress is the higher sensitivity of reproductive growth to undesirable conditions in comparison with generative growth (Esmaeel *et al.*, 2009). Harvest index is positively correlated to pod yield in groundnut (Wunna *et al.*, 2009). Groundnut genotypes with high HI under water stress had high TE and pod yield hence good for drought tolerance selection (Jongrungklang *et al.*, 2008).

2.3.3 Drought tolerance index

Drought tolerance index (DTI) is the relative yield performance of genotypes in drought stress condition and favorable environments. Drought tolerance index DTI is the common starting point for the identification of desirable genotypes for unpredictable rain fed conditions as it shows the stability of a genotype in yield performance under water stress and non stress condition (Majid *et al.*, 2011). Therefore groundnut genotypes with high DTI are good source of genetic materials in breeding for drought tolerance.

2.4 Heritability

Heritability is the measure of relative importance of genetic and non-genetic factors in the expression of phenotypic differences among genotypes in a population. Heritability in the broad sense is the proportion of the phenotypic variance of family means that is due to all genetic effects. Heritability is used to estimate expected response to selection and to choose the best breeding approach to improve the target trait(s). Traits with high heritabilities can be selected on a single-plant basis (e.g. mass selection) faster, and in a low number of environments. In contrast, traits with low heritabilities require selection on a family basis and in a greater number of environments to determine breeding values of genotypes. Heritability estimates for the same trait are variable (i.e. heritability of a trait is not a fixed value) and their magnitude depends on several factors (a) Environment, it is important to have adequate samples of environments from the target population of environments. In addition, estimates for genetic variance should be free of G×E variance. (b) Reference population, the amount of genetic variation and inbreeding present in the population affects heritability estimates. Higher inbreeding levels are associated with higher genetic variances and therefore with higher estimates of heritability. (c) Sample of genotypes evaluated, genotypes used to estimate heritabilities in one population should be chosen at random. If the sample is not a representative random sample (e.g. selected genotypes), the ratio between genetic and phenotypic variation is called Repeatability. Repeatability estimates in a single environment provide a measure of how much of the variation is genetic and therefore is a measure of the degree of precision of data and the ability to detect significant differences among genotypes. (d) Method of estimation, heritability of a quantitative trait can be computed by several methods (for example, variance components and parent-offspring regression) and heritability estimates can differ among them (e.g. heritability on a family basis is greater than on a plant basis). Heritability estimates calculated on the basis of selection unit are preferred to estimate expected response to selection (Ceccarelli, 2009).

Heritability estimates are useful for breeding quantitative traits. The major applications of heritability are (a) To determine whether a trait would benefit from breeding. If, in particular, the narrow sense heritability for a trait is high, it indicates that the use of plant breeding methods will likely be successful in improving the trait of interest. (b) To determine the most effective selection strategy to use in a breeding program. Breeding methods that use selection based on phenotype are effective when heritability is high for the trait of interest and to predict gain from selection. Response to selection depends on heritability. A high heritability would likely result in high response to selection to advance the population in the desired direction of change (Acquaah, 2007).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Conditions

Thirty groundnut genotypes from reference set collection developed at ICRISAT, Patancheru, India were evaluated for drought tolerance and yield under different watering regimes at Sokoine University of Agriculture (SUA), Morogoro, Tanzania. Weeds were controlled by hand weeding and insects were controlled by spraying Thionex 35 EC at the rate of 2ml/litre of water. The temperature range was 25 - 31°C and the relative humidity was 85 – 95% in the screen house during the experiment period.

3.2 Experimental Design and Planting

The experiment was planted on 15 December, 2012 and harvested on 1 April, 2013, where by a completely randomized design arranged in split plot experiment was used during planting, with watering regimes being main plot treatments and genotypes sub plot treatments. Each main plot had four replications and 30 pots for each replication. Three seeds of each genotype were planted in a pot of 12 kg of soil each. Each pot had five drainage holes.

3.3 Irrigation System, Intermittent Stress Imposition and Management

After sowing, 500 ml of water were applied to each pot and then twice on alternate days with 250 ml of water until the seedlings emergence. The plants were thinned to two individuals per pot at 7 days after sowing (DAS) and then to a single plant per pot at 14 DAS. The crops were irrigated to field capacity by 2 litres of water at 5 days intervals from sowing to about flowering time, by compensating evapotranspiration. From there onwards, irrigation for water stressed plants (WS) was 2 litres of water after every

10 days and for WW 2 litres of water were given to each pot after every 5 days. The decision to irrigate was based on leaf wilting symptoms of WS plants, irrigation being supplied when the wilting score of a majority of WS plants reached a value of three and below score of two for WW plants (Hamidou *et al.*, 2012)

Scoring scale of wilting symptoms (recorded early afternoon) was used to monitor stress in the WS block. The scale is as follows: 1 = no wilting, 2 = some leaves wilted (≤ 50 % leaves), 3 = most leaves wilted (≥ 50% leaves), 4 = permanent wilting on some leaves (≤ 50 % leaves), 5 = permanent wilting on most leaves (≥ 50% leaves) (Ratnakumar and Vadez, 2011).

3.4 Data Collection

3.4.1 Yield and yield components

At harvest time plant height in cm and number of pods per plant for each genotype were measured and recorded, after harvesting the groundnut pods from individual plant were air dried separately and weighed to get pod yield/plant. The roots were washed with water to remove the soil and then shoot and roots for each genotype were packed in paper bag and oven dried at 70 °C for 72 hours in order to obtain constant weight. After oven drying, shoot and root dry weight was recorded (Painawadee *et al.*, 2009).

3.4.2 Drought tolerant traits

The SPAD chlorophyll meter reading (SCMR) was recorded twice on each leaflet of the tetra foliate leaf along the mid-rib at 40, 60 and 80 days after sowing using SPAD chlorophyll meter. The third fully-expanded leaves from each plant were used for determination of SCMR, between 0830 and 1000 hours as during this time, there is high stomatal conductance to allow photosynthesis take place since evaporation demand is low particularly in stressed groundnut genotypes (Smartt, 1994).

Figure 1: Recording SPAD Chlorophyll Meter Reading using SPAD Chlorophyll Meter

Harvest index was calculated using the following relationship:

HI = Pod yield / (Pod yield + Shoot and root dry weight).. (1)

Drought Tolerance Indexes (DTI) of pod yield and number of pods per plant were calculated using the relationship as follows;

DTI (PY) = Pod yield under water stress condition / Pod yield under well watering condition.. (2)

DTI (NP) = Number of pods under water stress condition/Number of pods under well watering condition (Wunna *et al.*, 2009).. (3)

3.5 Data Analysis

The collected data were subjected to analysis of variance using GenStat Edition14.0 Statistical package so as to determine the effect of watering regime on genotypes performance in the collected data. Because of watering regime x genotype interaction, each watering regime was analyzed separately according to completely randomized design (Gomez and Gomez, 1984), using the following mathematical model:

$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$ ....(4)

Where; μ = the general error mean, α_i = the effect of the ith level genotype, ε_{ij} = is the random error. T-test analysis using GenStat Edition14.0 Statistical package was used to judge significance difference between the pairs of genotypes planted under the two watering regimes for the collected parameters, at 5% level of significance.

The estimate mean squares from ANOVA table for drought tolerance associated traits and pod yield were used to calculate genotypic variance and environmental variance, and then estimates of broad-sense heritability for genotypes was calculated by the formula described by Ceccarelli, (2009) as follows:

$h^2 = \sigma^2_G/(\sigma^2_G + \sigma^2_E)$..(5)

h^2 = heritability in broad sense, σ^2_G = genotypic variance {(genotype mean square – residual mean square)/number of replication} and σ^2_E = residual mean square (environmental variance). The correlation coefficients (r) among all the measured traits were determined using GenStat Edition14.0 Statistical package. The graphs were drawn using excel sheet.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Identification of High Pod Yielding Groundnut Genotypes under Different Watering Regimes

4.1.1 Pod yield

Analysis of variance showed very highly significance difference ($P \leq 0.001$) among groundnut genotypes for pod yield/plant under water stress and well watering conditions (Table 1). Pod yield per plant under water stress condition had a range of 4.1 – 10.9 g/plant with pod yield mean of 8.8 g/plant. The highest pod yielding genotype under water stress condition was ICG 2106 which was followed by ICR 48, ICG 8106, ICGS 44, ICG 3053 and ICG 11088. Pod yield under well watering condition ranged from 7.1 to 15.9 g/plant with pod yield mean of 11.9 g/plant. The highest pod yielding genotype under well watered condition was ICG 8106 which was followed closely by ICG 2777, ICG 11862, ICGV 95377 and ICGS 44.

Table 1: Yield and Yield Components in Well Watered and Water Stress Condition

	Number of pods/plant			Plant height (cm)			Pod yield (g/Plant)		
Genotypes	WW	WS	T-test	WW	WS	T-test	WW	WS	T-test
55-437	14	11	*	36	35	ns	12.8	8.4	*
FLEUR 11	12	8	*	44	36	*	11.8	8.3	*
ICG 11088	14	11	ns	50	37	*	12.2	9.9	ns
ICG 11862	16	11	*	46	37	*	13.8	8.9	**
ICG 12235	12	8	*	60	43	*	9.8	8.6	ns
ICG 12879	17	14	ns	50	33	***	12.6	9.2	*
ICG 13723	17	12	*	43	35	ns	9.5	9.1	ns
ICG 1834	16	12	ns	48	33	*	13.2	9.5	*
ICG 2106	18	13	ns	47	38	ns	12.9	10.9	ns
ICG 2777	21	12	*	45	33	*	14.5	8.8	*
ICG 3053	17	16	ns	44	29	**	12.9	10.1	ns
ICG 3584	17	10	**	47	33	*	12.2	8.5	**
ICG 8106	14	10	*	47	38	*	15.9	10.3	*
ICG 8567	16	12	*	47	37	*	12.1	9.1	*
ICG 8760	11	6	*	53	36	*	7.1	4.1	*
ICG 97182	17	13	ns	47	38	*	13.4	9.3	**
ICG 9961	14	12	ns	45	35	*	10.5	6.7	**
ICGS 44	17	12	*	47	32	**	13.5	10.2	ns
ICGV 02038	15	11	ns	47	37	ns	12.0	8.0	*
ICGV 02189	16	13	*	49	37	*	10.9	8.7	*
ICGV 02271	12	10	ns	42	32	*	11.5	9.1	ns
ICGV 02290	17	12	*	51	38	*	12.5	8.2	*
ICGV 88145	12	10	ns	49	41	ns	12.2	9.0	**
ICGV 91114	13	9	*	54	40	*	10.5	8.1	ns
ICGV 95377	19	14	*	46	40	ns	13.6	8.9	**
ICGV 97182	13	12	ns	60	31	**	9.3	8.3	ns
ICGV 99001	16	13	ns	58	39	*	7.6	6.2	ns
ICGV-SM 87003	13	13	ns	51	37	*	11.8	9.3	ns
ICR 48	13	11	ns	44	32	*	12.0	10.6	ns
JL24	15	10	*	43	33	*	13.1	9.1	*
Mean	15	11		48	36		11.9	8.8	
CV (%)	21.6	20.8		14.3	16.3		16.6	19.4	
S.E	1.63	1.16		3.43	2.92		0.99	0.85	
LSD	5	3		10	8		2.8	2.4	
Fpr.	**	***		**	ns		***	***	

ns= not significant, *, **, *** Significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$, respectively.

Paired t-test showed very highly significance difference ($P \leq 0.001$) in pod yield between the two watering regimes (Table 2). The difference in pod yield/plant for each pair of groundnut genotype planted under two watering regimes obtained from t-test showed no significant to highly significant effect of watering regimes in pod yield/plant for the pairs of groundnut genotypes (Table 1). This study supports the previous study that drought stress significantly reduced pod yield in groundnut (Jongrungklang *et al.*, 2008).

Table 2: Effect of Watering Regime on Yield, Yield Components and Drought Tolerant Traits

Watering Regime	SCMR 40 DAS	SCMR 60 DAS	SCMR 80 DAS	Number of pods per plant	plant height (cm)	Pod yield (g /Plant)	Harvest Index
WW	47.5	46.2	47.6	15.1	47.8	11.9	0.40
WS	47.5	53.6	54.9	11	36	8.8	0.39
T-test	ns	***	***	***	***	***	ns

ns= not significant and *** Significant at $P \leq 0.001$.

Among the five best pod yielding genotypes under each watering regime, two genotypes ICG 8106 and ICGS 44 were similar while the other three were different, this shows that there are some genotype by watering regime interaction in pod yielding (Fig. 2). The genotypes which have performed similar in the two watering regimes are stable and hence not affected by drought. The desired genotype for drought is one with minimal G × E interaction, and stable yield in its target environment and across other environments (Acquaah, 2007). Therefore stable genotypes in pod yield are good source of drought resistance genes in drought tolerance breeding programmes, especially if they have acceptable yield levels.

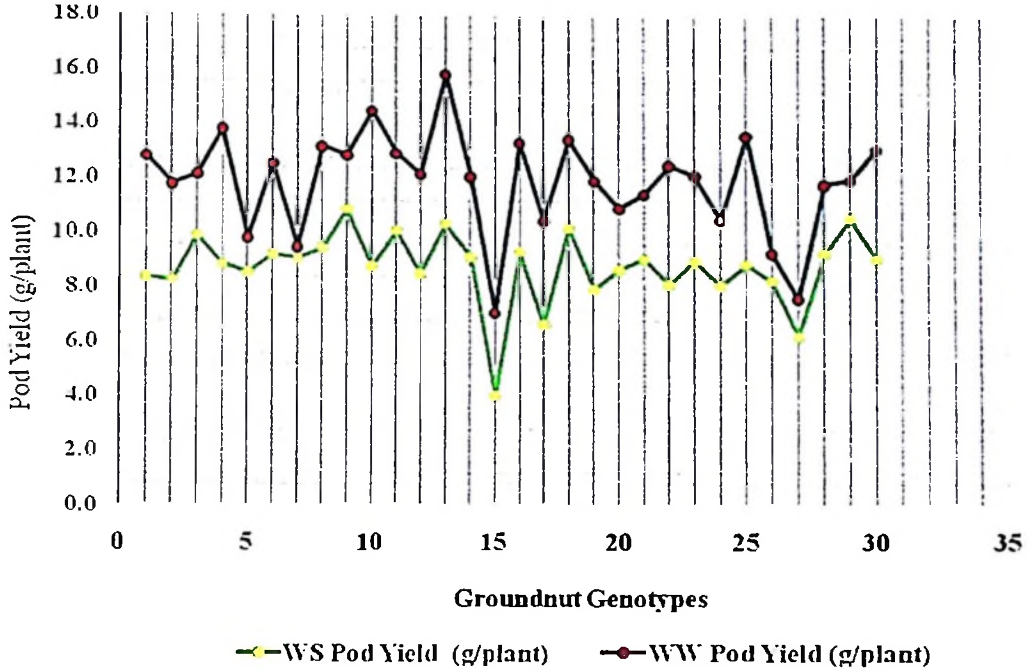

Figure 2: Pod Yield under Two Watering Regimes

Key:

1	55-437	7	ICG 13723	13	ICG 8106	19	ICGV 02038	25	ICGV 95377
2	FLEUR 11	8	ICG 1834	14	ICG 8567	20	ICGV 02189	26	ICGV 97182
3	ICG 11088	9	ICG 2106	15	ICG 8760	21	ICGV 02271	27	ICGV 99001
4	ICG 11862	10	ICG 2777	16	ICG 97182	22	ICGV 02290	28	ICGV-SM 87003
5	ICG 12235	11	ICG 3053	17	ICG 9961	23	ICGV 88145	29	ICR 48
6	ICG 12879	12	ICG 3584	18	ICGS 44	24	ICGV 91114	30	JL24

4.1.2 Number of pods per plant

Drought stress reduced significantly the number of pods/plant to the average of 11 pods/plant while under well watering condition the average number of pods /plant was 15 (Table 1). Analysis of variance showed highly significance variance ($P \leq 0.001$) in number of pods/plant among groundnut genotypes under water stress condition with the range of 6 to 16 number of pods/plant. The highest number of pods/plant under water stress condition was observed in ICG 3053 which was followed by ICG 12879, ICGV 95377, ICGV-SM 87003 and ICGV 99001.

Highly significance variation ($P \leq 0.01$) among groundnut genotypes for the number of pods/plant under well watering conditions was observed. The number of pods/plant under well watering condition ranged from 11 to 21. The highest number of pods/plant under well watering condition was observed in ICG 2777 which was followed closely by ICGV 95377, ICG 2106, ICG 97182 and ICG 3053.

Paired t-test showed highly significance difference ($P \leq 0.001$) for the number of pods per plant between well watering and water stress conditions (Table 2). The difference in number of pods/plant for each pair of groundnut genotype planted under two watering regimes obtained from t-test showed no significant to highly significant effect of watering regimes in number of pods/plant for the pairs of groundnut genotypes (Table 1).

Two groundnut genotypes ICGV 95377and ICG 3053 were the same among the top five genotypes from each watering regime while the other three were different, this showed that, there was some genotype by watering regime interaction for number of pods per plant in some genotypes (Fig. 3). Water deficits during pegging and pod set in groundnut reduce pod number while water deficits during pod filling generally reduce pod and kernel weight (Smartt, 1994).

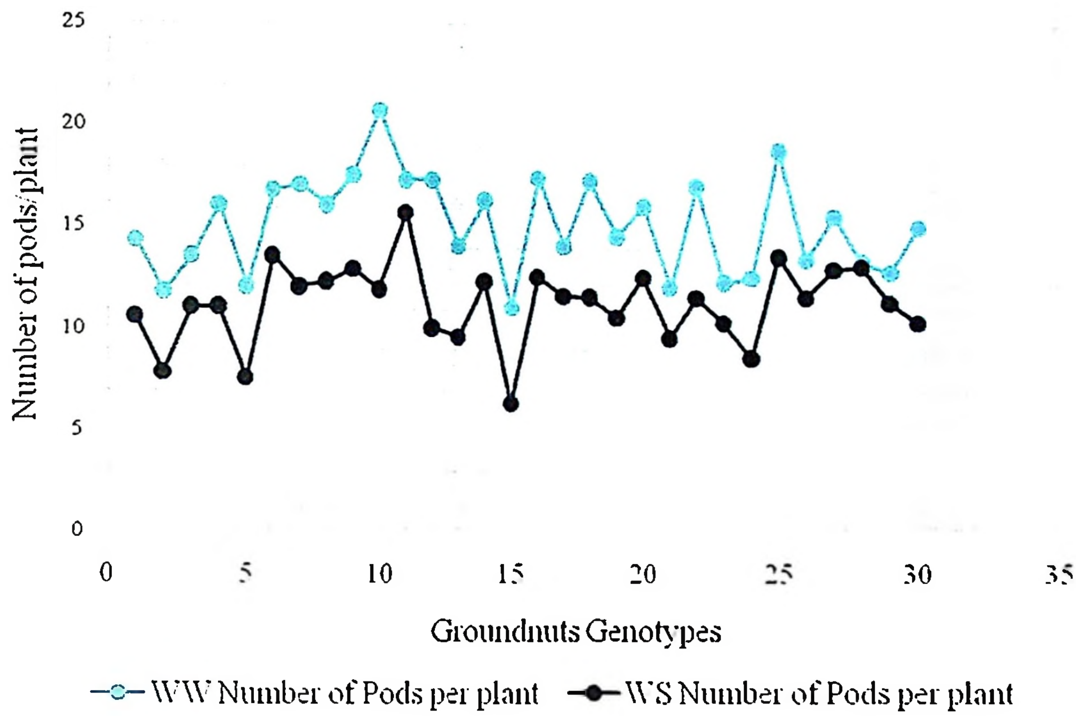

Figure 3: Number of Pods/Plant under the Two Watering Regimes

4.1.3 Plant Height

Analysis of variance showed highly significance difference ($P \leq 0.01$) in plant height among genotypes under well watered condition while no significance difference ($P \leq 0.05$) was observed under water stress condition (Table 1). The mean plant height under well watered condition was 48 cm and under water stress condition was 36 cm. Paired t-test showed very highly significance difference ($P \leq 0.001$) in plant height between the two watering regimes (Table 2). T-test in plant height for the pairs of groundnuts genotypes planted under two watering regimes showed no significant to highly significant effect of watering regimes on plant height (Table 1). Soil water deficits reduce leaf and stem growth through effects on plant water status, photosynthesis and leaf expansion (Smartt, 1994). Therefore groundnut genotypes with non significance difference in plant height under the two watering regimes have stable shoot growth.

4.2 Determination of the Levels of Drought Tolerance Traits (SCMR, HI and DTI) among 30 Groundnut Genotypes

4.2.1 Soil plant analysis development (SPAD) chlorophyll meter reading

Results on SCMR obtained in well watering and water stress condition are presented in Table 3. Analysis of variance showed highly significant difference ($P \leq 0.001$) in SCMR at 40 DAS under water stress condition among genotypes with a range of 43.9 to 52.5 and a mean of 47.5.The highest SCMR at 40 DAS under water stress condition was obtained from ICGV 02271 followed by ICR 48, FLEUR 11, ICG 8760 and ICG 97182. Highly significant difference ($P \leq 0.01$) among genotypes in SCMR at 40 DAS under well watering condition was also observed with the range of 44.7 to 52.0 and the mean of 47.5. The highest SCMR at 40 DAS under well watered condition was obtained from ICG 8760 which was followed closely by FLEUR 11, ICGV 02271, ICR 48 and ICGV 02290. Paired t-tests showed that there was no significant difference ($P \leq 0.05$) in SCMR at 40 DAS between the two watering regimes (Table 2).

Highly significant difference ($P \leq 0.01$) in SCMR at 60 DAS under water stress condition among genotypes was obtained while no significance difference ($P \leq 0.05$) in SCMR at 60 DAS was observed under well watering condition. The mean SCMR in water stress condition was 53.6 with the range of 47.6 – 58.0 and highest SCMR at 60 DAS under water stress condition was obtained from ICG 3053 followed by ICGV-SM 87003, ICGV 97182, ICG 1834 and ICGV 88145. Under well watering condition SCMR at 60 DAS ranged from 41.9 to 50.2 with the mean of 46.2. The highest SCMR at 60 DAS under well watered condition was obtained from ICGV 02271 which was followed closely by ICG 8760, ICG 2777, ICR 48 and ICG 97182.

Each groundnut genotype responded differently to water stress, hence the relative water content in the leaves of each genotype was affected differently with water stress (Fig. 4), and this caused variation in SCMR among the genotypes.

Figure 4: Wilting Symptoms in Groundnuts Genotypes at 63 DAS

Table 2 give results of paired t-test and they showed highly significance difference ($P \leq 0.001$) in SCMR at 60 DAS between the two watering regimes. T-test for SCMR at 60 DAS for the pairs of groundnut genotypes planted in well watering and water stress conditions (Table 3), showed no significant to highly significant effect of watering regimes on SCMR.

Table 3: SPAD Chlorophyll Meter Reading among 30 Groundnut Genotypes in Well Watered and Water Stressed Condition

Genotypes	WW 40 DAS	WS 40 DAS	WW 60 DAS	WS 60 DAS	T-test	WW 80 DAS	WS 80 DAS	T-test
55-437	48.0	48.2	46.4	52.3	*	46.9	53.5	*
FLEUR 11	51.5	51.6	47.0	55.0	*	51.9	59.2	**
ICG 11088	45.8	46.0	44.6	53.6	**	43.1	52.7	**
ICG 11862	47.3	46.4	47.2	55.5	**	48.7	56.3	*
ICG 12235	48.9	48.3	45.7	54.9	**	45.1	55.0	**
ICG 12879	44.9	45.5	45.1	54.8	***	46.2	57.2	***
ICG 13723	47.4	47.0	43.5	50.1	*	46.0	55.8	**
ICG 1834	44.8	46.0	45.4	56.8	***	46.5	54.1	**
ICG 2106	45.4	49.5	45.3	53.3	**	50.7	57.6	*
ICG 2777	47.2	46.9	47.8	53.5	**	46.7	56.0	**
ICG 3053	48.0	47.0	46.5	58.0	***	48.4	56.9	*
ICG 3584	48.0	46.1	44.7	52.0	ns	47.4	53.2	*
ICG 8106	48.8	46.5	46.9	54.2	**	46.8	55.1	*
ICG 8567	45.9	45.7	46.3	53.7	*	48.8	54.0	*
ICG 8760	52.0	50.3	48.7	53.0	ns	52.4	56.9	*
ICG 97182	48.4	49.7	47.7	47.7	ns	50.5	52.9	ns
ICG 9961	49.4	48.7	45.5	47.6	ns	48.0	54.0	*
ICGS 44	47.1	48.3	46.8	56.2	*	47.6	55.6	**
ICGV 02038	44.7	44.3	46.8	49.9	ns	45.1	53.1	**
ICGV 02189	46.3	48.4	47.5	55.1	*	47.4	55.7	*
ICGV 02271	51.5	52.5	50.2	56.2	ns	49.8	57.4	*
ICGV 02290	49.5	47.0	45.8	49.0	ns	46.3	52.6	ns
ICGV 88145	45.5	45.4	46.7	56.4	**	46.6	56.8	***
ICGV 91114	45.0	45.4	43.2	51.8	*	43.8	53.6	**
ICGV 95377	46.3	46.2	46.3	53.3	**	46.0	55.9	***
ICGV 97182	47.5	47.1	47.0	56.9	**	49.8	53.8	ns
ICGV 99001	45.2	43.9	41.9	49.6	**	45.8	46.9	ns
ICGV-SM 87003	48.3	48.3	45.5	57.9	**	49.1	55.8	*
ICR 48	49.9	51.7	47.8	56.4	*	50.4	54.3	ns
JL24	47.6	47.7	46.4	55.0	***	47.8	55.0	**
Mean	47.5	47.5	46.2	53.6		47.6	54.9	
CV (%)	6.2	5.1	6.1	7.5		7.1	6.4	
S.E	1.48	1.2	1.41	2.0		1.7	1.76	
LSD	4.16	3.37	3.96	5.63		4.77	4.96	
Fpr.	**	***	ns	**		*	*	

ns= not significant, *, **, *** Significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$, respectively.

Significance difference ($P \leq 0.05$) in SCMR at 80 DAS under water stress and well watering conditions among genotypes were observed. Water stress at 76 DAS affected the groundnut by causing wilting to the leaves due to low relative water content (Fig. 5). SCMR at 80 DAS in water stress condition had a range of 46.9 – 59.2 with the mean of 54.9. The highest SCMR at 80 DAS under water stress condition was obtained from FLEUR 11 which was followed closely by ICG 2106, ICGV 02271, ICG 12879 and ICG 8760. SCMR at 80 DAS under well watering condition had the range of 41.9 – 50.2 with the mean of 47.6. The highest SCMR at 80 DAS under well watered condition was obtained from ICG 8760 which was followed closely by FLEUR 11, ICG 2106, ICG 97182 and ICR 48. Paired t-tests showed highly significance difference ($P \leq 0.001$) in SCMR at 80 DAS between watering regimes (Table 2). T-test in SCMR at 80 DAS between pairs of groundnut genotypes planted under two watering regimes showed no significant to highly significant effect of watering regimes on SCMR (Table 3).

Most of the genotypes with highest SCMR under water stress condition, had significance difference in SCMR with their corresponding genotypes under well watering condition. Due to highly significance difference ($P \leq 0.01$) in SCMR at 60 DAS under water stress condition among genotypes compared to significance difference ($P \leq 0.05$) at 80 DAS. This shows that there is more variation among genotypes in SCMR at 60 DAS than at other times. The highest variation among groundnut genotypes in SCMR at 60 DAS, may have been caused by photosynthesis process which uses chlorophyll during this time to supply energy in vegetative growth, flowering and pegging processes, while at 80 DAS there is only pod set process (Page *et al.*, 2002) and the ratio of older to younger leaves have increased (Hossain and Hamid, 2007). Therefore this would be the suitable time for assessing SCMR in groundnut.

Figure 5: Appearance of Groundnut Genotypes under two Watering Regimes at 76 DAS

Drought stress caused increase in SCMR among the tested genotypes. This study supported the previous study on SCMR under water deficit condition (Wunna *et al.*, 2009). The increase in SCMR as a result of drought stress varied among genotypes. Drought stress is known to affect chlorophyll content in many crops including, wheat and turf grasses there by inhibiting photosynthetic capacity (Jiang and Huang, 2001; Jongrungklang *et al.*, 2008). The ability to maintain chlorophyll density under water stress condition has been suggested as drought resistance mechanism in groundnut (Jongrungklang *et al.*, 2008). Hence the increase in SCMR, the trait related to photosynthetic capacity contributes to drought tolerance.

4.1.2 Harvest index

Analysis of variance showed that there was highly significance variance ($P \leq 0.001$) in harvest index among genotypes under all watering regimes (Table 4). The harvest index under well watering condition ranged from 0.20 to 0.52 with the mean of 0.4. The highest harvest index (HI) under well watering condition was obtained in genotype ICGV 02038 which was followed closely by ICG 11862, 55-437, ICG 1834 and ICGS 44. Under water stress harvest index ranged from 0.17 to 0.50 with the mean of 0.39. The highest HI under water stress condition was obtained from genotype ICGV 02038 which was followed by ICG 8106, ICG 3584, ICG 11088 and ICG 11862. Paired t-tests showed no significance variance ($P \leq 0.05$) in harvest index between watering regimes (Table 2). Since HI in groundnut is the ratio of pod yield to total biomass, in this study drought stress decreased both pod yield and dry matter yield almost at same degree, as a result HI obtained under water stress condition did not differ significantly with that under well watering condition, compared to previous study by Shinde *et al.* (2010) who obtained significant reduction in HI by water stress. Harvest index implies the relative distribution of photosynthesis products between economical sinks and other existing sinks in the plant. Esmaeel *et al.* (2009) stated that water deficit is one of the limiting factors of plant growth and development that not only reduces production of dry matter but also causes a disorder to the partitioning of carbohydrates to grain thus reducing the harvest index. Harvest index has a direct proportion relationship with pod yield in groundnuts. Ratnakumar (2011) reported that Groundnut genotypes tolerant to intermittent drought maintain a high harvest index, hence genotypes with high harvest index in drought stress condition are good sources of drought resistance genes in drought breeding programmes.

4.1.3 Drought tolerance index

Analysis of variance showed highly significance difference ($P \leq 0.001$) among genotypes in drought tolerance index (DTI) for pod yield/plant (PY) (Table 4). Drought tolerance index for pod yield ranged from 0.27 to 1.02 with the mean of 0.75. The highest DTI (PY) was observed in genotype ICGV 97182 which was followed closely by ICG 3053, ICG 13723, ICG 12235 and ICG 2106.

Table 4: Drought Tolerance Index and Harvest Index among 30 Genotypes in Well Watered and Water Stressed Condition

Genotypes	Harvest Index WW	Harvest Index WS	Drought Tolerance Index Number of pods/plant	Drought Tolerance Index Pod yield/plant
55-437	0.47	0.41	0.74	0.64
FLEUR 11	0.39	0.37	0.66	0.70
ICG 11088	0.40	0.45	0.82	0.83
ICG 11862	0.48	0.45	0.69	0.64
ICG 12235	0.32	0.35	0.72	0.93
ICG 12879	0.41	0.43	0.88	0.78
ICG 13723	0.29	0.38	0.74	0.99
ICG 1834	0.47	0.36	0.80	0.72
ICG 2106	0.43	0.43	0.81	0.90
ICG 2777	0.45	0.42	0.58	0.59
ICG 3053	0.42	0.44	1.24	1.00
ICG 3584	0.43	0.45	0.52	0.69
ICG 8106	0.45	0.46	0.67	0.64
ICG 8567	0.42	0.44	0.77	0.77
ICG 8760	0.20	0.17	0.33	0.27
ICG 97182	0.41	0.37	0.73	0.67
ICG 9961	0.39	0.29	0.85	0.66
ICGS 44	0.47	0.42	0.60	0.69
ICGV 02038	0.52	0.50	0.75	0.71
ICGV 02189	0.42	0.42	0.78	0.81
ICGV 02271	0.43	0.44	0.71	0.80
ICGV 02290	0.38	0.37	0.68	0.65
ICGV 88145	0.43	0.36	0.85	0.74
ICGV 91114	0.34	0.31	0.69	0.75
ICGV 95377	0.46	0.43	0.74	0.68
ICGV 97182	0.36	0.39	0.89	1.02
ICGV 99001	0.27	0.29	0.86	0.90
ICGV-SM 87003	0.43	0.39	1.03	0.78
ICR 48	0.38	0.40	0.93	0.89
JL24	0.39	0.38	0.68	0.69
Mean	0.4	0.39	0.76	0.75
CV (%)	13	16.1	29.50	25.00
S.E	0.026	0.032	0.112	0.094
LSD	0.07	0.09	0.32	0.26
Fpr.	***	***	**	***

, * Significant at $P \leq 0.01$ and $P \leq 0.001$, respectively.

Drought tolerance index (DTI) for number of pods/plant (NP) was highly significance difference ($P \leq 0.01$) among the tested groundnut genotypes (Table 4). DTI (NP) ranged from 0.33 to 1.24 with the mean of 0.76. The highest DTI (NP) was observed in ICG 3053 which was followed closely by ICGV-SM 87003, ICR 48, ICGV 97182 and ICG 12879.

Drought tolerance index for pod yield and number of pods/plant shows the stability of a genotype performance. The higher the DTI, the more stable the genotype. Groundnut genotypes with high DTI (PY) had pod yield under drought stress condition which in most case had no significant difference with pod yield under well watering condition. Therefore groundnut genotypes with high DTI (PY) are sources of drought resistance genes for drought tolerance breeding programmes in groundnuts.

4.3 Heritability Estimates and Relationship between Yield and Yield Components with Drought Tolerance Traits

4.3.1 Heritability of yield and drought tolerant traits

Heritability is the percentage of all differences between groundnut genotypes that is caused by gene effects and can be transferred from generation to generation. Therefore, high heritability helps in effective selection for a particular character. Broad-sense heritability estimates obtained from 30 groundnuts genotypes for pod yield and drought tolerant traits ranged from low to medium as shown in Table 5. Under well watered condition the highest heritability value was rated as medium, and was observed from HI which had 0.59, followed by pod yield with 0.4, low heritability was observed from SCMR which had 0.25, plant height with 0.24 and number of pods per plant with 0.22.

Under water stress condition the highest broad-sense heritability estimates rated as medium was observed from HI which had 0.45 followed by SCMR with 0.35 and number of pods per plant with 0.32. Low heritability was obtained from pod yield which had 0.27 and plant height with 0.04. The variability in heritability estimates for the same trait under the two watering regimes was caused by the interaction between the genes that encode the trait and the environment in which the genes are being expressed (Acquaah, 2007). The heritability estimates in this experiment were not above 0.6 as the estimates were on plant basis and not on family basis, the heritability on family basis is greater than on plant basis (Ceccarelli, 2009)

In order for a trait to be more useful in selection of drought tolerance, the heritability estimates for the trait should be greater than the heritability for yield in the specific environment, so that selecting and advancing only the top few performers is likely to produce a greater genetic advance than selecting many moderate performers when heritability is low (Acquaah, 2007). In this study heritability estimates of HI, SCMR and number of pods per plant were higher than heritability estimates of pod yield per plant under water stress condition. Therefore, HI, SCMR and number of pods per plant can be used as selection criteria in breeding programmes for drought tolerance.

Table 5: Heritability Estimates in Broad Sense for Harvest Index, SCMR, Plant Height, Number of Pods and Pod Yield per Plant

	Heritability	
Characteristics	WW	WS
Harvest Index	0.59	0.45
Number of pods/plant	0.22	0.32
Pod yield/plant	0.40	0.27
SCMR	0.25	0.35
Plant height	0.24	0.04

4.3.2 Relationship between yield and yield components with drought tolerance traits (HI and SCMR)

4.3.2.1 Relationship among drought tolerant traits

The simple correlation coefficients between drought tolerant traits from the analysis are shown in Tables 6 and 7. No significance relationship ($P \leq 0.05$) between SCMR at 40, 60 and 80 DAS with HI was observed to the tested groundnut genotypes under the two watering regimes. The results from this study support the study conducted by Bootang *et al.* (2010) which found no association between SCMR and HI. Therefore from this study SCMR cannot be used as a surrogate trait for HI during selection of groundnut genotypes in breeding programmes for drought tolerance.

Table 6: Correlation among SCMR, HI, Number of Pods/Plant and Pod Yield in Well Watered Condition

	SCMR 40 DAS	SCMR 60 DAS	SCMR 80 DAS	Harvest Index	Number of pods/plant	Pod yield (g/plant)
SCMR 40 DAS	1.00					
SCMR 60 DAS	0.41***	1.00				
SCMR 80 DAS	0.41***	0.47***	1.00			
Harvest Index	0.14^{ns}	0.16^{ns}	-0.10^{ns}	1.00		
Number of pods per plant	-0.14^{ns}	-0.05^{ns}	-0.05^{ns}	0.24**	1.00	
Pod yield (g/plant)	-0.02^{ns}	0.20*	0.05^{ns}	0.63***	0.49***	1.00

ns= not significant, *, **, *** Significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$, respectively.

Table 7: Correlation among SCMR, HI, Number of Pods/Plant and Pod Yield in Water Stress Condition

	SCMR 40 DAS	SCMR 60 DAS	SCMR 80 DAS	Harvest Index	Number of pods/plant	Pod yield (g/plant)
SCMR 40 DAS	1.00					
SCMR 60 DAS	0.14^{ns}	1.00				
SCMR 80 DAS	0.20*	0.30***	1.00			
Harvest Index	-0.13^{ns}	0.08^{ns}	0.06^{ns}	1.00		
Number of pods per plant	-0.05^{ns}	0.24**	0.14^{ns}	0.39***	1.00	
Pod yield (g/plant)	0.06^{ns}	0.38***	0.19*	0.61***	0.64***	1.00

ns= not significant, *, **, *** Significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$, respectively.

4.3.2.2 Relationship between drought tolerant traits with yield and yield components

The relationship between yield and yield components with drought tolerance traits were from non significant to highly significant, positive and negative. Under well watered condition, moderate positive significant relationship (r = 0.2) was observed between SCMR at 60 DAS and pod yield/plant, this means that knowing the value of SCMR at 60 DAS gives little information for predicting pod yield in groundnut under well watered condition. HI and number of pods/plant had strong positive and highly significant relationship (r = 0.63 and r = 0.5) with pod yield/plant, this means that knowing HI and number of pods/plant gives a greater accuracy prediction of pod yield/plant. This study supports the earlier study conducted by Jogloy *et al.* (2011) on strong and positive relationship between HI and number of pods/plant with pod yield.

Under water stress condition, SCMR at 60 DAS had moderate positive and highly significant relationship (r = 0.38) with pod yield/plant while SCMR at 80 DAS had moderate positive and significant relationship (r = 19) with pod yield/plant. This means that, understanding the values of SCMR at 60 and 80 DAS in groundnut genotypes gives some significant information about pod yield under water stress condition. SCMR at 60 DAS also had moderate positive and highly significant relationship (r = 0.24) with number of pods/plant. Understanding the values of SCMR at 60 DAS in groundnuts genotypes gives some significant information about the number of pods/plant under water stress condition. HI and number of pods/plant had strong positive and highly significant relationship (r = 0.61 and r = 0.64) respectively with pod yield/plant. Understanding the values of HI and number of pods/plant gives greater accuracy information on pod yield/plant in groundnut.

This study supports the previous study which obtained significant relationship between SCMR and pod yield (Bootang *et al.*, 2010). Positive and highly significant relationship between SCMR at 60 DAS, which is an indirect measure of chlorophyll density and pod yield under water stress condition, means groundnuts genotypes with high SCMR could maintain higher photosynthetic capacity and because of thicker leaves they have more leaf carbon exchange rate and chlorophyll content and therefore leads to high pod yield. The higher significant correlation between SCMR 60 DAS with number of pods/plant and pod yield/plant under water stress condition compared to well watered condition, means SCMR can be used in selection of drought tolerant genotypes in breeding programmes. Strong positive and highly significant relationship between HI and number of pods/plant with pod yield/plant implies that genotypes with high HI and number of pods/plant under water stress condition had high pod yield. HI is the relative distribution of photosynthesis products between economical sinks and other existing sinks in the plant. Therefore HI can be used as a selection criterion in drought tolerance breeding programmes.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

i. The study was able to identify genotypes ICG 8106, ICG 2777, ICG 11862, ICGV 95377 and ICGS 44 as high pod yielding under well watered condition and ICG 2106, ICR 48, ICG 8106, ICGS 44, ICG 3053 and ICG 11088 as high pod yielding genotypes under water stress condition.

ii. There was significant variation among genotypes on drought tolerance traits with high yields under different watering regimes. Water stress in groundnut significantly increased SCMR and did not significantly affect harvest index.

iii. For effective selection of genotypes as drought tolerant genotypes, association of drought tolerance traits with pod yield and among themselves is important. In this study SCMR at 60 DAS, number of pods/plant and HI were found to be positively and significantly correlated to pod yield under all watering condition.

iv. A heritability estimate of a trait is also important due to the information on the variation of genotypes on certain trait on genetic bases. In this study high heritability estimates under water stress condition, was calculated from HI, SCMR and number of pods/plant. Therefore, these traits can be good criteria to be used in breeding and selection programmes in improving pod yield in drought prone areas. Based on this study eleven groundnut genotypes were identified as possible drought tolerant due to high pod yield, number of pods/plant, HI and SCMR 60 DAS , they includes ICG 2106, ICR 48, ICGS 44, ICG 3053, ICG 11088, ICGV-SM 87003, ICG 12235, ICG 13723, ICGV 02271, ICGV 97182 and ICGV 91114.

5.2 Recommendations

i. The findings recommend the best time for SCMR recording is at 60 DAS, as the information on chlorophyll concentration obtained during this time is highly correlated with pod yield.

ii. Researchers should be trained on how to use this portable device in recording chlorophyll concentration in different crops, as it is easy to use and non destructive method of measuring chlorophyll concentration.

iii. Due to the fact that this study was conducted in screen house, field experiment study using the same genotypes, first under controlled water supply and then without water control in drought prone areas should be conducted so as to confirm the results from this study.

REFERENCES

Acquaah, G. (2007). *Principles of Plant Genetics and Breeding.* Blackwell Publishing Ltd., Oxford. 584pp.

Amede, T., Paul. K., Wilson, R., Lubanga, L. and Nkoko, M. (2004). *Coping with Drought: Strategies to Improve Genetic Adaptation of Common bean to Drought Prone Regions of Africa.* CIAT Occasional Publication Series, No. 38. Addis Ababa, Ethiopia. 45pp.

Boontang, S., Girdthai.T., Jogloy. S., Akkasaeng, C., Vorasoot, N., Patanothai. A. and Tantisuwichwong, N. (2010). Response of Released Cultivars of Groundnut to Terminal Drought for Traits Related to Drought Tolerance. *Asian Journal of Plant Sciences* 9(7): 423 – 431.

Ceccarelli, S., Guimarães, E. P. and Weltzien, E. (2009). *Plant Breeding and Farmer Participation.* Food and Agriculture Organization of the United Nations, Rome. 671pp.

Devi, J. M., Sinclair, T. R. and Vadez, V. (2010). Genotypic variation in Groundnut for transpiration response to vapor pressure. *Crop Science* 50: 191 – 196.

Emmanuel, S. M. (Ed.) (2009). Developing short-and medium-duration groundnut varieties with improved yield performance, acceptable market traits and tolerance to foliar diseases. *Proceedings of McKnight Foundation Workshop,* Lilongwe, Malawi. 10 September, 2008. 39pp.

Esmaeel, G., Amir, A., Abdollah, H. G., Gorban, N. and Iraj, B. (2009). Study of the Effect of Drought Stress on Yield, Yield Components and Harvest Index of Sunflower Hybrid Iroflor at Different Levels of Nitrogen and Plant Population. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 37(2): 85 – 94.

FAO (2008). Food and Agricultural commodities production. [http://faostat.fao.org] site visited on 30 /3/ 2012.

Glynn, C. P., Ian, P. K. and Kelly, N. (2008). The Potential of a Chlorophyll Content SPAD Meter to Quantify Nutrient Stress in Foliar Tissue of Sycamore (*Acer pseudoplatanus*), English Oak (*Quercus robur*), and European Beech (*Fagus sylvatica*). *Arboriculture and Urban Forestry* 34(2): 89 – 100.

Gomez, K. A. and Gomez, A. A. (1984). *Statistical Procedures for Agricultural Research.* (2nd Ed.), John Wiley and Sons Inc., New York. 680pp.

Hamidou, F., Ratnakumar, P., Halilou, O., Mponda, O., Kapewa, T., Monyo, E., Faye, I., Ntare, B., Nigam, S. N., Upadhyaya, H. D. and Vadez, V. (2012). Selection of intermittent drought stress tolerant lines across years and locations in the reference collection of groundnut (*Arachis hypogaea* L.). *Field Crops Research* 126: 189 – 199.

Hossain, A. M. and Hamid, A. (2007). Influence of N and P Fertilizer Application on Root Growth, Leaf Photosynthesis and Yield Performance of Groundnut. *Bangladesh Journal of Agricultural Research* 32(3): 369 – 374.

ICRISAT (2008). Groundnut Area, Production And Number Of Varieties Released Globally. [http://www.icrisat.org] site visited on 30 /3/ 2012.

Jongrungklang, N., Jogloy, S., Vorasoot, N., Kesmala, T. and Patanothai, A., Toomsan, B. (2008). Identification of Groundnut genotypes with higher water use efficiency under drought stress conditions from Groundnut germplasm of diverse origins. *Asian Journal of Plant Sciences* 7: 628 – 638.

MAFC (2005). Food Crop Production, Area and Yield. [http://www.kilimo.go.tz] site visited on 2 /4/ 2012.

Majid, K., Mirza, H. and Roza, G. (2011). Assessment of yield and yield components and drought tolerance at end-of season drought condition on corn hybrids (*Zea mays* L.). *Asian Journal of Plant Sciences* 5(12): 1493 – 1500.

Mponda, O. K. and Kafiriti, E. M. (2008). *Jinsi Yakuzalisha Mbegu Bora za Karanga (Production of Improved Groundnut Variety* Seeds). Naliendele Agricultural Research Institute, Mtwara. 17pp.

Naturland, E. V. (2000). *Organic Farming in the Tropics and Subtropics*. German Agency for Technical Cooperation, German. 24pp.

Page, W. W., Busolo-Bulafu, C. M., Merwe, P. J. A. and Chancellor, T. C. B. (2002). *Recommended Groundnut Production Practices for Smallholder Farmers in Uganda*. Natural Resources Institute, Chatham. 17pp.

Painawadee, M., Jogloy, S., Kesmala. T., Akkasaeng. C. and Patanothai. A. (2009). Heritability and Correlation of Drought Tolerance Traits and Agronomic Traits in Groundnut (*Arachis hypogaea* L). *Asian Journal of Plant Sciences* 8(5): 325 – 334.

Ratnakumar, P. and Vadez, V. (2011). Groundnut (*Arachis hypogaea*) Genotypes Tolerant to Intermittent Drought Maintain a High Harvest Index and have Small Leaf Canopy under Stress. *Functional Plant Biology* 38(12): 101 – 1023.

Shinde B. M., Limaye A. S., Deore G. B. and Laware, S. L. (2010). Physiological Responses of Groundnut (*Arachis hypogaea* L.) Varieties to Drought Stress. *Asian Journal of Experimental Biological Sciences* 1: 68 – 71.

Smartt, J. (Eds.) (1994). *The Groundnut crop: A Scientific Basis for Improvement.* Chapman and Hall, London. 756pp.

Songsri, P., Jogloy, S., Kesmala, T., Vorasoot, N., Akkasaeng, C., Patanothai, A. and Holbrook, C.C. (2008). Heritability of drought tolerance traits and correlation of drought tolerance and agronomic traits in Groundnut. *Crop Sciences* 48: 2245 – 2253.

Wunna, H., Jogloy, S., Toomsan, B., Sanitchon, J. and Patanothai, A. (2009). Inheritance of Traits Related to Biological Nitrogen Fixation and Genotypic Correlation of Traits Related to Nitrogen Fixation, Yield and Drought Tolerance in Groundnut (*Arachis hypogaea* L.) Under Early Drought. *Asian Journal of Plant Sciences* 8: 265 – 275.