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HERITABILITY AND RELATIONSHIP BETWEEN DROUGHT TOLERANCE TRAITS AND YIELD IN GROUNDNUTS (*ARACHIS HYPOGAEA* L.) UNDER DIFFERENT WATERING REGIMES

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ABSTRACT

Improvement of groundnuts for drought tolerance could increase production in drought prone areas. This study aimed at determining the heritability estimates and relationship of HI and SCMR with yield and yield components using 30 groundnut genotypes planted under different watering regimes, so as to speed up the selection and breeding of groundnut genotypes tolerant to drought. A completely randomized design arranged in a split plot experiment with four replications was conducted in screen house in Morogoro, Tanzania. Data collection was done on plant height, number of pod/plant and pod yield/plant. Drought tolerant traits measured included, harvest index (HI), SCMR at 40, 60 and 80 DAS. Broad-sense heritability was calculated for HI, pod yield, number of pod/plant and SCMR. Results showed that 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.
Keywords: Groundnut, SCMR, Water stress, Heritability, Pod yield.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important leguminous crop in the world grown for oilseed, food and animal feed (Jasem et al., 2013). The genus and species names *Arachis hypogaea* comes from Greek words (Holbrook and Stalker, 2003). Groundnut is tetraploid with 2n=4x=40 chromosomes (Mamadou, 2011). It has 44 to 50 % edible oil, 25 % easily digestible protein and 20 % carbohydrate (FAO, 2008). In Tanzania, total groundnuts production is 465,290 tons produced within the area of 482,311 ha, this gives a yield of 965 kg ha^{-1} (MAFC, 2010).

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. Annually world-wide drought causes a loss of 6.7 million metric tons on groundnut production (Devi et al., 2010). Regardless of its importance in Tanzania, groundnut productivity is still low. Most of the groundnut growing areas in Tanzania are affected by intermittent drought of different duration and intensity.

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Long and severe drought experienced in Dodoma, Tanzania in the year 2007/08, caused 100 % loss in groundnut production in Chamwino, Bahi and Kongwa (Monyo, 2009). In Southern Tanzania, drought accelerated rosette outbreak and thus reduced productivity and production. 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.

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) and Harvest Index (HI) have been used during drought tolerance selection in breeding programme. Low genotype by environment interaction on Specific Leaf Area (SLA) and SCMR was obtained by Songsri et al. (2008). Wunna et al. (2009) reported the use of HI and DTI for yield and yield components in drought tolerance selection.

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. Higher SCMR under water stress condition shows that, the groundnut genotypes could continue having high photosynthesis rate per unit leaf area regardless of water stress. In groundnut SCMR has strong relationship with pod yield and Transpiration Efficiency (TE) under water stress conditions (Bootang et al., 2010). In groundnut harvest index is the ratio of pod weight to total biomass and it varies depending on the severity and timing of water stress relative to pod set. Smartt (1994) reported that, differences in pod yield among groundnut genotypes during a terminal drought were due to differences in harvest index which was associated with variation in pods and the effective duration of pod filling developmental stage.

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. A high heritability would likely result in high response to selection to advance the population in the desired direction of change (Acquaah, 2007).

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

MATERIALS AND METHODS

The experiment was conducted at Sokoine University of Agriculture (SUA) farm which is located at S 06° 50' 24.7" and E 37° 38' 59.8", Morogoro, Tanzania. Morogoro has mean annual rainfall of 1031 mm and temperature range of 18.6 – 30.0 ºC. A set of 30 groundnut genotypes were used in the study. The genotypes used were obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The genotypes were planted in screen house to determine heritability and correlation among drought tolerant traits and yield under different watering regimes. The screen house condition during experimental period recorded temperature range of 25 - 31ºC and the relative humidity was 85 – 95%

The genotypes were planted using a completely randomized design arranged in a split plot experiment in four replications with watering regimes being main plot treatments and genotypes sub plot treatments. Three seeds of each genotype were sown in a pot which had five drainage holes and filled with 12 kg of soil each. After sowing, 500 ml of water were applied to each pot on the sowing day, this was followed by applying 250 ml of water two times a day on alternate days until germination. Thinning was done 14 days after sowing (DAS), whereby one plant was left per every pot. 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 well watered plants (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, as illustrated in Table. 1. (Ratnakumar and Vadez, 2011).

Table. 1. Wilting symptoms scoring scale

Scale	Explanation
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)

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).

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 (Figure 1.0). 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 SCMR using SPAD Chlorophyll Meter at SUA

Harvest index was calculated based on the following relationship (Fageria et al., 2011):

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

The collected data were subjected to analysis of variance using GenStat 14th edition Statistical package for analysis. The estimate mean squares from ANOVA table for drought tolerance associated traits and pod yield were used to calculate genotypic variance and environmental variance. Broad-sense heritability estimates for the measured traits was calculated using the formula described by Ceccarelli et al. (2009) as follows:

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

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 14th edition Statistical package.

RESULTS AND DISCUSSION

Heritability of yield and drought tolerant traits

Heritability or percentage of all differences between groundnut genotypes that is caused by gene effects and that can be transferred from generation to generation was determined in this study as summarised in Table 2. Results showed that broad-sense heritability estimates obtained from 30 groundnuts genotypes for pod yield and drought tolerant traits ranged from low (0.04) to medium (0.59) for the groundnut genotypes drought phenotyping pot experiment conducted in Morogoro at SUA. 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 known to be greater than that on plant basis (Ceccarelli et al., 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 2: Heritability Estimates in Broad Sense for Harvest Index, SCMR, Plant Height, Number of Pods and Pod Yield per Plant

Characteristics	Heritability	
	Well Watered	Water Stress
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

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

Relationship among drought tolerant traits

The simple correlation coefficients between drought tolerant traits from the analysis are shown in Tables 3 and 4. 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 3: 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, SCMR = SPAD Chlorophyll Meter Reading and DAS = Days after sowing

Table 4: 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, SCMR = SPAD Chlorophyll Meter Reading and DAS = Days after sowing

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 ($P \leq 0.001$), positive and negative. Under well watered condition, moderate positive significant relationship ($r = 0.2$, $P \leq 0.01$) 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 ($r = 0.63$, $P \leq 0.001$ and $r = 0.5$, $P \leq 0.001$) 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 ($r = 0.38$, $P \leq 0.001$) with pod yield/plant while SCMR at 80 DAS had moderate positive and significant relationship ($r = 19$, $P \leq 0.05$) 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 ($r = 0.24$, $P \leq 0.01$) 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 ($r = 0.61$, $P \leq 0.001$ and $r = 0.64$, $P \leq 0.001$) 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. Such results imply that, HI is the relative distribution of photosynthesis products between economical sinks and other existing sinks in the plant. Therefore this can be used in breeding program as a selection criterion in drought tolerance breeding programmes.

CONCLUSION

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. 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 groundnut pod yield in drought prone areas.

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