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Impact of moisture stress at flowering stage on the growth and yield of selected groundnut (Arachis hypogaea L.) cultivars

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Abstract

Groundnut (Arachis hypogea L) production fluctuates considerably as a result of rainfall variability. Unpredictable time and the extent of water deficit occurs every year and causes a reduction in yield and quality. Under these conditions, the use of cultivars tolerant to drought and producing high yield should be advantageous. This experiment was carried out in Agronomy farm of Eastern University, Sri Lanka during the 'Yala' season 2017. This study was made to determine the impact of moisture stress on the growth and yield on selected groundnut cultivars. Three groundnut cultivars viz; 'Lanka jumbo', 'Tissa' and 'Indi' were used for this study. Continuous ten days of water stress was imposed on the groundnut plants during the flowering stage and the effects were evaluated. This experiment was laid out in the Randomized Complete block design with six treatments and four replications and the treatments were arranged in 3× 2 Factorial manner. There were significant ($p<0.05$) differences between the treatments in the tested parameters. The highest chlorophyll a (1.0), b (0.8) was detected in 'Indi' groundnut cultivar and the lowest chlorophyll a (0.5), b (0.4) was detected in 'Tissa'. The highest leaf area index (0.6) was detected in 'Indi' cultivar and the lowest (0.3) was detected in 'Tissa'. The highest yield (0.8 t ha^{-1}) was observed in 'Indi' and the lowest (0.33 t ha^{-1}) was found in 'Tissa'. Hence, considering the measured growth and yield attributes, 'Indi' groundnut cultivar could resist drought better than the rest of the cultivars. As such, this cultivar could be suggested for cultivation in the drought-prone areas of the Batticaloa district.

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Keywords: Chlorophyll contents; Groundnut; Leaf area index; Moisture stress; Yield

1. Introduction

Groundnut (Arachis hypogaea L.) is an oil seed crop that provides food for direct human subsistence and other several food products (Ngo Nkot et al., 2008). Groundnut is legume cash crop for the farmers in arid and semi-arid regions and its seeds contain high amounts of edible oil (43-55%), protein (25-28%), and minerals (2.5%) (Abou Kheira, 2009). Groundnut is frequently subjected to drought stresses of different duration and intensities. It leads to the reduction of crop yield, and the magnitude of reduction would depend on groundnut cultivars. Not only the yield of groundnut but also the quality of products decreases under drought stress. Due to erratic rainfall and frequent drought during the crop growth period, groundnut yields are generally low and unstable under rain-dependent conditions (John et al., 2011) due to poor adaptation of improved varieties and the influence of drought stress depends on the magnitude of stress, its duration, growth stage and type of genotype (Prasad et al., 2010). Drought stress during reproductive stages like flowering and pod filling is pivotal for yield in groundnut and this reduction of crop yield depends on groundnut varieties (Shinde and Laware, 2010) and tolerant genotypes will be able to give better yield considerably (Ratnakumar and Vadez, 2011) due to physiological and biochemical changes that were triggered by drought stress. There are significant genotypic variations in response to drought and their tolerance levels in groundnut (Azevedo neto et al., 2010). It is necessary to screen the selection of tolerant groundnut lines for breeding purposes (Ratnakumar and Vadez, 2011) and better understanding of the stress-induced responses of physiological and biochemical traits can prove to be very useful to screen drought tolerant genotypes (Vijayalakshmi et al., 2012). Recently groundnut cultivation in the Batticaloa district was heavily affected by drought. It has become important to study the performance of different groundnut cultivars under moisture stress condition. Hence, the present study was conducted to assess the impact of drought stress at on the growth and yield performance of popularly cultivated groundnut genotypes in order to quantify their tolerance to drought stress.

2. Materials and Methods

This experimental study was conducted at the agronomy farm of Eastern University, Sri Lanka where the climate was warm (28-32^{o}C) and average annual rainfall 1250mm. For this experiment 192 bags were selected and each having the 42 cm height and 45 cm diameter were prepared. A number of three groundnut cultivars viz; ‘Tissa’, ‘Indi’ and ‘Lanka Jumbo’ were used for this study. Potting mixture was prepared by using top soil, red soil and compost at the ratio of 1:1:1. Only one vigorous seedling was allowed to grow in each bag. Urea, TSP and MOP were added as basal and urea was applied as top dressing. Gypsum blocks were inserted into soil and readings were inserted and reading were recorded on the 10th day from commencement of the stress. The rain shelters were erected using bamboo sticks and polyethylene (1000 gauge) sheet to prevent the entry of water into experimental filed. The experiment was arranged in 3×2 factorial randomized complete block design with six treatments and four replications. Moisture stress was imposed during the flowering stage for 10 days continuously (T2, T4, T5). For the control plants watering was practiced to field capacity at two days interval (T1, T3, T5).

2.1. The treatment structure

Groundnut plants were subjected to moisture stress during the flowering stage. The time of appearance of 50% flowers was considered as the flowering stage for each cultivar. The experiment was conducted with six treatments and four replications. The details of the treatments are as follows:

T1- Regular watering at two days interval to the ‘Lanka jumbo’ groundnut cultivar – (Control).
T2- Moisture stress was given for 10 days to the ‘Lanka jumbo’ cultivar during the flowering stage.
T3--Regular watering at two days interval to the ‘Tissa’ groundnut cultivar – (Control).
T4 -Moisture stress was imposed for 10 days to the ‘Tissa’ cultivar during the flowering stage.
T5 - Regular watering at two days interval to the ‘Indi’ groundnut cultivar – (Control).
T6 -Moisture stress was given for 10 days to the ‘Indi’ cultivar during the flowering stage.

2.2. Chlorophyll contents

Five plants were randomly selected from each replicate of the treatments both from the stressed and control plants during the flowering stage at the 10^{th} day from the commencement of stress. A number of fresh forty leaves were randomly collected from these plants. These leaves were cut into pieces and washed with water and were blotted between sheets of filter papers. A quantity of 1 g of fresh leaf sample was weighed by an electronic balance and was crushed using mortar and pestle using 10 ml of 80% acetone (W/V).

The homogenate was then centrifuged (Heraeus Pico 17 microcentrifuge) at 5000 rpm for 10 minutes and the supernatant was collected. The residues were again washed with 80% acetone and were centrifuged. The process was repeated again and the final volume of the pooled supernatant was collected. The absorbance was read at 663, 646 and 750 nm wave lengths. The optical density of the chlorophyll extract was recorded by a spectrophotometer (BK-V1600 VIS) at the above wave lengths using 10mm cuvettes. The amount of chlorophyll present in the leaf extracts was estimated according to Smith and Benitez (1955) as follows:

mg ‘Chlorophyll a’ g^{-1} tissue = $\{12.7\ (D_{663}) - 2.69\ (D_{645}) \times V\} / 1000 \times W$
mg ‘Chlorophyll b’ g^{-1} tissue = $\{22.9\ (D_{645}) - 4.68\ (D_{663}) \times V\} / 1000 \times W$

Where,
D: Optical density reading of the chlorophyll extract at the specific wavelength
V: Final volume of the 80% acetone - chlorophyll extract
W: Fresh weight of the tissue (g)

2.3. Leaf area index

A number of six plants from each replicate of the treatments were randomly selected from each replicate on 10th day from commencement of stress. Leaf area was measured using a leaf area meter (LI-3100C). The LAI was calculated for each plant as the ratio of the total leaf area of the plant divided by the land area occupied by the plant. The leaf area index of control plants was measured in the same way soon after watering to field capacity.

2.4. Yield

A number five plants were randomly selected from each replicate of the treatments at the time of harvest and the pods were collected and the yield was determined.

2.5. Analysis of data

The data were statistically analyzed and the difference between treatments means was compared using DMRT.

3. Results and Discussion

3.1. General appearance of plants

The regularly watered plants of all the three cultivars showed well developed turgid leaves and canopy. During the flowering stage, regularly watered plants showed the highest number of flowers. During the pod development stage, the regularly watered plant canopies were well developed. Water stressed plants showed severely wilted and leathery leaves. All these cultivars of water stressed plants shed most of their flowers. The growth rate of stressed plants was lower. During the pod development stage, the water stressed plants showed lower number of pods

3.2. Soil moisture content

Soil moisture content of the stress pots is illustrated in Figure 3.1. During the flowering stage there was a steep decrease in the percentage water content. This was because at flowering stage most of the soil moisture would have been used for the flower development, peg formation and also soil water would have been lost gradually by evaporation and transpiration by plants.

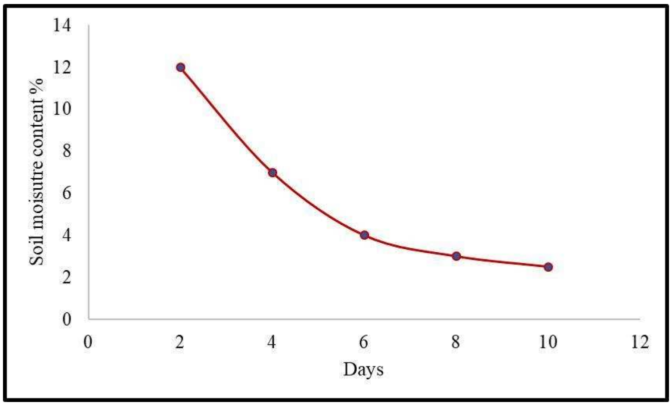

Fig. 1. Soil moisture characteristic curve of groundnut plants during the stress period (Flowering stage).

3.3. Chlorophyll contents

It was found that there were significant ($p<0.05$) differences between the treatments in the chlorophyll a, chlorophyll b values between the stress and control treatments during the flowering stage (Table 1). In the treatment where stress was experienced by plant during flowering stage for 10 days, the highest amount of chlorophylls a, b were found in cultivar 'Indi' and the lowest amounts were found in cultivar 'Tissa'. Water deficit stress significantly reduced the chlorophyll contents in all cultivars.

Water deficit stress imposed on the groundnut plants during the flowering stage destroys the chlorophyll and prevents its biosynthesis as well, which was reported by researchers in many crops, including peanut (Sharada and Naik 2011, Arjenaki et al., 2012). It was also reported that drought increased chlorophyll content in sesame at the initial stage and that later it remained unchanged (Mensah et al., 2006). Ability to synthesize more chlorophyll under water deficit condition at initial stage of growth is a good measure of the ability of groundnut genotypes to cope with drought stress during initial stages of growth (Arunyanark et al., 2008). Here, the tolerant cultivar 'indi' and 'Lanka Jumbo' showed highest chlorophyll content at flowering stage indicating their tolerance to water deficit stress.

Table 1. Effects of moisture stress during the flowering stage on chlorophylls a, b of selected groundnut (Arachis hypogaea L.) cultivars

Variety	Stress		Control	
	Chl. a (mgg^{-1})	Chl. b (mgg^{-1})	Chl. a (mgg^{-1})	Chl. b (mgg^{-1})
Lanka Jumbo	0.8 b	0.6 b	1.8 a	0.8 a
Tissa	0.5 c	0.4 c	1.6 b	0.7 b
Indi	1.0 a	0.8 a	1.8 a	0.9 a

*Values in the same column followed by the same letter do not differ significantly ($p< 0.05$)
*Values are the means of 20 plants in four replications

3.2 Leaf Area Index

It was found that there were significant ($p<0.05$) differences between treatments in the Leaf area index values between the stress and control treatments during the flowering stage (Table 2). In the treatment where stress was experienced by plant during flowering stage for 10 days, the highest Leaf Area Index was found in 'Indi' cultivar and lowest was found in 'Tissa' groundnut cultivar.

Table 2. Effects of moisture stress during the flowering stage on Leaf Area Index of selected groundnut (Arachis hypogaea L.) cultivars

Variety	Stress	Control
Lanka Jumbo	0.5 b	0.7 a
Tissa	0.3 c	0.6 b
Indi	0.6 a	0.8 a

*Values in the same column followed by the same letter do not differ significantly ($p< 0.05$)
*Values are the means of 20 plants in four replications

Results obtained by a group of workers including Choi et al. (2000) and Garg et al. (2001) pointed out diminished leaf area on account of moisture stress. Such diminished in leaf area was attributed to the negative effect of stress on the rate of cell elongation which resulted in leaves reduced in cell volume and cell number (Kawakami et al., 2006). Drought-induced reduction in leaf area is ascribed to suppression of leaf expansion through reduction in photosynthesis (Rucker et al., 1995). Data obtained from the study by Abdalla and El-Khoshiban (2007) on Triticium aestivum showed that there is a direct relationship between the severity of drought and leaf area on the treated plants of both varieties.

3.3 Yield

It was found that there were significant (p<0.05) differences between treatments in the yield between the stress and control treatments (Table 3). In the treatment where stress was experienced by plant during flowering stage for 10 days, the highest amount of yield was recorded in cultivar ‘Indi’ and lowest amounts were recorded in cultivar ‘Tissa’.

These results supported previous finding that pod yield were reduced when peanut was subjected to terminal drought (Boontang et al., 2010) and the reduction also varies among peanut genotypes. Prabawo et al. (1990) reported that irrigation applied before and/or after early pod filling stages increased pod yields of Spanish type groundnuts soil moisture stress at different growth stages. Suther and Patel (1992) found that pod yield was higher with 80% available soil water than with 20% available water. Between two stress treatment, stress given at flowering stage 18.45 % reduction in pod yield while, 30.63 % reduction due to stress imposed at pod development stage than no stress (Vagahsia et al., 2010).

Table 3. Effects of moisture stress during the flowering stage on yield of selected groundnut (Arachis hypogaea L.) cultivars

Variety	Stress	Control
Lanka Jumbo	0.7 b	2.3
Tissa	0.3 c	1.4
Indi	0.8 a	1.7

*Values in the same column followed by the same letter do not differ significantly (p< 0.05)
*Values are the means of 20 plants in four replications

4. Conclusions

It was concluded that flowering stage is the most critical stage to moisture stress and caused highest yield reduction in selected groundnut cultivars. ‘Indi’ groundnut cultivar was the most drought tolerant among the tested groundnut cultivars. Hence, ‘Indi’ cultivar could be suggested to have high stress tolerance and better yield than the rest grown in the sandy regosol of the Eastern Province. Frequency and quantity of irrigation thus could be adjusted properly so that less or no moisture stress is experienced by plants during the flowering stage in order to sustain the potential yield in the dry zone of Sri Lanka where water availability is Scarce. The stress tolerant cultivar could be used for crop management programmes.

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