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RESPONSE OF GROUNDNUT (*ARACHIS HYPOGAEA* L.) GENOTYPES TO PLANT GROWTH REGULATORS AND DROUGHT STRESS

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Abstract

The present study was carried out to investigate the physiological (relative water content) pod dry weight, pods plant^{-1}, pod yield (kg plot^{-1}), shelling (%), plant height and biochemical (endogenous ABA level) traits of peanut cultivar Swat Phalli-96 under drought stress. The result showed that drought stress significantly ($p<0.05$) reduced relative water content (RWC), pod dry weight, pods plant^{-1}, pod yield (kg plot^{-1}), shelling (%) and plant height. GA and IAA applied as seed treatment or foliar spray had no significant ($p >0.05$) effect on various parameters under drought stress conditions. However, foliar application of ABA (10^{-4} M) partially ameliorated the adverse effects of drought stress on growth and yield components. Foliar application of ABA to plants when subsequently exposed to drought stress resulted in elevated levels of endogenous ABA. The endogenous ABA levels in shoot increased earlier in response to applied ABA than that of root.

Introduction

Water shortage around the globe in general and Pakistan in particular has emphasized the need to improve water use efficiency of different crops including groundut. Water deficit, extreme temperatures and low atmospheric humidity lead to drought, which is one of the most limiting factors for better plant performance and higher crop yield (Bartels & Salamini, 2001; Szilgyi, 2003; Hirt & Shinozaki, 2003; Hamayun *et al.*, 2010; Khan *et al.*, 2011). Improved productivity under periodic drought stress is a major challenge for global agriculture. Increasing the yield of agricultural crops under drought conditions is a serious issue for plant scientists because of the (1). low heritability of the trait (2). the unpredictable nature of most periods of drought stress encountered in growing areas and (3). gaps in our understanding of drought biology (Bruce *et al.*, 2002; Gutterson & Zhang, 2004; Sharp *et al.*, 2004; Nelson *et al.*, 2007). Average losses of some major crop plants due to environmental stresses are estimated to be in the range of 50-80% of their genetically determined productivity and the highest proportion of yield losses can be directly attributed to drought stress. The challenge for our farmers and researchers is to find ways to increase the crop output unit^{-1} of water. Plants use various mechanisms to cope with changes in the environment. These include modification in root architecture, leaf morphology, physiological characteristics and others associated with the developmental biology. By selecting for these traits, it is possible to improve complex traits such as yield under stress conditions. Usually a combination of these attributes is present in crops that produce good yields under drought conditions. Under field conditions, drought severity, timing and duration vary from year to year and a cultivar which is successful in one year, might fail in another year. Significant potential exists for the improvement of crop productivity by selecting plants that are better equipped to cope with unfavorable environmental conditions, such as drought. One approach to improve crop performance is the selection of those genotypes that have improved yield during water deficit conditions.

Abscisic acid (ABA) plays an important role in abiotic stress including drought (Bakht *et al.*, 2006; Bakht *et al.*, 2011; Shafi *et al.*, 2011). Previous studies has shown that root-originated xylem sap ABA can move to reproductive structures and accumulate there to a high level under drought conditions in wheat crop (Liu *et al.*, 2003). This elevated ABA content in the crop reproductive structures had been thought to be involved in controlling kernel pod^{-1} abortion, presumably via inhibition of cell division in the young ovaries (Setter & Flannigan, 2001; Liu *et al.*, 2003). In addition, exogenous application of ABA to developed maize ovaries inhibits cell division in the embryo and endosperm, and this effect is probably due to depression of cell-cycle gene expression by high levels of ABA (Setter & Flannigan, 2001). Taken together, these studies suggested that drought induced increase in xylem sap (ABA) might affect expansion in growth of crop reproductive structure resulting in a weak sink intensity, which fails to attract assimilates from source organs and eventually leads to abortion. The present study was aimed to investigate the effect of seed and foliar application of different phytohormones on various groundnut genotypes under water stress conditions.

Materials and Methods

The present study was conducted to investigate the response of groundnut genotype Swat Phalli-96, to seed and foliar application of different growth regulators (Gibrrellic acid (GA), Indole-3-acetic acid (IAA), Abscisic acid (ABA) and induced drought stress. These experiments were carried out at Agriculture Research Institute Mingora, Swat KPK (1150 asl, 34^{o} 10' to 35^{o} 56' North latitude and 72^{o} 7' to 73^{o}0' East longitude) Pakistan using randomized complete block design (RCBD) having three replications. The seeds of groundnut cultivar Swat Phalli-96 were sown in earthen pots measuring 30 cm x 40 cm, containing soil and farmyard manure in the proportion of 3:1. Recommended agronomic practices were carried out uniformly for all the treatment. Seed were soaked in 10^{-4} M solution of different growth regulators viz., GA, IAA and ABA for 6 h prior to sowing. For control seeds were soaked in distilled water.

For foliar application, peanut plants were sprayed with GA, IAA and ABA having the same concentration used for seed soaking at 40 days after sowing. Plants were sprayed between 10.00-12.00 h. Pots were covered with aluminum foil during spraying to avoid contamination of soil with the applied growth-regulators/hormones. Drought stress was imposed at three critical growth stages i.e. 40 days after sowing (DAS; flowering initiation), 41-60 DAS (flowering and peg formation stage) and 61-80 DAS (pod development stage). Relative water content of the leaves was determined following the method of Weatherly (1950). Soil moisture was measured at the start, mid and end of each induced drought period (Fig. 1). Height of three plants in each treatment was taken from the ground to the tip. The length of 20 pods randomly selected in each treatment was measured. At maturity, plants were harvested and yield was calculated, whereas the harvested plants were dried till constant weight**.** Endogenous ABA level was determined according to Parry & Horgan (1991).

Statistical analysis: All data are presented as mean values of three replicates. Data were analyzed statistically for analysis of variance (ANOVA) following the method of Gomez & Gomez (1984). MSTATC computer software was used to carry out statistical analysis (Russel & Eisensmith, 1983). The significance of differences among means was compared by using Least Significant Difference (LSD) test (Steel &Torrie, 1997).

Results and Discussion

Plant growth and yield: No significant ($p>0.05$) effects of either seed soaking or foliar application of GA and IAA on any parameter under study were observed. Therefore, the present paper only presents the effects of foliar application of ABA. The relative water content (RWC) decreased in drought stressed plants at all stages of plant growth. However, the magnitude of the adverse effects of drought was less in plants treated with ABA. This pattern was consistent at all stages of plant growth. Maximum decrease was observed at 41-60 days after sowing (DAS) which is the critical period of drought stress (Fig. 2). Similar results have also been reported for groundnut, wheat and barley by Khan *et al*., (1998) and Liu *et al*., (2003). Dry weight of stem, leaves, peg and pods was significantly ($p<0.05$) affected by drought stress applied at different growth stages. Drought stress reduced 64% pod dry weight when compared with control. A decrease of 15% in pod dry weight was noted when drought stress was applied at 41-60 DAS compared with 21-40 DAS. When drought stressed plants were sprayed with ABA, there was an increase of 21% in pod dry weight compared with drought stressed plants alone (Fig. 3). It has been reported that wheat and other grain crops under water deficit during grain filling stage substantially affect grain weight (Rahman & Yoshida, 1985) due to early plant senescence, cessation of grain filling (Hossain *et al.,* 1990) and shortening of the grain filling period (Royo *et al*., 2000).

There was decrease of 20% in pods plant^{-1} when drought stress was applied at 41-60 DAS compared with 21-40 DAS. Foliar application of ABA to drought stressed plants increased pods plant^{-1} by 15% at 41-60 DAS and 12% at 61-80 DAS (Fig. 4). Drought stress reduced shelling percentage by 15% when compared with control. Application of ABA and imposition of drought stress showed an increase of 8% when compared with drought stressed plants and a decrease of 5% when compared with control (Fig. 5). Drought stress applied at 41-60 DAS was less detrimental to the production of haulm yield. A decrease of 5% in haulm yield was recorded when compared with the drought stress imposed at 61-80 DAS. It is interesting to note that stress applied at 41-60 DAS performed better with respect to haulm yield compared with stress applied at other growth stages of the groundnut plants. When drought stressed plants were sprayed with ABA, an increase of 15% in haulm yield was recorded compared with drought stress alone treatment (Fig. 6). Similar results are also reported by Rahman & Yoshida, (1985), Hossain *et al.,* (1990) and Royo *et al*., (2000). Drought stress at all growth stages was inhibitory to plant height when compared with the control. However, the application of ABA at all stress stages appeared to partially ameliorate the inhibitory effects of drought on plant height. Plant height was more when drought stress was applied at 41-60 DAS compared with drought stressed imposed at later growth stages (Table 1).

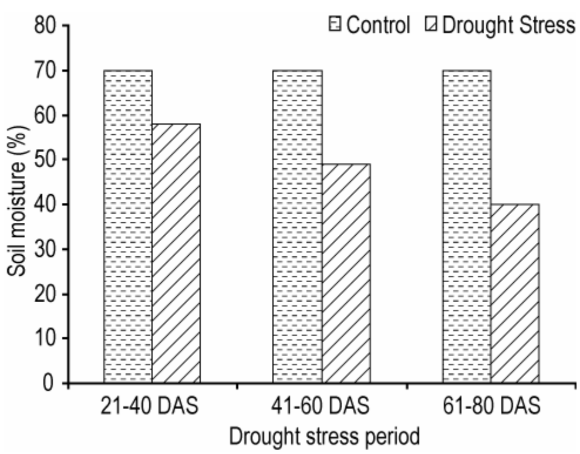

Fig. 1. Soil moisture (%) in pot as affected by different drought stress period.

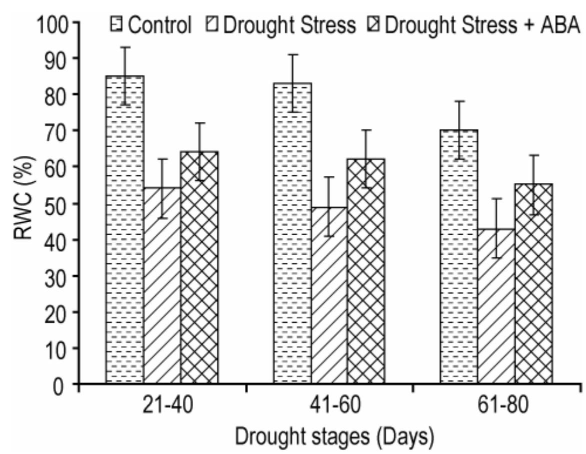

Fig. 2. Relative water content (%) in different drought stages as affected by drought stress and ABA application. The bar show ± LSD at $p<0.05$.

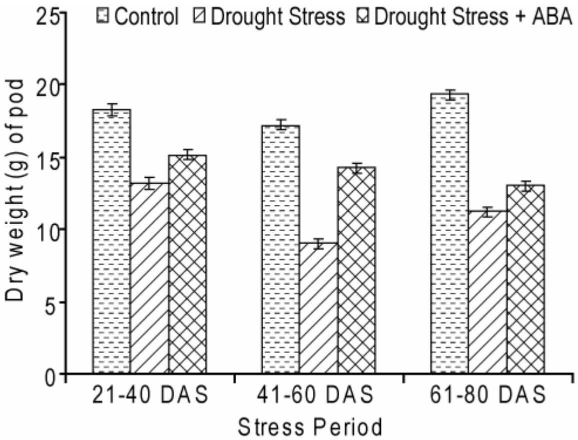

Fig. 3. Effect of drought stress and foliar application of ABA on dry weight of pod of groundnut variety Swat Phalli-96. The bar show ± 1 LSD at p<0.05.

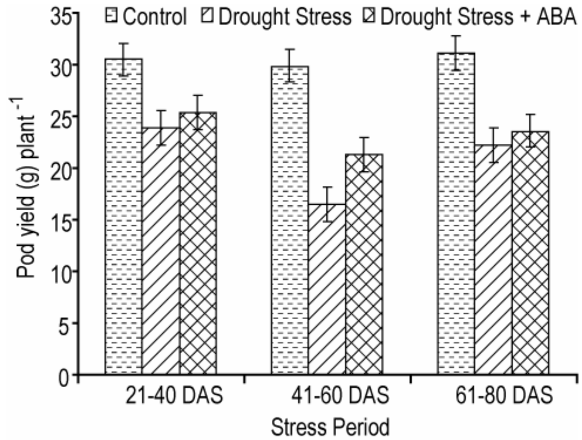

Fig. 4. Effect of drought stress and foliar application of ABA on pod yield (g) plant^{-1} of groundnut variety Swat Phalli-96. The bar show ± 1 LSD at p<0.05.

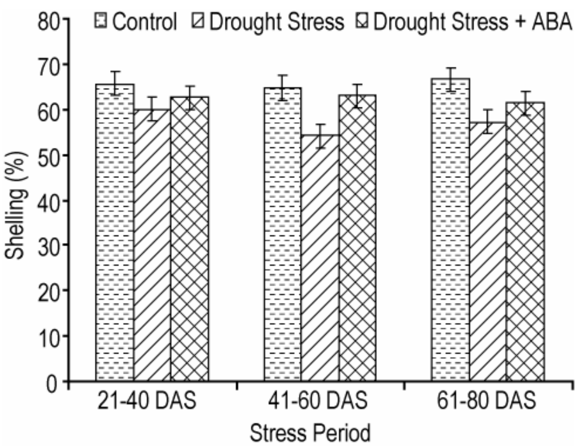

Fig. 5. Effect of drought stress and foliar application of ABA on shelling of groundnut variety Swat Phalli-96. The bar show ± LSD at p<0.05.

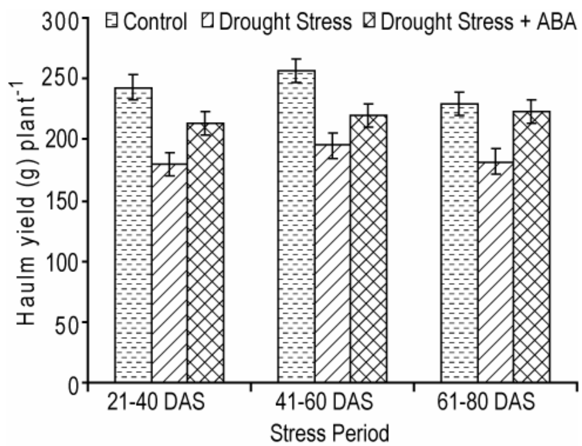

Fig. 6. Effect of drought stress and foliar application of ABA on haulm yield (g) plant^{-1} of groundnut variety Swat Phalli-96. The bar show ± 1 LSD at p<0.05.

Table 1. Plant height (cm) of groundnut variety Swat Phalli-96 as affected by drought stress and ABA application.

Treatment	Growth stages (days after sowing)			
	21-40 DAS	**41-60 DAS**	**61-80 DAS**	**Mean**
Control	37.10 b	47.10 a	35.93 b	38.18 a
Drought Stress	17.50 e	18.00 e	18.25 de	17.92 c
Drought stress + ABA	19.46 c-e	21.25 cd	22.23 c	20.98 b
Mean	24.68 b	26.92 a	25.47 ab	

Means followed by different letters are significantly different at p<0.05 using LSD test
LSD value for growth stages at p<0.05 = 1.186
LSD value for drought stress at p<0.05 = 1.186
LSD value for interactions at p<0.05 = 3.231

Endogenous ABA level: The data on endogenous ABA levels was collected from the plants exposed to drought stress at 41-60 DAS and applied with GA, IAA and ABA either as seed soaking or foliar spray. Data was recorded on 7, 14 and 21 days post treatment of drought stress and phytohormone application. The result indicated that only foliar application of ABA showed significant (p<0.05) effects on the endogenous ABA levels whereas the other treatments were non-significant (p>0.05). Therefore, for simplicity only results of the foliar application of ABA (10^{-4} M) are presented here.

The endogenous levels in the shoot tissues of control plants significantly (p>0.05) increased over a period of 21 days of measurements. Exposure of plants to drought stress induced the production of endogenous ABA resulting in nearly a 3-fold increase by day 21 when compared with control. ABA application on drought stressed resulted in 4-fold increase in endogenous ABA of shoot (Fig. 7). Similar results were also obtained when endogenous root ABA levels were measured (Fig. 8). Exposure of control plants to drought stress resulted in progressive and significant ($p<0.05$) increase in endogenous ABA levels by 3-fold at day 21. Endogenous levels of ABA in shoot was significantly ($p<0.05$) affected by ABA application in time dependent manner. The difference in increase of endogenous ABA levels of shoot tissue was more pronounced at day 7, 14 and 21 when drought stressed and drought stressed + ABA treated plants were compared (Fig. 7). The difference in endogenous shoot ABA levels between drought stressed and drought stressed + ABA treated plants were 58.18% at day 7 when compared with 88.61% at day 14 and 92.04% at day 21. The endogenous ABA levels in drought stressed plants was non-significantly ($p>0.05$) different from the drought stressed + ABA treated plants at day 7 and 14 while by day 21, there was significant ($p<0.05$) difference between the drought stressed and drought stressed + ABA treated plants for root endogenous ABA levels (Fig. 8). Application of ABA prior to the onset of drought stress has been reported to reduce damage to tissue (Setter & Flannigan, 2001; Hansen & Doerffling, 2003; Bartels, 2004).

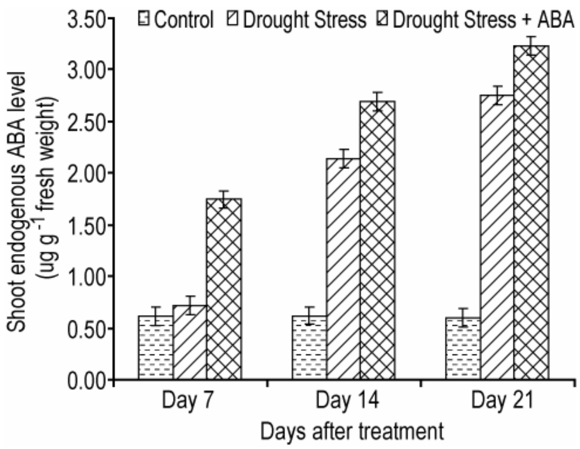

Fig. 7. Effect of drought stress and foliar application of ABA on shoot endogenous ABA level (µg g^{-1} fresh weight). The bar show ± 1 LSD at $p<0.05$.

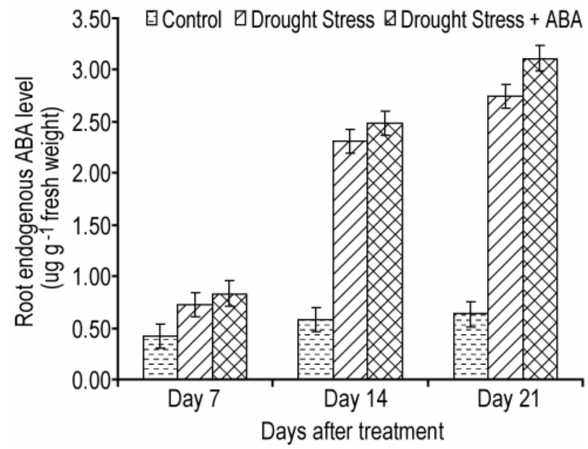

Fig. 8. Effect of drought stress and foliar application of ABA on root endogenous ABA level (µg g^{-1} fresh weight). The bar show ± 1 LSD at $p<0.05$.

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