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Changes in carbohydrate status during water stress in groundnut (*Arachis hypogaea L.*)

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ABSTRACT

The effect of water stress on carbohydrate metabolism along with dry matter and relative water content (RWC) was studied in one month old healthy groundnut cultivar K-134 at three levels (mild, moderate and severe) of water stress for a duration of eight days, and the data were collected at different time intervals (days-4 and 8) after induction of stress. The patterns of leaf dry matter and RWC ran in parallel and showed significant decrease at moderate and severe water stress levels on all days of sampling. The activity of the amylase increased in the leaves of the stressed plants with a simultaneous decrease in starch content and an increase in the levels of reducing and non-reducing sugars. The relative accumulation or reduction of these parameters were dependent on stress severity and duration.

KEYWORDS | Groundnut; Dry weight; RWC; Drought tolerance; Sugars

Introduction

Abiotic stresses represent the most limiting factors for plant productivity and play a major role in the distribution of plant species across different types of environments. Among all abiotic stresses drought is a major factor that limits the agricultural crop production. Plant experience drought stress either when the water supplies to roots become difficult or when the transpiration rate becomes very high. These conditions often coincide under arid and semi-arid climates. Generally pulse crops which are cultivated in semi arid regions dependent on current rainfall are suffering from intermittent drought stress during vegetative or reproductive growth period. The ability of the whole plant to respond and survive cellular water deficit depends on whole- plant mechanisms that can integrate the cellular responses (Bray, 1997). The maintenance of internal water levels is an important mechanism for survival of plants during water stress. It is the degree to which the plant can withstand the water deficit without perceptible growth inhibition and yield loss that constitutes its drought tolerance. Plants respond to drought by initiating a number of developmental, physiological, biochemical and molecular changes. Understanding the mechanisms underlying those different responses can support the design of new management tools and genotypes for modern precision agriculture. Drought is one of the major abiotic stress affecting yield and quality of rainfed peanut worldwide, where about 70% of the peanuts are grown (Reddy et al., 2003). Hence, there is need to develop drought resistant cultivars that could tolerate the effects of eater deficit conditions. The purpose of present study was to contribute a better understanding of the physiological responses of groundnut plants to drought stress. The present study was undertaken to study carbohydrate status and other allied physiological aspects in groundnut under well watered and water stress conditions

Material and methods

Seeds of groundnut (Arachis hypogaea L.) cultivar (K-134) were sown in earthen –pots containing 8kg of red loamy soil and farm yard manure (3:1 proportion). Pots were maintained for one month in the departmental botanical garden under natural photoperiod of 10-12 h and temperature 28 4 0C. One-month-old plants were then divided into four-sets and arranged in randomized complete black design. One set of pots received water daily to field capacity and served as control (100 %). The remaining three sets received water daily to 75, 50 and 25 % of the field capacity and were characterized as mild, moderate and severe stresses, respectively. After induction of stress, the pots were maintained for another 8 days and the experimental data were collected at different time intervals i.e. on day-4 and 8. The plants were washed with deionized water and blotted dry with filter paper. For the determination of dry mass, the leaves were dried at 80o C in a hot air oven until a constant mass was formed. RWC of leaf discs were measured in both control and stressed plants according to Turner (1981). Leaf samples were collected on day-4 and 8 after stress induction for analysis of various parameters. Carbohydrate fractions were extracted with 80% ethanol according to the method of Highkin and Frankel (1962). The reducing sugars were estimated by Nelson's method (1944) as modified by Somogyi (1952). The non-reducing sugars were estimated by following the method of Scott (1960) from the alcoholic extract. Starch was estimated by following the method of McCready et al., (1960). Amylase was assayed according to the method of Sridhar and Ou (1972). The data were analyzed statistically using Duncan's multiple range (DMR) test to drive significance (Duncan, 1955).

Result and Discussion

Effect of water stress on physiological parameters are presented in Table 1. From the table it is clear that the RWC decreased at all stress regimes and on all days of sampling. The decrease was significant in all stress treatments except in mild stress treatments on the day-4 and 8. It remained nearly constant in control plants of the cultivar throughout the experimentation. The degree of decrease in RWC of stressed leaves increased with increase in stress intensity and also on stress duration. The decline in RWC was reported by several investigators under stress conditions in groundnut (Madhusudan, et al., 2002; Akcay et al., 2010). The present study also reveals the maintenance of higher RWC under prolonged mild and moderate stress treatments indicates cultivar adaptive nature to that stage. Leaf dry mass was decreased in water stressed plants of groundnut when compared to controls. Drought treatment produced a marked decrease in leaf RWC in mild and moderate stress conditions on day-4 and 8, paralleled by a substantial decrease in dry weight of leaves of the cultivar. These results confirm previous findings (Madhusudan, et al., 2002). It is suggested that the relative water content could help the tolerant cultivar to perform physio-chemical processes more efficiently leading to the maintenance better dry matter. Water stress affect many aspects of carbohydrate metabolism besides photosynthesis. Osmolyte accumulation in plant cells results in a decrease of cell osmotic potential and thus in maintenance of water absorption and cell turgor pressure, contributing to sustaining physiological processes, such as stomatal opening, photosynthesis and expansion growth (Subbarao et al., 2000). Water-soluble carbohydrates are the major substrates for leaf growth and have been indicated as potential

osmoregulators/osmoprotection. The analysis of carbohydrate fraction particularly sugars would provide information on the contribution of sugars in osmotic adjustment during drought stress. The leaf starch content in the cultivar decreased at all stress regimes and on all days of sampling. However, the decrease was marginal in mild stress, while at moderate and severe stress the starch decreased remarkably. The activity of amylase was significantly increased at all stress regimes and on all days of sampling except at mild stress treatment on day-4. Reducing sugar content in the leaves of the cultivar was significantly elevated throughout the experimentation, but not at mild stress treatment on day-4. During day-8, the reducing sugar content was significantly increased at all stress levels. The non-reducing sugar content was significantly increased in the cultivar at all levels of stress and on all days of sampling. In the present study, an increase in the sugar levels (reducing and non reducing sugars) was observed under stress. Similar results were also reported by several investigators under salt and water stress conditions (Reddy et al., 1990; Upadhyaya et al., 2008), and the increased levels of sugars have been proposed to be involved in the maintenance of turgor (Upadhyaya et al., 2008). Slow development of water deficit may induce osmotic adjustment in some plant species resulting in the maintenance of cell turgor at low water potential during drought. Besides possible osmotic roles, the availability and inter organ transport of sugars apparently play several other important regulatory functions in stressed plants. The decrease in starch content and simultaneous elevation in sugar pool under stress conditions in the present study could be explained due to accelerated hydrolysis by the enzyme amylase. Similar reports of accelerated hydrolysis at the expense of starch during drought stress conditions has been reported (Reddy et al., 1990). The shift in carbon partitioning from non-soluble carbohydrate (starch) to soluble carbohydrates (Chaves, 1991) could greatly contribute to osmotic adjustment capabilities by increasing glucose, fructose, sorbitol etc. Soluble sugars played a vital role in desiccation tolerance and several studies have attempted to relate the magnitude of changes in soluble carbohydrates to drought tolerance (Ashraf and Tufail, 1995). Since tolerance must depend on the energy status of cells in which appropriate responses are induced, many tissues of stressed plants are likely to have an increased demand for rapidly metabolizable carbohydrate. This must be satisfied because a likely decrease in carbon fixation and increased diversion of carbon from growth or storage to osmolyte synthesis. Soluble sugars are frequently associated with active osmotic adjustment. Further, antioxidant and free radical scavenging properties were also attached to the accumulated sugars (Zhu, 2001).

Table 1. Dry weight (DW), Relative water content (RWC) , Total starch, Reducing sugars, Non reducing sugars, and Activity of amylase in leaves of control and water stressed groundnut cultivar K-134, on day-4 and 8 after induction of water stress.

Parameters	Day	Control	Mild	Moderate	Severe
DW of Leaf (g plant-1)	04	0.342c (100)	0.342c (100)	0.342c (100)	0.278a (81.28)
	08	0.506c (100)	0.506c (100)	0.506c (100)	0.347a (68.57)
RWC (%)	04	90.52c	84.82c	74.02b	62.17a
	08	89.72c	83.19c	69.76b	54.74a
Starch (mg g-1 DW)	04	62.98c (100)	61.33c (97.38)	56.42b (89.59)	51.84a (82.32)
	08	64.02c (100)	60.39c (94.34)	53.17b (83.06)	48.74a (76.14)
Reducing sugars (mg g-1 DW)	04	9.15c (100)	9.89c (108.04)	11.27b (123.19)	13.24a (144.76)
	08	9.68c (100)	11.28c (116.49)	13.94b (144.02)	16.78a (173.31
Non reducing sugars (mg g-1 DW)	04	24.06d (100)	26.64c (109.98)	30.95b (128.63)	37.67a (156.58)
	08	24.89d (100)	30.73c (123.45)	38.35b (154.07)	48.56a (195.09)
Amylase (µg reducing sugar mg-1 protein min-1)	04	2.06c (100)	2.19c (106.54)	2.82b (137.06)	3.23a (156.62)
	08	2.18d (100)	2.71c (124.28)	3.26b (149.37)	4.31a (197.54)

The mean values (n=5) in a row followed by different letter for each plant species are significantly different (P≤0.05) according to Duncan's multiple range (DMR) test. Figures in parentheses represent per cent of control

Conclusions

It may be concluded that osmotic adjustment occurs in groundnut at mild water stress resulting in the maintenance of turgor, there by the carbohydrate status and finally the dry matter production. However, moderate and severe stress inhibited the levels of the end products of carbohydrate as evident from decrease in dry matter production.

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