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NUTRIENT ACQUISITION IN DIFFERENTIALLY ADAPTED POPULATIONS OF *CYNODON DACTYLON* (L.) PERS. AND *CENCHRUS CILIARIS* L. UNDER DROUGHT STRESS

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Abstract

The water famine is one of the major factors for converting huge cultivated land into deserts all over the world. Likewise, in Pakistan, Salt Range due to low rainfall is also converting into uncultivable area. In the present study, a greenhouse experiment was conducted at University of Agriculture, Faisalabad, to assess the extent of water stress toleranc in terms of mineral nutrient status. Two populations of each of two grass species i.e., *Cynodon dactylon* (L.) Pers. and *Cenchrus ciliaris* L. were used in this experiment. One population of each of two grass species was collected from drought-hit area ‘‘Salt Range’’ and other from often irrigated Faisalabad. Each population of these of grass species were subjected to three different levels of water stress (control, 75% and 50% of field capacity. Imposition of water stress markedly decreased the shoot fresh and dry biomasses, shoot, P, N and Ca^{2+}. However, populations of both grasses collected from the Salt Range were better in growth than Faisalabad region. Each population of both grasses collected from Salt Range accumulated high K^+, Ca^{2+}, N and P concentrations. The higher growth of the Salt Range populations of both grass species could be related to the greater accumulation of K^+, N, and Ca^{2+} in the shoots as compared with the populations from Faisalabad.

Introduction

Drought stress is one of the major factors for the reduction in agricultural productivity in the majority of regions of the world, particularly in the arid and semi arid regions (Boyer, 1982; Ashraf, 1994; Bajaj *et al*., 1999). It is now known that extent of drought tolerance varies from species to species in almost all plant species (Lin *et al.*, 2006). Although, the general effects of drought on plant growth are quite well known, the primary effects of water deficit at the biochemical and molecular levels are not well understood (Chaves *et al*., 2003, Zivcak *et al.*, 2008; Jaleel *et al*., 2008).

For making the crops water stress tolerant, understanding about plant responses to water-limited environment is of great importance. Plant tolerance to drought results from both morphological adaptation and responses at the biochemical and genetic levels (Levitt, 1972). The adverse effects of drought stress on plant growth and development may be due to ionic imbalance (Kidambi *et al.,* 1990), alteration in different metabolic activities of plants (Ashraf, 1994; 2004; Ashraf & O’Leary, 1996; Lawlor & Cornic, 2002), inhibition of enzymatic activities (Ashraf *et al*., 1995), disturbances in solute accumulation (Khan *et al.,* 1999) and alteration in nutrient and water acquisition (Agnew & Warren, 1996).

Naturally occurring drought prone areas impose a considerable selection pressure on the plant species occurring there and selectively allow some of plant populations to grow

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and produce offspring there. Salt Range located in Pakistan lies between 71° 00'-74° 00 east and 32° 10'- 33° 15' north with an area of about 10529 km^2. This site is unproductive due to low rainfall and brackish ground water as well as most areas therein are rich in salinity (Afzal *et al*., 1999; Ahmad *et al*., 2002). Thus, the plant species inhabiting the Salt Range have been experiencing severe drought and saline conditions since the time they started growing there. It is expected that the populations of different species of the site have evolved drought and salinity tolerance in view of the time span they have been inhabiting there.

Among the diverse consequences of drought, restricted nutrient uptake is a common phenomenon (Agnew & Warren, 1996). It has been suggested that under drought stress, accumulation of mineral nutrients such as P, N, K^+, and Ca^{2+} may have a role in drought tolerance as has been observed in soybean (Samarah *et al*., 2004). Water stress generally increases K^+ concentration especially under low phosphorus levels (Premachandra *et al*., 1990). Similarly, under water stress, Tanguilig *et al*. (1987) also reported increased uptake of K^+ in maize and wheat (Yasin *et al*., 1993; Ashraf *et al*., 1998). The decrease in N concentration due to water stress has been reported in various crops including wheat (McDonald & Davies, 1996; Singh & Usha, 2003), in soybean and rice (Tanguilig *et al*., 1987) and in maize (Premachandra *et al*., 1990). On the other hand, Sarwar *et al*. (1991) studied the response of different wheat varieties to water stress and reported significant increase in N content under water stress. Ghoulam *et al.* (2002) reported that sugar beet plants accumulate more potassium, sodium and chloride in the leaves than roots, which are effective in osmotic adjustment induced by drought stress.

In the present study, nutrient status of differently adapted populations of *Cynodon dactylon* and *Cenchrus ciliaris* was investigated so as to find out the effects of varying water stress levels on the pattern of nutrient accumulation and its role in the drought tolerance of each population of both grass species.

Materials and Methods

Two potential drought tolerant grasses, *Cynodon dactylon* (L.) Pers. (Bermuda grass locally called Khabbal grass or Dhoob grass) was collected from Ucchali lake (saline area) and the *Cenchrus ciliaris* L. (Buffel grass, locally called Anjan ghas) was collected from Kallar Kahar (drought-hit area) of the Salt Range. For comparison, ecotypes of both species were collected from the fertile and well irrigated area from the Faisalabad region. A pot experiment was conducted in the Botanic Garden of the University of Agriculture Faisalabad, during April to August 2005. The average day and night temperatures were 39.2 ± 4 ^oC and 23.5 ± 5 ^oC, respectively. The relative humidity ranged from 31.6 to 65.8 %, and daylength from 11-12 h. Small ramets of uniform size of these grasses from two different habitats (Salt Range and Faisalabad) were transplanted in to plastic pots (20 cm diameter and 24 cm depth) containing 8 kg dry sandy loam soil. The saturation percentage of the soil used was 32 and pH, 8.65. The plants were allowed to establish for 88 days before the start of water deficit conditions. There were three drought stress treatments (control, 75% or 50% of field capacity). Before the start of drought stress, plants were clipped so as to maintain uniform plant size. Plants were harvested, 30 days after the start of drought treatments. Plants were uprooted carefully and washed with distilled water. Plant samples were dried in an oven at 65 ^oC to constant dry weight. Plant fresh and dry biomass of each population of both species was recorded.

Determination of mineral elements: The dried ground shoot or root material (0.15 g each) was digested with sulphuric acid and hydrogen peroxide mixture following Wolf (1982). The volume of each digest was made up to 50 mL with distilled water, filtered and used for the determination of mineral elements. Cations such as Na^+, K^+ and Ca^{2+} were determined with a flame photometer (Jenway, PFP-7). Nitrogen was estimated by the micro-Kjeldhal's method (Bremner, 1965) and phosphorus (P) spectrophotometrically following Jackson (1962).

Statistical analysis of data: The data for each variable were subjected to an analysis of variance using the COSTAT v 6.3, statistical software (Cohort Software, Berkeley, California). The mean values were compared with the least significance difference test following Snedecor & Cochran (1980).

Results and Discussion

A significant reduction in fresh and dry biomass of two populations of each of two grass species i.e., *C. dactylon* and *C. ciliaris* was observed when 88-day old plants were subjected to water stress for a period of 30 days. However, while comparing the populations on percent of control basis, it is evident that each population from the Salt Range was significantly higher than its respective one from Faisalabad in percent plant fresh and dry biomass (Table 1; Fig. 1). On the basis of mean plant fresh and dry biomass it was not possible to differentiate the populations of each species. Thus, the populations were compared on percent of control basis. These results are in agreement with some earlier investigations in which it was observed that water stress markedly reduced the growth of sugar beet (Bloch *et al*., 2006), wheat (Passioura, 2006), and maize (Ashraf *et al.*, 2007). Furthermore, genetic variation for drought tolerance was observed among various grass species (Ashraf *et al*., 1986) and in different maize cultivars (Ashraf *et al.*, 2007) under drought stress.

Pattern of shoot and root Na^+ accumulation was non-significant in each population of both grasses. Likewise, a non-significant effect of drought was observed on shoot and root Na^+ and K^+ concentration however, Na^+ was significantly greater in *C. ciliaris* than that in *C. dactylon* (Table 1; Fig. 1). It was prominent that populations from the Salt Range accumulated greater amount of K^+ than those collected from Faisalabad (Table 1; Fig. 1). It is now evident that macronutrients such as N, P, K^+, and Ca^{2+} are essentially required for the regulation of a multitude of phenomena such as the activities of enzymes, protein synthesis, integrity of cell wall and plasma membrane, and as components of proteins, photosynthetic protein complexes, photosynthetic pigments, RNA and DNA (Taiz & Zeiger, 2002). Potassium in plants in the form of cation (K^+) plays a vital role in regulation of the osmotic adjustment by lowering osmotic potential of the cells. It has been reported that water stress generally increased the K^+ concentration especially under low phosphorus levels (Premachandra *et al*., 1990). Similarly, under water stress, Tanguilig *et al*. (1987) also reported increased uptake of K^+ in maize. Increased K^+ uptake in maize suggests that under water-stress conditions, K^+ is absorbed preferably to N and P. Sinha (1978) and Khondaker *et al*. (1983) observed that drought tolerant varieties can accumulate more K^+ as compared to the susceptible varieties. Water stress also increased K^+ concentration in wheat genotypes (Yasin *et al*., 1993; Ashraf *et al*., 1998). Soil moisture influences both the diffusion of K^+ in the soil and plant root growth

Table: 1 Mean squares from analyses of variance of data for growth and different ions of different populations of *Cynodon dactylon* and *Cenchrus ciliaris* when 88 day-old plants were subjected to different water deficit conditions for 30 days.

Source of variation	Degrees of freedom	Plant fresh biomass	Plant dry biomass	Shoot Na^+	Root Na^+
Drought (D)	2	4554.9***	1481.6***	2.938ns	1.179ns
Populations (Pop)	1	141.0ns	0.01ns	1.484ns	4.687ns
Species (Sp)	1	4441.7***	2145.8***	315.6***	2.520ns
D x Pop	2	129.6ns	158.7*	3.344ns	0.248ns
D x Sp	2	174.8ns	71.97ns	4.705ns	4.457*
Pop x Sp	1	126.04ns	96.42ns	0.374ns	0.01ns
D x Pop x Sp	2	136.7ns	144.9*	2.135ns	3.119ns
Error	36	77.41	37.64	2.126	1.288
		Shoot K^+	**Root K^+**	**Shoot P**	**Root P**
Drought (D)	2	2.844ns	3.441ns	5.309*	4.861*
Populations (Pop)	1	41.38***	4.606*	0.007ns	5.494*
Species (Sp)	1	3.281ns	0.646ns	14.47***	63.71***
D x Pop	2	0.711ns	0.300ns	6.463**	1.962ns
D x Sp	2	4.00**	4.998*	1.695ns	6.692**
Pop x Sp	1	18.812**	0.037ns	0.017ns	4.095ns
D x Pop x Sp	2	3.091ns	0.249ns	0.519ns	1.368ns
Error	36	3.091	1.075	1.045	1.0248
		Shoot N	**Root N**	**Shoot Ca^{2+}**	**Root Ca^{2+}**
Drought (D)	2	51.701**	13.13ns	13.51*	0.029ns
Populations (Pop)	1	56.16**	3.57ns	0.502ns	0.066ns
Species (Sp)	1	6.09ns	3.74ns	21.346*	0.74ns
D x Pop	2	23.84ns	19.98*	1.657ns	9.147***
D x Sp	2	45.93**	11.75ns	17.968**	1.468ns
Pop x Sp	1	19.76ns	8.24ns	2.079ns	0.016ns
D x Pop x Sp	2	19.49ns	13.44ns	3.398ns	2.542*
Error	36	7.377	5.803	3.106	0.668

*, **, *** = significant at 0.05, 0.01, 0.001 levels, respectively, ns = non-significant.

(Alam, 1994). Khan *et al*. (1999) reported K^+ as the major osmotic contributor in wheat genotypes that plays a major role in osmoregulation under water deficit conditions.

In the present work, reduction in shoot and root P concentration was observed due to drought stress and the most effective level of drought stress was 50% of field capacity. However, populations collected from the Salt Range were better in root P. Alam (1994) reported that phosphorous deficiency could be one of the earliest effects of mild to moderate levels of water stress. Its uptake decreases with decreasing soil moisture in different crops e.g., in pepper (Turner, 1985), and wheat (Khan *et al*., 1994; Ashraf *et al*., 1998). In contrast, Kidambi *et al*. (1990) reported that P uptake was not influenced in alfalfa and rainfoin by water stress.

A considerable increase in shoot Ca^{2+} while a decrease in shoot N was observed in all populations of both grasses at different water stress levels. Inconsistent increase or decrease was observed at 50% of field capacity. However, both populations collected from the Salt Range were higher in shoot N and Ca^{2+} than those from Faisalabad (Table 1; Fig. 2). An increase in Ca^{2+} concentration with decreasing soil moisture supply in alfalfa and soinfoin (*Onobrychis viciifolia*) was observed by Kidambi *et al*. (1990). On the other hand, reduction in Ca^{2+} concentration under water stress in wheat genotypes has also been reported (Yasin *et al*., 1993; Khan *et al*., 1994; Ashraf *et al*., 1998). An increase in cytosolic Ca^{2+}, as a second messenger, might induce further physiological

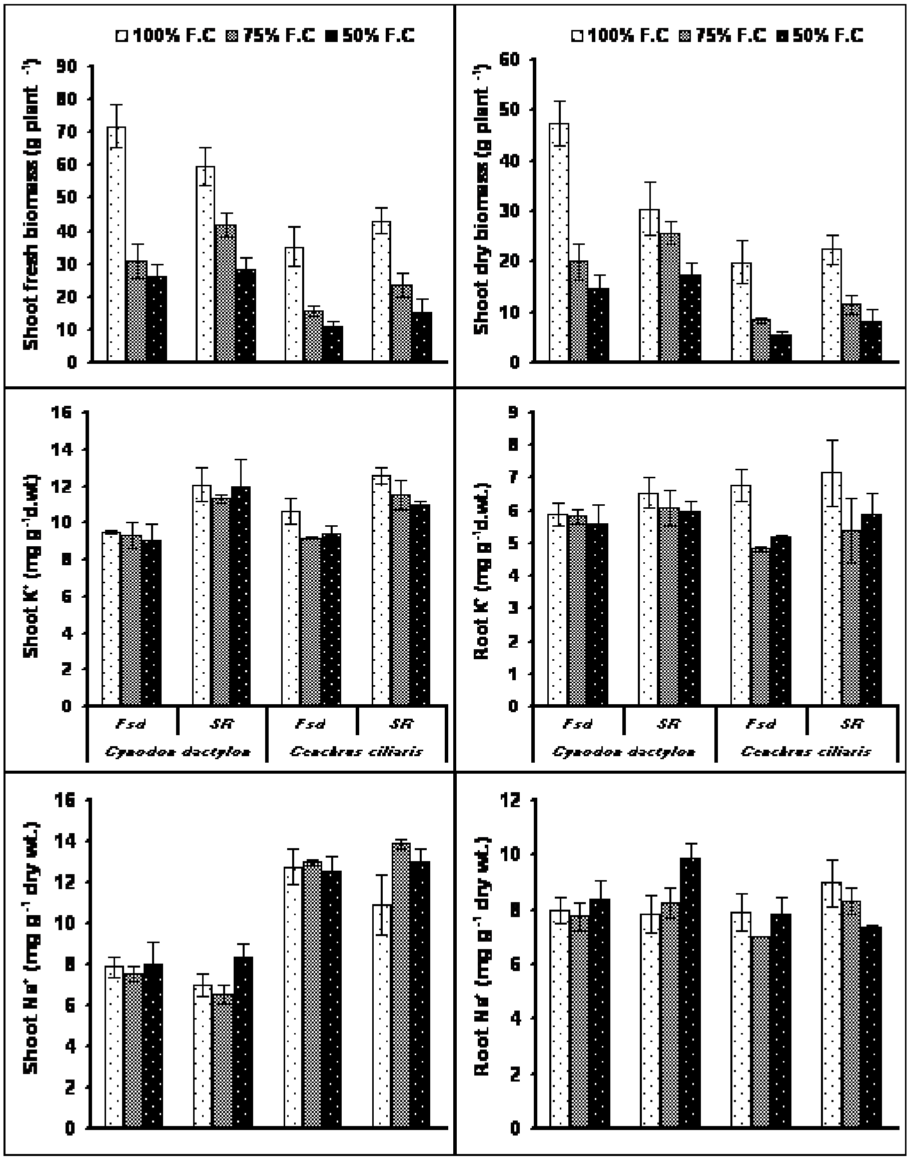

Fig. 1 Fresh and dry shoot biomass and shoot and root Na^+ and K^+ concentrations of different populations of *Cynodon dactylon* (L.) Pers. and *Cenchrus ciliaris* L. when 88-day old plants were subjected to well-watered or water deficit conditions for 30 days.

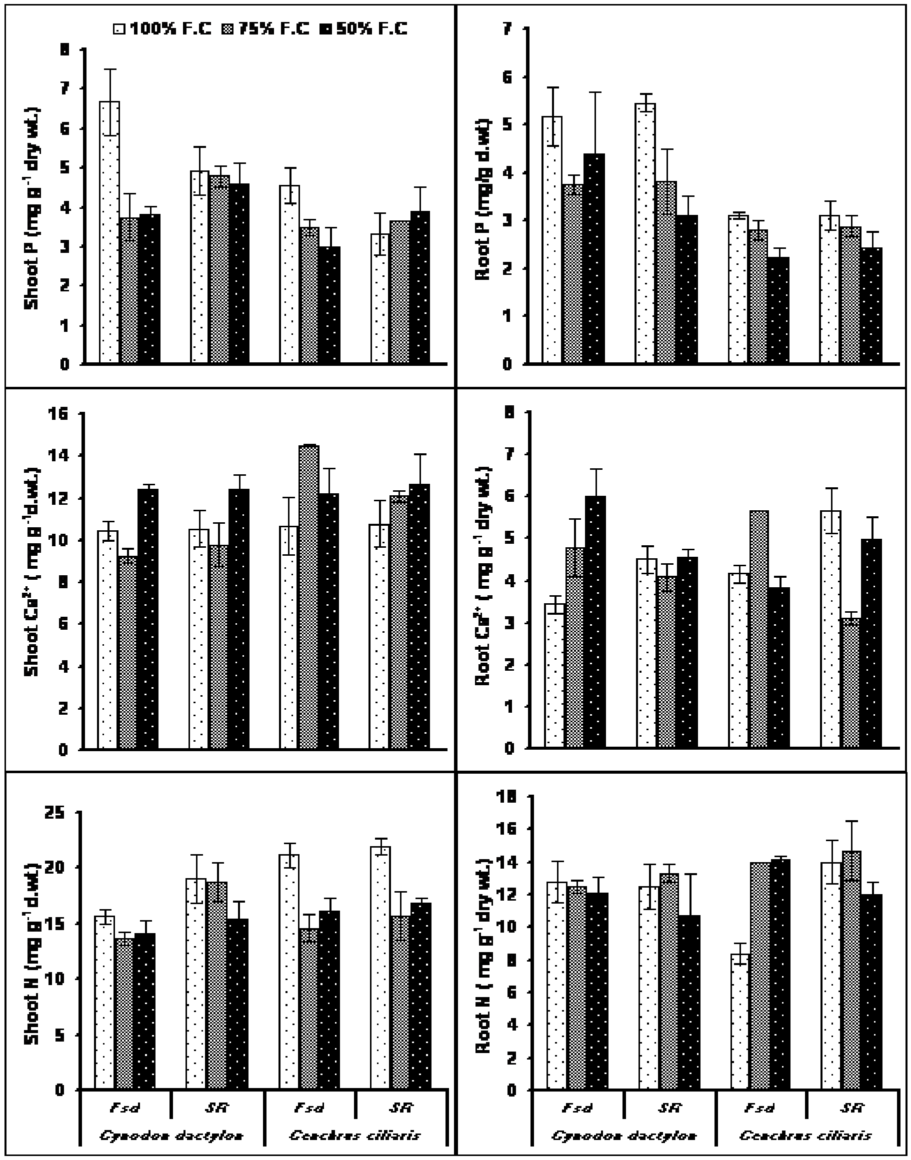

Fig. 2 Shoot and root P, Ca^{2+} and N concentrations of different populations of *Cynodon dactylon* and *Cenchrus ciliaris* when 88-day old plants were subjected to well-watered or water deficit conditions for 30 days.

responses including expression of osmotic responsive genes (Pardo *et al*., 1998). Tahir (1990) generally recorded an increase in N concentration under different moisture regimes. The decrease in N concentration due to water stress has been reported in different crops including wheat (Khondaker *et al*., 1983; Morgan & Condon, 1986;

McDonald & Davies, 1996; Singh & Usha, 2003), soybean and rice (Tanguilig *et al*., 1987), and maize (Premachandra *et al*., 1990). In conclusion, the higher growth of the Salt Range populations of both grass species could be related to the greater accumulation of K^+, N, and Ca^{2+} in the shoots as compared with the populations from Faisalabad.

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