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Effect of salt stress on carbohydrate contents in four grass species

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ABSTRACT

Salinity is one of the major abiotic stresses that adversely affect crop productivity and quality with increasing impact on the socio-economic fabric and health, especially of the farming communities. Carbohydrates play numerous roles in living organisms, such as the storage and transport of energy and as a part of structural components. In the present investigation seedlings of *Cymbopogon nardus* (L.) Rendle; *Pennisetum alopecuroides* (L.) Spreng var. Mourdy and *Vetiveria zizanioides* (L.) Nash were treated with increasing concentrations of Sodium chloride (25, 50, and 100, 200 and 300 mM). It is found that the amount of soluble sugars in the leaves was increased at lower levels of salinity. The starch content in the leaves of all grass species was greatly influenced by salinity stress. It is evident that the starch content of the leaves of all the four grasses is increased with increasing the levels of salinity upto 100 mM NaCl. Maximum accumulation, 46.10% over control (100 mM) was observed in *Cymbopogon nardus while* in *Cynodon dactylon* it was decreased initially and then increased by 1.31% (100 mM) only. All the species showed a drastic reduction in starch content under the influence of higher levels of salinity stress. The details of the investigation carried out are discussed in the paper.

KEYWORDS

Carbohydrates;
Cymbopogon nardus;
Cynodon dactylon;
Pennisetum alopecuroides;
Vetiveria zizanioides;
Salinity.

INTRODUCTION

Abiotic stress is the negative impact of non-living factors on the living organisms in a specific environment. It is well established that abiotic stress is the most harmful factor concerning the growth and productivity of crops worldwide. Salinity is one of the major abiotic stresses that adversely affect crop productivity and quality[16,19] with increasing impact on the socio-economic fabric and health, especially of the farming communities. Salinity is a general term used to describe the presence of elevated levels of different salts such as sodium chloride, magnesium and calcium sulphates and bicarbonates in soil and water.

Sehgal and Abrol[10] report that 187.2 mha area in India is degraded, of which 162.4 mha is degraded by water and wind erosion and 21.7 mha by salinity and water logging. Statistics about the extent of salt affected areas vary according to authors, but estimates are in general close to one billion hectares, representing about 6% of the earth's continental extent. In addition to these naturally salt affected areas, about 77 mha have been salinised by human activities[6] Based on the FAO[8] soil map of the world, the total area of saline soils is 397 mha and of sodic soils is 434 mha at global level. Of the current 230 mha of irrigated land, 45 mha are salt-affected soils (19.5%) and of the almost 1500 mha of dryland agriculture, 32 mha are salt-affected soils (2.1%) to varying degrees by human-induced processes.

The United States Salinity Laboratory Staff[20] defined a saline soil as one having electrical conductivity of saturation extract of soil greater than 4 mS cm^{-1} or equivalent to approximately 40 meq $l^{-1}$and an exchangeable sodium percentage less than15%. Usually, pH of saline soils remains below 8.5. Salinisation is the result of human activities such as introduction of irrigation without proper drainage system, industrial effluents and overuse of fertilisers, removal of natural plant cover and flooding with salt rich waters, high watertable and the use of poor quality groundwater.

Salinity puts various problems to the plants either at the population, organism or even at the molecular level. Physiologically and genetically salt tolerance is a complex among the variety of plants with a wide range of adaptations in halophytes and less tolerant plants[18]. Tolerance to high soil (Na^+) involves processes in many different parts of the plant and is manifested in a wide range of specialisations at disparate levels of organisation, such as gross morphology, membrane transport, biochemistry and gene transcription. Along with this, multiple adaptations to high (Na^+) operate concurrently within a particular plant and mechanisms of tolerance show a large taxonomic variation[12]. Carbohydrates play numerous roles in living organisms, such as the storage and transport of energy (starch, glycogen) and as a part of structural components (cellulose in plants, chitin in animals). Sugar content increases under lower levels of salinity[1] but in contrast to this Rathert[9] observed that the sucrose and starch are the predominant carbohydrates affected by salinity, and soluble sugars are more sensitive to salt stress than starch.

The present investigation was carried out to determine the effect of various levels of NaCl salinity on carbohydrate contents namely soluble sugars and starch in selected experimental species.

EXPERIMENTAL

The seedlings of *Cymbopogon nardus* (L.) Rendle; *Pennisetum alopecuroides* (L.) Spreng var. Mourdy and *Vetiveria zizanioides* (L.) Nash were collected from government nursery, Kagal while those of *Cynodon dactylon* (L.) Pers. were collected from Shivaji University campus. The seedlings were uniformly cut to a minimum height required for their growth and were transplanted into the earthen pots (30 cm height with a narrow base) to grow and establish under normal conditions with proper irrigation. After four weeks of their normal growth salinity stress was commenced. The plants were treated with increasing concentrations of Sodium chloride (25, 50, 100, 200 and 300 mM). Every alternate day, they were watered with a double amount of water to maintain the uniform salt concentration in the pots and to cope up with the loss of water by evaporation from the soil surface and by transpiration from the plant surface. Carbohydrates i. e. soluble sugars and starch concentration in the leaves was estimated according to the method described by Nelson[13]. Statistical analysis of the data was carried out by using GraphPad software. Tukey-Kramer multiple comparison test of significance was carried out which suggested the variation among the column means is significant or not at different levels of significance. The data was analysed for three different levels of significance based on the 'p' values as

*	Significant	($p = 0.01$ to 0.05),
**	Very Significant	($p = 0.001$ to 0.01) and
***	Extremely Significant	($p < 0.001$)

RESULTS AND DISCUSSION

The effect of NaCl salinity on soluble sugars content of the leaves of *Cymbopogon nardus*, *Cynodon dactylon*, *Pennisetum alopecuroides* and *Vetiveria zizanioides* is recorded in TABLE 1 and Figure 1. It is evident from the results that the amount of soluble sugars in the leaves was increased at lower levels of salinity. For *Cynodon* the highest level of soluble sugars was 9.70% over the control at 50 mM NaCl while *Cymbopogon*, *Pennisetum* and *Vetiveria* showed an increase in their concentrations by 26.38, 40.92 and 35.15% respectively at the same level and showed a perfect negative correlation with increasing levels (200 and 300 mM) of salinity in the leaves.

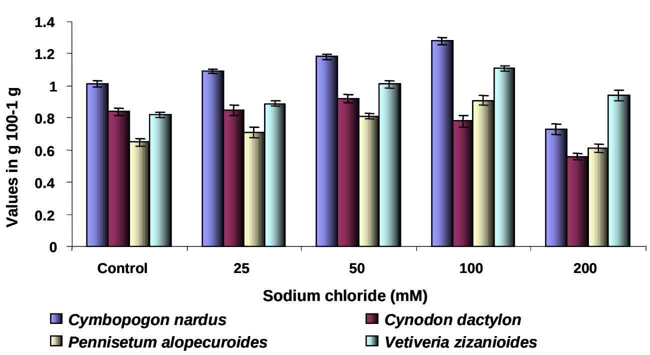
Sugars in plants generally serve mainly as source of carbon and energy, osmotica, stress protectants and signal molecules. In general, the roles of particular soluble saccharides in plants are very difficult to distinguish from one another, as they are thought to be mutually tightly interconnected. Nevertheless, some roles seem to be prominent or prevailing in particular situations. Shonjani[17] observed an increase in glucose, fructose and maltose contents (except sucrose) in maize. Al-Sobhi[14] also noticed the increase in content of soluble and insoluble sugars and total carbohydrates in the shoot and root of the seedlings of *Calotropis procera* plants with increasing salinity level and age. Khosravinejad *et al*.[7] observed the increase in soluble sugars in the leaves of two varieties of barley namely Afzal and EMB82-12 where the increase in Afzal var. was higher than that EMB82-12.

Munns[15] has reported that the concentration of sugars always rises after plants are exposed to salinity in both growing and fully expanded tissues. The accumulation of soluble carbohydrates in plants has been widely reported as a response to salinity or drought, despite a significant decrease in net CO_2 assimilation rate[5]. Carbohydrates such as sugars (glucose, fructose, sucrose, fructans) and starch accumulate under salt stress[2], playing a leading role in osmoprotection, osmotic adjustment, carbon storage and radical scavenging. Soluble sugars, apparently play a role in the development of salt tolerance[21].

TABLE 1 : Effect of sodium chloride on soluble sugar content of the leaves of four grass species

Sr. No.	Name of the species	Sodium Chloride (mM)					
		Control	25	50	100	200	300
1.	Cymbopogon nardus	1.01 (±0.020)	1.09* (±0.015)	1.18*** (±0.019)	1.28*** (±0.023)	0.73*** (±0.031)	0.52*** (±0.046)
2.	*Cynodon dactylon*	0.84 (±0.023)	0.85 (±0.034)	0.92*** (±0.024)	0.78 (±0.038)	0.56*** (±0.020)	0.40*** (±0.039)
3.	*Pennisetum alopecuroides*	0.65 (±0.023)	0.71 (±0.032)	0.81*** (±0.017)	0.91*** (±0.028)	0.61 (±0.025)	0.44*** (±0.038)
4.	*Vetiveria zizanioides*	0.82 (±0.015)	0.89* (±0.016)	1.01*** (±0.023)	1.11*** (±0.017)	0.94** (±0.031)	0.63*** (±0.042)

Each value is expressed as g 100^{-1} g fresh tissue
Each value is a mean of three determinations



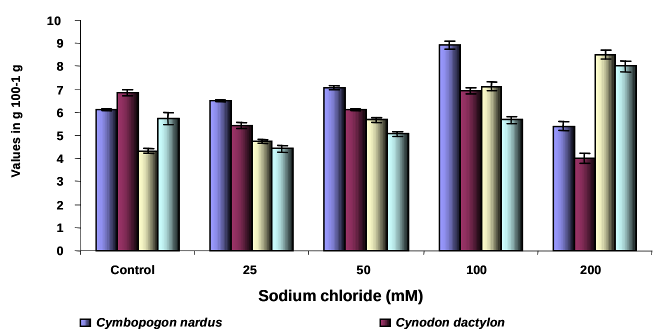
The salt tolerant lines have generally greater soluble sugars than the salt sensitive ones[3]. El-Haddad and O'leary[4] found increased soluble sugars in *Sorghum* more than in *Atriplex*, as an effect of salinity. According to them, soluble sugars increased from 30% to 144% in stressed plants of *Sorghum*. A decrease in total soluble sugars of leaves at higher salinity level might be due to more translocation of them to other parts of plant either for synthesis of different amino acids or for other metabolic activities while accumulation at lower levels of salinity might be a part of an osmotic adjustment adopted by the plants to face adverse conditions.

The effect of NaCl salinity on starch content of the leaves of four grasses is recorded in TABLE 2 and Figure 2. It is evident that the starch content of the leaves of all the four grasses is increased with increasing the levels of salinity upto 100 mM NaCl. Maximum accumulation, 46.10% over control (100 mM) was observed

TABLE 2 : Effect of sodium chloride on starch content of the leaves of four grass species

Sr. No.	Name of the species	Sodium Chloride (mM)					
		Control	25	50	100	200	300
1.	Cymbopogon nardus	6.12 (±0.051)	6.49* (±0.045)	7.07*** (±0.090)	8.94*** (±0.170)	5.40*** (±0.186)	3.22*** (±0.090)
2.	*Cynodon dactylon*	6.84 (±0.137)	5.43 (±0.137)	6.12*** (±0.052)	6.93 (±0.137)	4.0*** (±0.225)	2.14*** (±0.170)
3.	*Pennisetum alopecuroides*	4.33 (±0.101)	4.75 (±0.090)	5.68*** (±0.109)	7.13*** (±0.186)	8.51 (±0.179)	4.01 (±0.238)
4.	*Vetiveria zizanioides*	5.74 (±0.251)	4.42*** (±0.137)	5.07* (±0.103)	5.67 (±0.137)	8.0*** (±0.225)	3.40 (±0.237)

Each value is expressed as g 100^{-1} g fresh tissue
Values in parenthesis indicate standard deviation
Each value is a mean of three determinations
*** Significant (p = 0.01 to 0.05)**
**** Very Significant (p = 0.001 to 0.01)**
***** Extremely Significant (p < 0.001)**



in *Cymbopogon nardus while* in *Cynodon dactylon* it was decreased initially and then increased by 1.31% (100 mM) only.

In contrast to this *Pennisetum alopecuroides* showed a regular increase in it and maximum increase was found at 200 mM as 96.69% while it was decreased initially and then increased by 39.29% (200mM). All the species showed a drastic reduction in starch content under the influence of higher levels of salinity stress. Djanaguiraman *et al*.[11] observed a decrease in starch content of rice under the salinity regime at 100 mM NaCl. However, a reverse trend was observed in soluble sugars content at the same concentration.

The reduction in total starch content of the grass leaves might be due to its utilization in other parts of the plant either for synthesis of different amino acids or for other metabolic activities showing an adaptive feature of plants to salinity stress.

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