

RESPONSE OF *PHRAGMITES AUSTRALIS* TO WATER STRESS FROM FLOODING TO DROUGHT

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Abstract

Leaf samples of *Phragmites australis* collected from five locations varying from totally flooded to dry regime showed a sharp decrease in the fresh leaf water content of the plant from flooding to dry locations accompanied by an incomparable decrease in OP. This incremental osmotic regulation occurred due to the accumulation of soluble sugars, amino acids, proteins, proline and the nutrient elements K, Na, Ca, Mg and Fe. Low OP under flooding was attributed to the condensation of sugars and amino acids into polysaccharides and protein. Both drought and flooding conditions resulted in the accumulation of polysaccharides, protein and proline.

Introduction

The effects of drought and water flooding stresses on different plant species have been extensively studied. Drought adapted plants accumulate mineral salts and organic solutes to maintain suitable turgidity in the cell for efficient photosynthesis (Ackerson, 1981; Reid & Wample, 1985). Inhibition of growth could be achieved in many ways, but low turgor seems to have the greatest and most rapid influence (Boyer, 1970).

In contrast, flooding has a symficient effect on respiration and electron transport system because it reduces the available oxygen (Kramer, 1969). Flooding also results in the accumulation of proteins and polysaccharides (Grineva & Nechiporenko, 1977). Accumulation of protein content is also attributed to the inhibition in protein hydrolysis (Mocquot *et al.*, 1981). Many amino acids are reported to accumulate in flooded plants especially proline which is associated with the change in leaf turgidity (Wample & Bewley, 1975).

This study aims to investigate the variations in water relations and accumulation of compatible solutes and nutrient elements in response to drought and flooding in *Phragmites australis* under natural habitat.

Materials and Methods

Leaf samples of *Phragmites australis* growing along the edge of Tanta irrigation canal were collected from five locations representing a transect. In the first location, the plant root was permanently flooded by canal water. In other locations there was a gradual decrease in soil moisture. On one of the locations which is a part of the railway bank the plants were not irrigated at all.

For soil moisture determinations, 10 soil samples were collected at 0-10 cm and 10-50 cm depth using 7 cm inner diameter auger. Soil samples were kept in aluminum cups. Fresh weight was taken before drying in an oven at 105°C till constant dry weight for determining the soil moisture content. Soil osmotic potential was calculated indirectly by recording the electrical conductivity and converting it to O.P. as proposed by (Black *et al.*, 1965). Plant leaf samples were clipped at midday from the upper ten leaves, of at

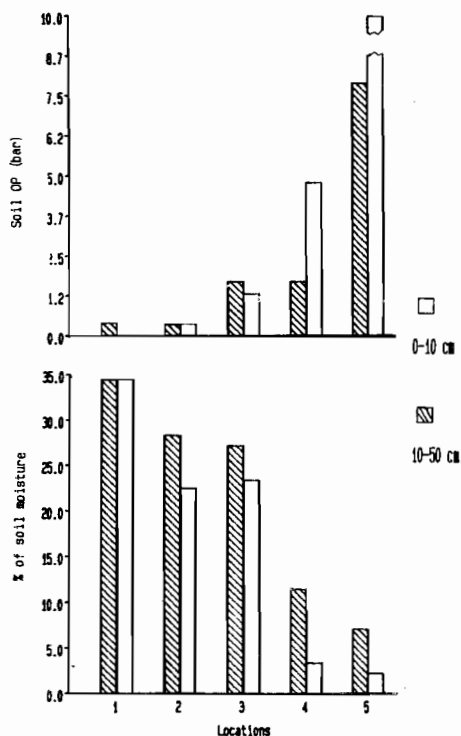


Fig.1. Variations in osmotic potentials (-bar) soil moisture (% of oven dry weight) at 0-10 and 10-50 cm depths from five locations varying from totally flooded to dry condition.

least ten plants of equal length. Leaves were washed thoroughly with distilled water. Five leaves from each location were selected at random, carefully dried with filter paper, weighed as fresh and dry (at 60°C), powdered and stored for analysis of metabolites. The remaining five leaves were used to make discs which were weighed as fresh, saturated and dried at 80°C for actual and relative water content measurements. The rest of leaf samples were dried at 80°C to constant weight and ashed for determination of nutrient elements.

Sugar determinations were carried out by phenolsulphuric acid method (Dubois *et al.*, 1956). The total osmotic potential of leaf extract was measured using Advanced Wide-Range osmometer WII, (Advanced Instruments, Inc). Ionic osmotic potential was measured by an electrical conductivity meter. The difference between the total and ionic OP measurements was considered as non-ionic OP. The pH of extract was measured by a pH meter.

Soluble proteins were measured in the extract using Bradford's method (1976). Total soluble amino acids were determined by the method of Ya & Tunekazu (1966). Free proline was measured in the extract using the method of Bates *et al.*, (1973). Major ions in the ash extract were measured using a flame photometer and atomic absorption spectrophotometer.

The data obtained were statistically analyzed using correlation coefficient, correlation matrix and analysis of variance by Little & Hills (1978).

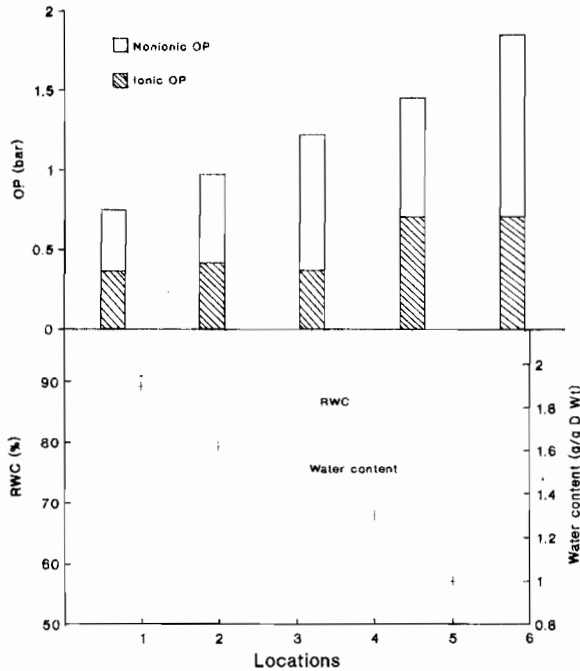


Fig. 2. Leaf water content (g/g dry weight), relative water content (RWC) and leaf extract osmotic potentials (-bar) for *Phragmites australis* collected from five locations varying from totally flooded to dry conditions.

Results

Soil moisture and osmotic potentials: Soil moisture percentage exhibited significant (P) decrease from the flooded location to the dry one. Soil moisture at location that was not irrigated was approximately similar to the hygroscopic moisture, (moisture released by drying the air soil at 105°C) especially at the lower depth. This decrease was also accompanied by sharp decrease in osmotic potential of the soil solution (Fig.1).

Plant relative water content (RWC) and OP: Plant leaf water content varied significantly (P) from wet to dry conditions (Fig.2). Leaf water content in plants grown at the dry location was about half as compared to plants at the flooded location. On the other hand RWC of *P. australis* exhibited about 10% decrease, from flooded to dry locations. Leaf water content correlated positively (0.939) with soil moisture and negatively (0.939) with soil OP. Both correlations were highly significant.

Leaf OP decreased with the decrease in soil moisture from higher to lower moisture regimes (Fig.2). The decrease in OP in plant leaves at the driest location was nearly three times than in leaves of plants at flooded one. The total OP correlated significantly (0.989**) with non-ionic OP resulting from metabolites accumulation and with ionic OP (0.8455**) resulting from accumulation of nutrient elements. The ionic OP represents 57% of the total OP in plants at flooded sites. Ionic OP did not exhibit notable change in moderate to flooded conditions, but decreased by about 50% in plants at the drier sites as compared to the ionic OP of the plants at flooded location. The non-ionic OP

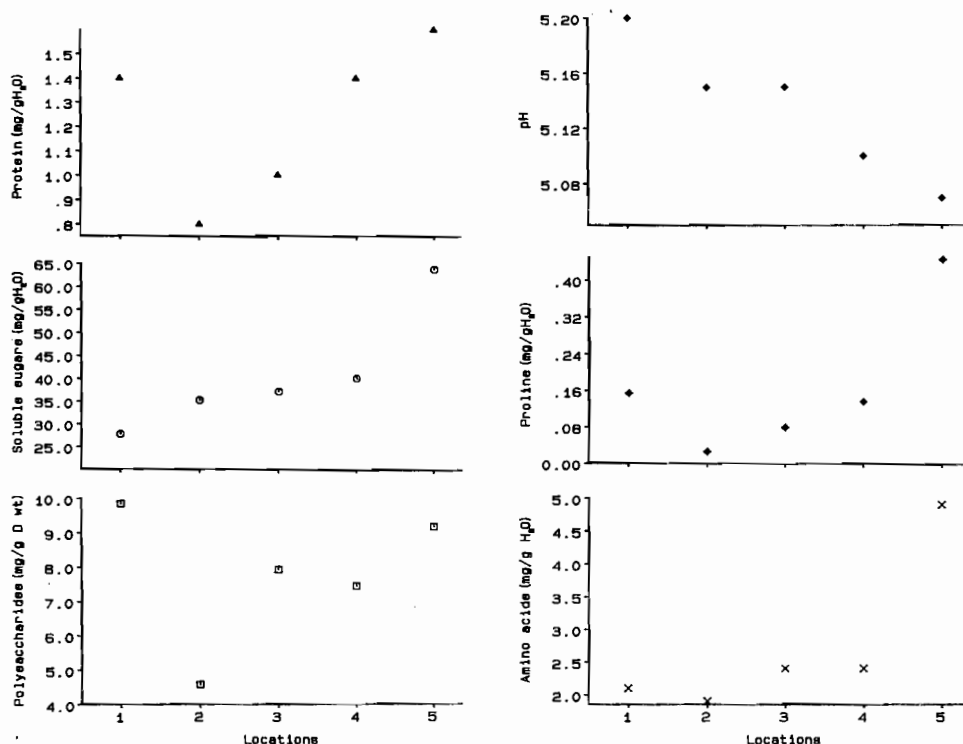


Fig.3. The amount of proteins, soluble sugars, polysaccharides, amino acids, proline (mg/g leaf water content) and total acidity (pH) for leaves of *Phragmites australis* collected from five locations varying from totally flooded to dry conditions.

increased from 43% in plants of the first location (flooded site) to 68% in plants of the fifth location (driest site). Total OP, ionic and non-ionic OP correlated significantly and positively with soil OP (0.955^{*}, 0.898^{*}).

Accumulation of metabolites: Soluble sugars, polysaccharides, amino acids, proline and proteins metabolites were found to accumulate in the plants with the decrease in soil moisture from flooded to dry locations (Fig.3). Proteins, polysaccharides and proline attained relatively higher values in plants of the flooded location especially polysaccharides which exhibited the maximum value. Proline content exhibited more or less equal values in plant leaves at flooded and relatively drier location. pH of the plants decreased whereas, total acidity increased slightly with water stress from flooded to dry location. Soluble sugars and amino acids exhibited negative correlation with leaf OP (-0.978^{**}, -0.929^{**}). Polysaccharides and proline also correlated negatively (-0.858^{*}, -0.824^{*}) with leaf OP.

The concentration of Na, K, Ca, Mg, and Fe (mg/g leaf water content) increased significantly in leaf extracts of the plants at the driest locations (Table 1). Ca content showed highly significant correlation (-0.925^{*}) with leaf ionic OP and significant (-0.870P^{*}) with total OP. Na content also correlated significantly with total OP (-0.925^{*}). K and Fe were higher in plant leaves under flooded location as compared to drier locations.

Table 1. The concentrations of K, Na, Ca, Mg and Fe (mg/g leaf water content) in *Phragmites australis* leaves collected from five locations varying from flooding to drying.

Locations	Elements concentration (mg/g leaf water content)				
	K	Na	Ca	Mg	Fe
1. (Flooding)	14.58±2.1	1.32±.20	1.53±.3	0.24±.03	0.98*10 ⁻²
2.	11.13±3.2	1.58±.11	1.76±.5	0.84±.10	0.73*10 ⁻²
3.	11.53±1.3	1.67±.15	1.32±.2	0.52±.05	0.83*10 ⁻²
4.	17.62±3.5	1.69±.42	2.23±.4	0.59±.02	0.46*10 ⁻²
5. (Dry)	13.90±2.1	1.90±.23	2.70±.2	1.36±.25	1.80*10 ⁻²

Discussion

In the present study, *P. australis* plants were studied at five different locations varying from totally flooded condition at the root system to drought stress. In spite of decrease in the leaf water content leaf RWC of *P. australis* showed little reduction. It is suggested that ability of the plant to maintain turgor at higher water deficit can largely be attributed to the active solute accumulation, osmotic adjustment, shrinkage of cell wall (following water loss) or the alteration in cell wall elasticity which is decreased by the high concentration of Ca (Roberts *et al.*, 1981; Hanson & Hitz, 1982). High Ca content was recorded in the plant leaves at the driest locations. This accumulation of Ca in *P. australis* affects the cell wall extensibility after shrinking of the cell following water loss and hence the small decrease in RWC of the plant evident at the dry locations. Leaf OP decreased three times from flooded to dry location. This decrease was mainly due to the decrease in leaf non-ionic OP which represented from 43 to 68% of the total OP from flooded to dry location coupled with accumulation of soluble sugars, total soluble sugars and the nitrogenous compounds in *P. australis* under water stress conditions could be referred to the continuous assimilation of CO₂ (and not hydrolysis of polysaccharides) and proteins which were accumulated. Assimilation of CO₂ under water stress has also been reported by Smirnoff *et al.*, (1985) in barley and durum wheat.

The decrease of the ionic OP, especially at dry location, was accompanied with the increase in the contents of Na, Ca, Mg and Fe. The increase of Na from flooded to dry location was coupled with the decrease in the plant leaf water content. This increase in Na content appears to be an adaptation to maintain a constant osmotic potential gradient between the shoot tissue and the external solution (Glenn, 1987). Meanwhile, the increase in Ca content from flooded to the dry location plays the main role in controlling cell elasticity (Roberts *et al.*, 1981), which being very important for osmotic adjustment.

Flooding increased the OP in the plant cells than expected with increase in plant leaf water content. This increase was found to coordinate with the active metabolism of hexoses and amino acids into polysaccharides and proteins, respectively, in the leaf tissue of flooded plants (Bertani *et al.*, 1981). However, the slight increase in free amino acids could be referred to the increase in proline which accumulated under flooding condi-

tions. Both drought and flooding stress share a common accumulation of proteins, polysaccharides, amino acids and proline.

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