Water Stress-Induced Osmotic Adjustment in Expanding Leaves of Tepary Bean (Phaseolus actifolins, Gray) Seedlings

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Abstract

Tepary beans perform better than common beans under drought conditions. The mechanism of drought tolerance in tepary bean seedlings was explored by determining the water potential, osmotic potential, relative water content and level of free sugars and concentration of K ions within expanding leaves. Two week old seedlings were subjected to a gradual water stress with sorbitol solutions exhibiting OP values of -0.19 MPa and -0.47 MPa.

Tugor remained constant whereas WP, OP and RWC declined following the stress treatment. Osmotic adjustment (OA) occurred in each treatment but the contribution of sucrose and fructose to OA was minor. Some sorbitol was translocated to leaves and contributed to OA. The K ions did not contribute to the OA. A significant decrease in cell size was observed.

Introduction

Drought is recognized as a major agricultural problem in arid and semi-arid regions of the world. Drought prevents crops from attaining their full genetic potential for yield. Various drought tolerant plant species have developed mechanisms to maintain productivity under stress conditions. Two physiological adaptations of plants to water stress are transpirational control and osmotic adjustment (OA). Osmotic adjustment occurs when both OP and WP of the same leaf decrease but the turgor potential remains constant.

Goertz and Coons (1987) reported that tepary beans exhibit drought tolerance but little is known about their mechanism of drought tolerance. Parsons and Howe (1984) reported that OA is the mechanism of drought tolerance in tepary bean whereas Markhart (1985) reported that large deep roots contributed to their drought tolerance rather than OA. The aim of this research was to determine (a) if 2 week-old tepary bean seedlings exhibited OA following exposure to gradual increased levels of sorbitol (b) if the observed OA is caused by accumulation of solutes such as free sugars and K ions or by decrease in cell size.

Material and Methods

Tepary bean seeds were germinated and grown in vermiculite for 7 days in glass house. Then, the vermiculite was removed from the roots and the plants were transplanted to aerated Hoagland solution. Next, the seedlings were treated with various concentrations of sorbitol mixed with Hoagland solution. The initial solutions were changed after 2 days with new sorbitol solutions having OP double the first increment. All treatments in each experiment were replicated three times and repeated three times over time. The experimental design was a randomized complete block design. Psychrometers were used to measure the OP and WP of the expanding leaves. The relative water content of the leaf tissue was determined by the method of Ibarra-Caballero et. al., 1988. Total leaf free sugars and starch were measured by the method of Dubois et. al., (1956). Qualitative analysis of the sugars was conducted with HPLC system. Sugars which had been passed through an ion exchange

column were injected into Waters HPLC system and sugar identified by their retention times. K ion levels in the leaf tissue were determined by atomic absorption spectrophotometry.

Results and Discussion

Water stress generated by sorbitol treatment led to an osmotic adjustment (OA) in the expanding leaves of 2 week old seedlings. The osmoticum of leaf tissue increased by 60 mM for seedlings treated with -0.19 MPa sorbitol and 232 mM for seedlings treated with -0.47 MPa sorbitol as compared to controls (Table 1.). Water and osmotic potential of the leaves were both reduced by water stress whereas TP remained constant. The concentration of free sugars in the treated seedlings increased. Sorbitol was the abundant free sugar in plants. The increase of sucrose was slightly greater than the increase of fructose but less than sorbitol. The contribution of sucrose to the true osmotic adjustment was approximately 2 to 5%, whereas sorbitol accounted for 32 to 44% of the OA. K ions did not contribute to OA and the level of these ions actually declined in the treated plants.

The cell size of the leaves from treated seedlings was smaller than the control indicating that the reduced cell size also may account for some of the observed OA.

References

Dubois, M. et. al. 1956. Colorimetric method for determination of sugars and related substances. Anal. Chem. 8: 350-356.

Goertz, J.S. and J. Coons. 1987. Emergence of tepary and navy bean with increasing salinity. In Vegetable Report, University of Arizona. Series S-1 pp 13-15.

Ibarra-Caballero et. al. 1988. Proline accumulation as symptom of drought stress in maize. J. Exp Bot. 39:889-897.

Markhart, A.H. 1985. Comparative water relations of Phaseolus vulgaris and Phaseolus actifolius. Plant Physiol. 77: 113-117.

Parsons, L. and T. Howe. 1984. Effect of water stress on the water relations of Phaseolus vulgaris and drought resistance Phaseolus actifolius. Physiologia Plantarum 60:197-202.

Table 1. Osmotic potentials (mM) at full turgor and osmotic adjustment (mM) for expanding leaves of tepary bean seedlings after being treated with various levels of sorbitol for 72 hours.

Treatment	Solution Osmotic Potential	Osmotic Potential at Full Turgor	Osmotic Adjustment
	(MPa)	(mM)	(mM)
Control	-0.03	244.6 C	---- c
(T_1)	-0.19	305.2 b	60.6 b
(T_2)	-0.47	476.5 a	231.9 a

Means followed by different letters are significant at 0.05 level (LSD).