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Effect of water stress on plant growth in *Atriplex hortensis* L.

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SUMMARY
Investigations on the effects of water-deficit stress conditions on the physiological characteristics of plants may provide a means to understand the basis of drought resistance. *Atriplex* spp. have been used as a resource for the rehabilitation of degraded land. The responses of two varieties of *Atriplex hortensis* [green orach (*A. hortensis* L. var. *purpurea*) and red orach (*A. hortensis* L. var. *rubra*)] to four levels of soil moisture (100, 80, 60, or 40% of field capacity) were investigated. The experiment was conducted under greenhouse conditions. Growth declined progressively with the application of increasing water stress. Water-stressed plants exhibited significant reductions in height and biomass. Water-deficit stress also caused a significant decline in total leaf area, but had no significant effect on leaf water content in red orach. Reductions in soil water content caused reductions in the relative water content (RWC) of leaves in both varieties of *A. hortensis*, but the decrease in RWC was more pronounced in green orach than in red orach. The results of this study indicate differences in drought tolerance between the two varieties of *A. hortensis*. Based on these findings, the more drought-tolerant red orach may be grown, preferentially, under water stress conditions or in water-limiting soils.

Drought is considered to be a major environmental factor that limits plant growth and yield, worldwide, especially in arid and semi-arid areas (Boyer, 1982). Drought induces many physiological, biochemical, and molecular responses, among which the rate of photosynthesis is one of the primary physiological targets (Lawlor, 1995). There is a long-standing controversy as to whether drought primarily limits photosynthesis through causing stomatal closure (Ort *et al.*, 1994) and reduced mesophyll conductance in general (Flexas *et al.*, 2004), or by metabolic impairment (Lawlor, 1995). The availability of water in the soil is a major limiting factor for plant growth. Limited availability of soil water leads to reduced growth of the aerial parts and, to a lesser extent, of the root system. Several other responses such as stomatal closure and an increased synthesis of osmolytes such as betaine and proline have been described (Bohnert and Sheveleva, 1998). These responses are controlled, at least in part, by abscisic acid (ABA), a phytohormone that increases its concentration in plants subjected to water-deficit stress (Zeevaart and Creelman, 1988).

In general, shoot growth is more sensitive to water deficit than root growth (Sharp and Davies, 1989). The mechanisms underlying sustained root growth under water stress conditions include osmotic adjustment (Saab, 1992) and an increase in the capacity of the cell walls to allow partial recovery of turgor and the re-establishment of an osmotic potential gradient (Ψ) for water uptake (Hsiao and Xu, 2000). The level of involvement of drought-induced ABA and of ethylene in shoot and root growth is still under debate (Sharp and LeNoble, 2002). It seems that an important role for the accumulation of endogenous ABA in maintaining root elongation under drought conditions is the inhibition of ethylene production. Stomatal control of water loss has been identified as an early event in plant responses to water deficit under field conditions, leading to a limitation in carbon uptake and assimilation by the leaves (Cornic and Massacci, 1996). Stomata close in response to a decline in leaf turgor and/or in leaf water potential (Ludlow, 1980), or to a low humidity atmosphere (Maroco *et al.*, 1997). This suggests that the stomata respond to the chemical signals (e.g., ABA) produced by dehydrating roots, while the leaf water status remains constant (Davies and Zang, 1991). The effects of water-deficit stress on plants can be expressed as various morphological, physiological, and biochemical changes. For instance, changes in leaf morphology (Akinci, 1997), effects on shoot and root growth and development, limited photosynthetic activity by decreasing the influx of CO_2, and/or decreases in carboxylation and in the electron transport chain activities of chloroplasts in mesophyll cells.

Halophytes are distinguished from glycophytes by their increased tolerance of drought conditions. The use of halophytic plants for pasture and fodder production on saline soils is often the only economically feasible solution available (Khan and Duke, 2001). *Atriplex* spp. (saltbushes) dominate in many arid and semi-arid regions of the World, particularly in habitats that

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