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Growth Response of Atriplex Species to Salinity and Hypoxia

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ABSTRACT

Growth response of two Atriplex species (*A. amnicola* and *A. lentiformis)* to salinity and hypoxia was studied under hydroponic green house conditions. Two-month-old seedlings were transferred to ½ strength Hoagland nutrient solution in plastic containers. Salinity levels (50 and 400 mol m^3 NaCl) were developed in five equal increments and hypoxia was induced by disconnecting the aeration of nutrient solutions. The combined effect of high salinity and hypoxia severely reduced the growth of both shoot and root. *Atriplex amnicola* produced more biomass than *A. lentiforms.* On relative growth basis, *A. lentiformis* showed better tolerance than *A. amnicola*. Role of osmotic adjustment in relation to leaf water balance and stress tolerance is discussed.

Key Words: Atriplex; Salinity; Hypoxia; Growth

INTRODUCTION

About 6.7 mha are salt affected in Pakistan and half exist as waste lands (Khan, 1993). Amelioration of the most of these soils through drainage alone or in combination with chemical amendments is not economically feasible. Alternatively, a proper plant succession programme is necessary to deal with such soils for utilization and biological soil reclamation. Kallar grass (*Leptochola fusca*) as a pioneer plant species has been used to grow in deteriorated saline sodic soils. A number of tree and forage species have been identified that can grow successfully and produce economically significant yield as well as improve in soil characteristics. The revegetation of salt affected wastelands through productive halophytic salt tolerant plants of agricultural significance has considerable economic, environmental and social implications for developing countries like Pakistan (Qureshi *et al.,* 1982).

Halophytes are often characterized as plants growing successfully in highly saline environment. Atriplex is a conspicuous genus among the halophytic shrubs because of its forage value. This genus comprises species that are highly salt tolerant (EC_e upto 100 dS m^{-1}), nutritionally balanced, highly productive (upto 30-40 tons ha^{-1} yr^{-1}) and have wide adaptability under varying geographical, edaphic and climatic conditions (Runeiman & Malcolm*,* 1989).

Extensive studies have been made on various aspects of Atriplex species varying from productivity trials to feeding experiments (Malcolm, 1986). The performance of these species has been investigated under a variety of growth conditions in Pakistan and other countries (Aronson *et al.,* 1988; Qureshi *et al.,* 1993). In this paper, growth and physiological response of two Atriplex species measured under greenhouse conditions to salinity and waterlogging (hypoxia) has been presented.

MATERIALS AND METHODS

Seeds of two Atriplex species (*A. amnicola* and *A. lentiformis*) collected by crushing and removing the seed brackets, were germinated in moist silica sand in plastic trays. After germination, seedlings were irrigated with ½ strength Hoagland nutrient solution (Hoagland & Arnon, 1950). Two-month-old seedlings were transplanted in plastic containers having ½ strength nutrient solution. Seedlings were transplanted in polystyrene sheet after wrapping at root/shoot junction with foam. The nutrient solutions were aerated.

After two weeks of transplanting, plants were exposed to salinity (50 and 400 mol m^{-3} NaCl). The salinity was developed in five equal increments by adding calculated amount of NaCl to nutrient solution within five days. Hypoxia was imposed after achieving the required salinity by disconnecting the aeration. The plants were allowed to grow in stressed conditions for four weeks. During this period, solutions were changed weekly. At harvesting, fresh weights of shoot and root were recorded and plant leaf samples were collected in eppendorf tubes for extracting the sap for ionic analysis. Net assimilation rate (NAR) and transpiration rates were determined using portable photosynthesis system LCA-3 (The Analytical Development Co. Ltd., England) one day before harvesting the plants. Na^+ and K^+ in the leaf sap were determined by flame photometer and Cl^- by chloride meter.

RESULTS AND DISCUSSION

The shoot fresh weight in both the Atriplex species was adversely affected by salinity and hypoxia separately (Table I). The combined stress of salinity and hypoxia resulted in maximum shoot and root weight reduction. *Atriplex amnicola* gave better absolute shoot and root yield

Table I. Effect of salinity and hypoxia on shoot and root fresh weights of two *Atriplex spp.*

	Salinity (mol m^{-3})			
	50		400	
Species	Aeration	Hypoxia	Aeration	Hypoxia
		Shoot fresh weight (g/plant)		
A. amnicola	57.66 ± 4.14*	28.97 ± 3.12 (50%)**	25.00 ± 4.32 (43%)	17.97 ± 2.81 (31%)
A. lentiformis	28.88 ± 2.00	23.91 ± 2.81 (82%)	17.96 ± 2.91 (62%)	10.28 ± 0.94 (36%)
		Root fresh weight (g/plant)		
A. amnicola	21.55 ± 4.23	11.41 ± 1.91 (53%)	3.72 ± 0.55 (17%)	3.21 ± 0.62 (15%)
A. lentiformis	10.18 ± 0.89	5.37 ± 1.02 (53%)	4.60 ± 1.04 (45%)	2.52 ± 0.31 (25%)

Table II. Effect of salinity and hypoxia on transpiration rate and net assimilation rate of two *Atriplex spp.*

	Salinity (mol m^{-3})			
	50		400	
Species	Aeration	Hypoxia	Aeration	Hypoxia
		Net assimilation rate (µ mol m^2 s^{-1})		
A. amnicola	1.12 ± 0.02	0.85 ± 0.04	0.75 ± 0.01	0.80 ± 0.04
A. lentiformis	0.97 ± 0.09	1.00 ± 0.11	1.32 ± 0.07	1.20 ± 0.07
		Transpiration rate (µ mol m^2 s^{-1})		
A. amnicola	0.20 ± 0.04	0.25 ± 0.03	0.30 ± 0.04	0.27 ± 0.04
A. lentiformis	0.22 ± 0.11	0.30 ± 0.21	0.30 ± 0.26	0.32 ± 0.24

*values are means of three observations ±s.e.; **Values in parenthesis are per cent of control

than *A. lentiformis* under control and stress conditions indicating higher biomass production ability. However, on relative basis (see values in parenthesis), *A. lentiformis* performed better than *A. amnicola* showing more tolerance to stresses. As these species are generally recommended for fodder production from problem soils, *A. amnicola* may be preferred over *A. lentiformis* because of the poor growth of later which may be its genetic characteristics.

Sodium concentration in leaf significantly increased at high salinity (400 mol m^{-3} NaCl) in both the species (Fig. 1), however, *A. amnicola* maintained lower Na^+ concentration

Fig. 1. Sodium concentration (mol m^{-3}) in leaf sap of two atriplex species as affected by salinity and hypoxia. Vertical bars = ± s.e.m

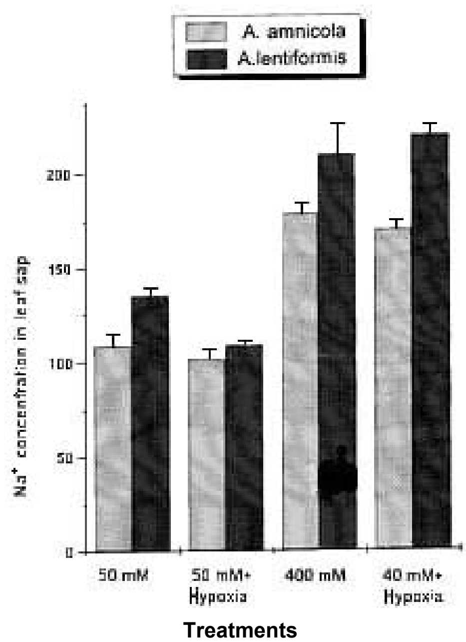


Fig. 2. Potassium concentration (mol m^{-3}) in leaf sap of two atriplex species as affected by salinity and hypoxia. Vertical bars = ± s.e.m

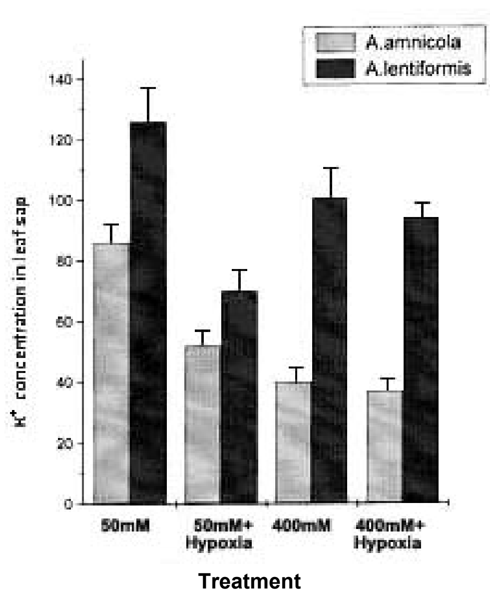
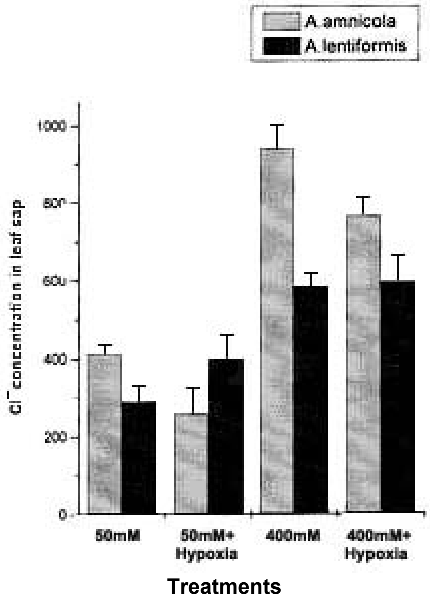


Fig. 3. Chloride concentration (mol m^{-3}) in leaf sap of two atriplex species as affected by salinity and hypoxia. Vertical bars = ± s.e.m



at 400 mol m^{-3} NaCl salinity and salinity + hypoxia compared with *A. lentiformis.* Hypoxia did not influence significantly the Na^+ level both at low and high salinity levels in both the species. Leaf K^+ content decreased with hypoxia under low as well as high salinity but this decrease was significant under low salinity level (Fig. 2). Imposition of higher salinity stress decreased K^+ content of leaf sap under aerobic conditions but under hypoxic conditions, K^+ content significantly increased in *A. lentiformis*. Maintenance of higher K^+ concentration in *A. lentiformis* leaves might be associated with its tolerance to stress especially under hypoxia (Wyn Jones & Storey, 1978; Sandhu *et al*., 1981). As expected, the leaf Cl^- concentration increased in both the species at high salinity (Fig. 3). Higher Cl^- concentration in leaves of *A. amnicola* at high salinity could be attributed to better osmotic adjustment of the species since Cl^- plays vital role for osmoregulation under stress condition (Flower & Yeo, 1986).

The transpiration rate was statistically same in both the species at low salinity. However, it was about 50% higher under high salinity level (Table II). This could be due to better osmotic adjustment which led to stomatal opening (Ludlow *et al.,* 1985). Higher levels of Na^+ and Cl^- (Fig. 1, 3) in leaf under high salinity further supports these findings. Osmotic adjustment of leaves thus maintained transpiration to lower leaf water potential, necessary for water uptake from root and root medium.

The net CO_2 assimilation rate (NAR) under control conditions was higher in *A. amnicola* than *A. lentiformis* (Table II). The higher NAR was responsible for higher growth in case of *A. amnicola* when grown under non-stress conditions. However, the NAR decreased under stress conditions in *A. amnicola;* whereas, *A. lentiformis* maintained higher NAR which resulted in relatively less reduction in fresh weight of both shoot and root.

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