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BRIEF COMMUNICATION

Growth and phosphorus uptake of *Atriplex amnicola* at different levels of NaCl

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Abstract

Growth of *Atriplex amnicola* P.G. Wilson was not affected by different levels (10, 100, and 200 mM) of NaCl. Na concentrations in roots and shoots increased significantly at higher levels of NaCl. K/Na ratios in plant parts were higher compared to those in the external solutions, indicating selectivity for K over Na. P uptake, as determined using ^{32}P, was not affected by increasing NaCl in the root medium.

Atriplex species are well adapted to arid and saline regions of the world. Because of their high salt tolerance, many *Atriplex* species could be used for increased plant establishment and productivity in extreme environments. *Atriplex amnicola* P.G. Wilson (syn. *Atriplex rhagodioides* F. Muell.), highly tolerant to salinity (Mahmood and Malik 1987), was introduced in the experimental saline sodic area near Lahore, Pakistan. High biomass production of this species in low-fertility saline soils prompted study of its nutrient sources. Bilal *et al.* (1990) reported a high root-associated nitrogenase activity that accounted for nitrogen nutrition of *A. amnicola*. Further, the species is able to maintain potassium uptake under highly saline conditions (Mahmood and Malik 1987, Aslam *et al.* 1988). The present study concerns the growth and P uptake of *A. amnicola* under saline conditions.

Seeds of *Atriplex amnicola* (Accession No. 949) were germinated in sand. Four weeks old seedlings of similar size and appearance were transferred to polyethylene pots. Each pot had three seedlings. The seedlings were grown hydroponically

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on diluted half-strength Johnson's solution (Johnson *et al.* 1957). After one week, the plants were subjected to three levels (10, 100, and 200 mM) of NaCl. These salinity levels had electrical conductivity of 2.41, 12.1, and 23.0 dS m^{-1}, respectively. The pH of the solutions was maintained at 6.0. Higher salt levels (100 and 200 mM) were attained gradually with step-wise increases of 25 mM NaCl every day. After levels attaining the salt levels, the solutions were completely replaced with half-strength Johnson's solution containing 10, 100, and 200 mM NaCl. Each treatment had six pots and the solutions were kept aerated.

Table 1. Dry matter yield, cation composition and P uptake of *Atriplex amnicola* grown at different levels of NaCl salinity. Means of 4 replicates ± standard errors.

Parameter	Salinity level [mM NaCl] 10 (2.41)*	100 (12.1)	200 (23.0)
Root			
Dry matter [mg pot^{-1}]	40.6 ± 4.4	36.0 ± 6.0	39.1 ± 4.8
Na [mg g^{-1}(d.m.)]	5.25 ± 1.1a**	20.2 ± 2.7b	28.3 ± 3.7b
K [mg g^{-1}(d.m.)]	11.5 ± 0.43	7.32 ± 1.4	6.95 ± 0.56
K/Na ratio	2.077	0.361	0.245
Ca [mg g^{-1}(d.m.)]	8.47 ± 0.03	8.28 ± 0.27	8.73 ± 0.50
P [mg g^{-1}(d.m.)]	14.76 ± 0.80	15.05 ± 1.29	14.68 ± 0.34
P uptake [mg pot^{-1}]	0.621 ± 0.08	0.579 ± 0.06	0.623 ± 0.07
count rate [s^{-1} µg^{-1}(P)]	12.88 ± 0.77	13.18 ± 1.10	14.58 ± 1.60
Shoot			
Dry matter [mg pot^{-1}]	267 ± 22.0	248 ± 40.4	289 ± 28.3
Na [mg g^{-1}(d.m.)]	32.5 ± 2.8a	81.2 ± 9.5b	84.2 ± 1.6b
K [mg g^{-1}(d.m.)]	31.9 ± 3.4	33.8 ± 6.4	37.8 ± 0.5
K/Na ratio	0.983	0.417	0.448
Ca [mg g^{-1}(d.m.)]	8.77 ± 0.36	7.62 ± 1.4	6.13 ± 0.42
P [mg g^{-1}(d.m.)]	12.29 ± 0.45	12.05 ± 1.99	12.11 ± 0.73
P uptake [mg pot^{-1}]	3.25 ± 0.22	3.40 ± 0.68	3.72 ± 0.49
count rate [s^{-1} µg^{-1}(P)]			
top part***	13.78 ± 2.15	17.40 ± 1.80	17.43 ± 4.97
basal part***	11.43 ± 0.30	16.38 ± 0.17	16.53 ± 1.40
whole shoot	10.97 ± 1.30	16.90 ± 1.80	16.93 ± 1.35
K/Na ratio in solution	0.364	0.048	0.024

* Figures in parentheses are electrical conductivity [dS m^{-1}].
** Values followed by different letters in a row are significantly different at $P = 0.05$ level or better.
***Values are average of two determinations.

To four pots from each salt level, ^{32}P was added at the rate of 740 kBq(^{32}P) per pot [= 1850 kBq(^{32}P) l^{-1}]. The plants were harvested after 3 d. The samples were digested with HNO_3 and $HClO_4$ and analysed for phosphorus and ^{32}P. Total phosphorus was determined following the method of Scheel (1936). For ^{32}P, 1 cm^3 aliquots were transferred to vials containing 10 ml of scintillation cocktail (*PICO-AQUA*™, *Packard*), shaken thoroughly and the resulting gels were counted for 10 min using a liquid scintillation counter (*BETAmatic, Kontron Analytical*). The samples from remaining two pots from each treatment were used for determination of Na, K and Ca by flame-photometry.

Dry matter yields of roots and shoots of *A. amnicola* grown at different salinity levels were not very different (Table 1). The species is highly tolerant to salinity and similar yields were obtained over a range of mixed-salt salinity up to level of 20 dS m^{-1} (Mahmood and Malik 1987). Such yield responses are reported for other *Atriplex* spp. (Klienkopf *et al.* 1975, Soufi and Wallace 1982). Further, similar yields may be attributed to a shorter growth period under saline conditions.

Sodium concentrations in roots and shoots increased significantly at higher salinity compared to 10 mM NaCl level, however, these were similar for plants grown at 100 and 200 mM NaCl levels. K concentrations in roots slightly decreased and in shoots increased with increasing salinity, but not significantly. Ca concentrations in roots and shoots were almost similar for different salinity levels (Table 1). Higher uptake of Na under saline conditions is a common observation for many species. *Atriplex polycarpa* and *A. canescens* contained high concentrations of Na at high levels of Na salts in the root medium (Wallace *et al.* 1982).

Table 2. Correlation of dry matter yield, P concentrations and total P uptake with recovery of ^{32}P in roots and shoots of *Atriplex amnicola* grown at different levels of NaCl salinity.

Parameter	Root		Shoot	
	^{32}P conc. [counts s^{-1} µg^{-1}(P)]	^{32}P uptake [counts s^{-1} pot^{-1}]	^{32}P conc. [counts s^{-1} µg^{-1}(P)]	^{32}P uptake [counts s^{-1} pot^{-1}]
Root				
Dry matter [mg pot^{-1}]	11.03*	0.0144**	3.07	0.0094
P [mg g^{-1}]	8.32	-	-	-
P uptake [mg pot^{-1}]	6.68	-	-	-
Shoot				
Dry matter [mg pot^{-1}]	-	-	8.35	0.0135**
P [mg g^{-1}]	-	-	8.43	-
P uptake [mg pot^{-1}]	-	-	10.02*	0.0155**

* Significant at $P = 0.05$ level
**Significant at $P = 0.01$ level

In the present study, plant roots and shoots had higher K/Na ratios than those in the external solutions at all salinity levels (Table 1), indicating selective absorption and uptake of K over Na. *Atriplex* and other halophytes are capable of maintaining K uptake even when grown in solutions having Na/K ratios greater than 100 (Black 1960), and K in the tissue is not depressed beyond minimal levels. These observations are corroborated by many reports that salt tolerance in *Atriplex* spp. is achieved by accumulating ions against a concentration gradient, selective K uptake, and then partitioning ions in specialized tissues or secreting excess salts.

In addition to osmotic and specific ion effects, acquisition of nutrients seems important for plant growth under salt stress conditions. P concentrations in plant roots and shoots and total P uptake by *Atriplex amnicola* were not affected by various salinity levels. As the plant tissue contains P taken up during whole growth period including that before salinity treatment, ^{32}P was used to investigate uptake after imposing salt stress. ^{32}P concentrations in roots were similar for all salinity levels. For shoots, ^{32}P was higher at high salinity compared to 10 mM NaCl level, but not significantly so. Further, ^{32}P concentrations in basal and top portions of shoots were similar (Table 1). Higher ^{32}P in shoots than roots and its even distribution between basal and top portions of shoots indicate that salinity had no effect on absorption and translocation of P by *A. amnicola*.

The correlation values were significant between root or shoot masses and total ^{32}P uptake, but non-significant for ^{32}P concentrations (Table 2), meaning that ^{32}P concentration was not decreased despite dilution due to higher total P uptake. These observations clearly indicate that the species is capable of P uptake under highly saline conditions. The high productivity of *A. amnicola* in low fertility saline soils may be attributed to its efficiency for P uptake in addition to root-associated nitrogenase activity and high salt tolerance.

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