Na^{+} Uptake Pathways in the Halophyte *Suaeda maritime*

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The 21st International Grassland Congress / 8th International Rangeland Congress took place in Hohhot, China from June 29 through July 5, 2008.

Proceedings edited by Organizing Committee of 2008 IGC/IRC Conference

Published by Guangdong People's Publishing House

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Key words: Halophyte, Na^+ net uptake, $^{22}Na^+$ influx, Na^+ uptake pathways

Introduction Reducing Na^+ influx must be the key step for controlling Na^+ accumulation compared with vacuolar Na^+ compartmentalization and Na^+ extrusion (Apse et al., 1999; Ma et al., 2004; Martínez-Atienza et al., 2007), neither of which would be sufficient alone. However, the pathways by which plants take up Na^+ are uncertain since Na^+ uptake by plant roots has largely been explored using species that accumulate little Na^+ into their leaves. By way of contrast, the halophyte *Suaeda maritima* accumulates, without injury, concentrations of the order of 400 mM NaCl in its leaves. Here we use *S. maritima* to examine Na^+ uptake pathways.

Materials and methods Twenty one to 23 day old seedlings were used to evaluate the effects of inhibitors of ion transport on growth and ion accumulation. Na^+ analysis was performed using an atomic absorption spectrophotometer. $^{22}Na^+$ influx was evaluated according to the method described by Essah et al. (2003).

Results TEA^+, Cs^+ and Ba^{2+} significantly reduced the net uptake of Na^+ from 150 mM NaCl over 48 h, by 54%, 24% and 29%, respectively (Tables 1 and 2). TEA^+, Cs^+ and Ba^{2+} also significantly reduced $^{22}Na^+$ influx by 47%, 30% and 31%, respectively (Figure 1). In contrast to the situation in 150 mM NaCl, neither TEA^+ nor Cs^+ significantly reduced net Na^+ uptake or $^{22}Na^+$ influx in 25 mM NaCl (Table 1, Figure 1). Ba^{2+} did significantly decrease net Na^+ uptake (by 47%) and $^{22}Na^+$ influx (by 36% with 1 mM Ba^{2+}) in 25 mM NaCl (Table 2, Figure 1).

Conclusions We propose that two distinct low-affinity Na^+ uptake pathways exist in *S. maritima*: Pathway 1 is insensitive to TEA^+ or Cs^+, but sensitive to Ba^{2+} and mediates Na^+ uptake in low salinities (25 mM NaCl); Pathway 2 is sensitive to TEA^+, Cs^+ and Ba^{2+} and mediates Na^+ uptakein higher external salt concentrations (150mM NaCl).

Table 1 *Effect of TEA^+ and Cs^+ on net Na^+ flux (μmol g^{-1} fresh weight root min^{-1}) of S. maritima.*

NaCl concentration (mM)	Inhition		
	None(control)	TEA^+ (10mM)	Cs^+ (3mM)
150	0.56±0.04a	0.26±0.03c	0.43±0.03b
25	0.20±0.02a	0.15±0.01a	0.18±0.03a

Table 2 *Effect of Ba^{2+} on whole plant Na^+ content (μmol/plant) and root net Na^+ flux (μmol g^{-1} fresh weight root min^{-1}) of S. maritima.*

	BT	25Na	25NaBa	150Na	150NaBa
Na^+ coment	7.0±0.56d	50±5.61b	22±1.4c	100±7.7a	51±4.4b
Na^+ netflux		0.19±0.02c	0.10±0.01d	0.43±0.02a	0.31±0.03b

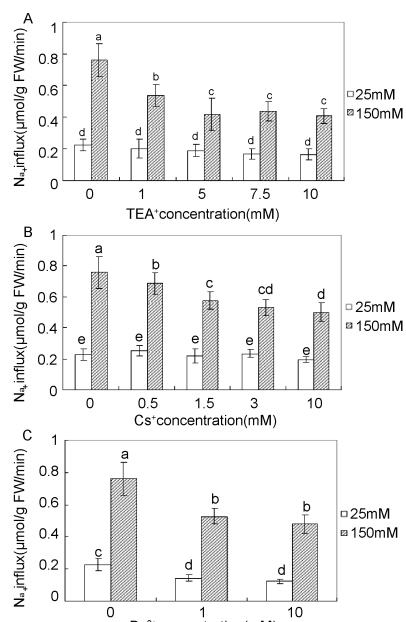

Figure 1 *Root $^{22}Na^+$ influx of S. maritima seedlings treated with different inhibitors.*

Acknowledgements This work was supported by National Natural Science Foundation of China (30671488, 30700562, 30770347), National High-Tech Project of China (863"Project) (2006AA10Z126), National Key Basic Research Project of China(973"project) (2007CB108901) and New Century Talent Supporting Project of China(NCET-05-0882).

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