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Effects of sodium chloride on survival and stem elongation of two Asian pear rootstock seedlings

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Abstract

Survival, leaf burn, and mineral uptake of two Asian *Pyrus* rootstocks were evaluated under NaCl irrigation. Potted seedlings of 2-year-old pear rootstocks, *Pyrus betulifolia* Bunge (BET) and *P. pyrifolia* (Burm. f.) Nakai (PYR) were irrigated with 0, 25, 50, 100, 150 or 200 (BET only) mM NaCl solution. BET showed high survival rate and slight leaf injury even under 100 mM NaCl irrigation. PYR however exhibited severe leaf injury and most of the tested plants died under 25 mM NaCl irrigation. Leaf Na concentration in BET subjected to 100 mM was similar to that of PYR at 25 mM. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: NaCl; *Pyrus betulifolia*; *Pyrus pyrifolia*; Rootstock; Salinity

1. Introduction

Pear rootstocks affect the nutritional status of the scion (Woodbridge, 1973) and proper choice of rootstocks can ameliorate the detrimental effects of salinity (Francois and Maas, 1994). Francois (1982) demonstrated that the ornamental evergreen pear *P. kawakamii* is tolerant to salinity. Such salt-tolerant rootstocks may be useful for cultivation, but detailed information is currently limited.

P. pyrifolia (Burm. f) Nakai (PYR) is native to east Asia (Lombard and Westwood, 1987). Seedlings of this species have been widely used as rootstocks

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for Japanese pear. *P. betulifolia* Bunge is native to northeast China and is now used as rootstocks for Japanese and European pear cultivation. *P. betulifolia* may be able to grow under saline conditions as it possesses higher tolerance to drought (Hayashi, 1955). The present study evaluated the effects of NaCl irrigation on the survival, stem elongation and mineral absorption of these two species.

2. Materials and methods

The experimental site was Kyoto University Orchard, Osaka, Japan (34.5°N, 135.4°E). This experiment was conducted under a well-ventilated polyplastic-roofed greenhouse where average air temperature ranged from 7°C (January) to 31°C (August). Daily average solar irradiation in summer (June to September) was 17 MJ m⁻² outside the polyplastic-roof and approximately 80% of sunlight permeated the greenhouse.

Two-year-old seedlings of *Pyrus betulifolia* Bunge strain Blue (BET) and PYR were obtained from a commercial nursery. The plants were carefully examined to exclude genetic variants. In early March 1993, the seedlings were planted into 10 l clay pots, which were filled with coarse river sand and clay loam (gleysol, 1:1, v/v). Initial chemical properties of the soil prepared are shown in Table 1. The plants were pruned to three shoots. A slow-release compound fertilizer (12N–10P–10K plus trace elements) was applied at 2 g per plant in mid April. In early May, 25 plants from each species were transferred into the greenhouse. The plants were supplied with 500 ml of 0 (control), 25, 50, 100, 150 or 200 mM NaCl solution. Irrigation commenced on 15 May and continued once a day every morning for next 10 weeks. Surplus solution drained naturally from the bottom of pots to avoid build-up of salts in the growth media.

Total lengths of stems and visible symptoms of leaf injury were recorded at weeks 5 and 10 of NaCl treatment. The number of dead plants was counted for each treatment plot.

Well expanded leaves were collected from each stem at weeks 5 and 10. Tissue samples were wiped lightly with cotton wool made wet with deionized water and oven-dried at 80°C for 24 h. To determine Na and K concentrations, 100 mg of

Table 1
Physicochemical composition of soil used in this study

pH (H ₂ O)	EC (dS m ⁻¹)	CEC	Relative water content at saturation (%)	Total C (%)	Total N (%)	Exchangeable cation (mg/100 g)			Available P ₂ O ₅ (g kg ⁻¹)
						Ca ²⁺	Mg ²⁺	K ⁺	
5.9	0.65	27.5	17.2	0.7	0.2	8.1	1.4	1.3	0.3

powdered tissue sample was dry ashed at 600°C for 6 h and then soaked with 0.5 N HCl. The Na and K ion concentrations were determined using an atomic absorption spectrophotometer (AA630-12; Shimadzu Corp., Japan). For Cl, 100 mg of powdered tissue sample was soaked in 50 ml deionized water, shaken three times for 1 h, and then filtered with 0.5 µm pore filter (MX-13K; Showa Denko Corp., Japan). The Cl concentration in the extracted fraction was determined using an ion chromatograph (System 430; Waters Corp., USA) with an IC-524A column (Showa Denko Corp., Japan).

3. Results and discussion

Stem elongation of BET was not affected by any concentrations of NaCl at week 5 (Table 2). However, stem elongation of PYR was reduced at 100 mM and above. At week 10, stem elongation was greatly reduced at 150 mM in BET and at 50 mM in PYR.

At week 10, leaf burn on PYR was observed at lower NaCl irrigation than on BET. Dark-brownish leaf burn was observed at the base of a plant first and gradually developed to the upper parts. BET in 150 mM plot and PYR in all the salinised plots suffered heavily from leaf burn and defoliated. All PYR treated

Table 2

Stem elongation, leaf burn rating and survival rate of *P. betulifolia* and *P. pyrifolia* after 10 weeks of NaCl irrigation

NaCl (mM)	Week 5 Stem elongation ^a	Week 10		
		Stem elongation ^a	Leaf burn rating ^b	Survival rate (%)
<i>P. betulifolia</i>				
0	49.4 ± 4.3	171.0 ± 5.8	–	100
25	54.6 ± 7.4	107.4 ± 8.0	–	100
50	42.8 ± 6.9	85.2 ± 16.1	–	100
100	54.0 ± 8.5	93.6 ± 10.4	±	100
150	41.8 ± 2.6	57.8 ± 7.9	+	80
200	34.4 ± 3.8	35.4 ± 4.3	++	40
<i>P. pyrifolia</i>				
0	15.0 ± 5.2	34.0 ± 6.8	–	100
25	22.2 ± 4.4	33.8 ± 5.8	++	40
50	13.6 ± 4.2	17.6 ± 6.2	++	40
100	6.6 ± 2.8	11.8 ± 3.3	+++	0
150	2.4 ± 1.5	3.4 ± 1.5	+++	0

^a Mean ± SE of five replicates.

^b Leaf burn rating using five levels of visually identified symptoms: –, none; ±, leaf tip burn; +, ≤50% leaf laminae burn; ++, ≥50% leaf laminae burn; +++, defoliation.

Table 3

Effects of 10 week NaCl irrigation on sodium, potassium and chloride concentrations in leaves of *P. betulifolia* and *P. pyrifolia*

NaCl (mM)	<i>P. betulifolia</i>		<i>P. pyrifolia</i>	
	Week 5	Week 10	Week 5	Week 10
Na				
0	10 ± 2 ^a	17 ± 1	7 ± 1	20 ± 2
25	8 ± 2	28 ± 6	13 ± 3	181 ± 54
50	15 ± 2	117 ± 41	41 ± 6	358 ± 64
100	20 ± 4	171 ± 74	94 ± 34	419 ± 205
150	26 ± 14	296 ± 159	233 ± 45	643 ± 212
200	103 ± 75	524 ± 65		
K				
0	330 ± 28	267 ± 40	259 ± 28	323 ± 41
25	391 ± 8	247 ± 26	368 ± 27	588 ± 64
50	360 ± 11	311 ± 23	366 ± 55	476 ± 91
100	391 ± 29	393 ± 34	340 ± 24	437 ± 81
150	370 ± 49	414 ± 15	358 ± 48	377 ± 49
200	428 ± 13	400 ± 73		
Cl				
0	20 ± 8	49 ± 6	14 ± 2	25 ± 10
25	37 ± 20	169 ± 54	392 ± 59	1180 ± 217
50	45 ± 14	704 ± 189	544 ± 101	823 ± 121
100	107 ± 34	617 ± 180	696 ± 96	1177 ± 304
150	163 ± 76	597 ± 206	1112 ± 45	1189 ± 48
200	307 ± 126	1001 ± 275		

^a Mean ± SE mmol kg⁻¹ DW of five replicates.

with 100 mM or greater NaCl died. No plants died after NaCl irrigation was discontinued.

Leaf Na concentration in BET at week 5 was negligible except at 200 mM (Table 3). In contrast, that of PYR increased with 100 and 150 mM NaCl. At week 10, Na concentration increased proportionally to NaCl concentration applied. Leaf K concentration was elevated after 5 weeks of NaCl irrigation in both species. Leaf Cl concentration in BET increased in proportion to NaCl by week 5. On the other hand, Cl concentrations in PYR was elevated even at 25 mM NaCl. At week 10, Cl of BET was also increased by 50 mM NaCl. The Cl concentration in PYR was also increased at week 10.

Fruit trees are most susceptible to salinity during their young stage (Maas, 1990). Downton (1977) reported leaf burn in young Sultana grapevine cuttings 17 days after 125 mM NaCl irrigation. Zekri (1991) observed leaf burn and defoliation in young sour orange and Cleopatra mandarin seedlings after 6 months of -0.2 MPa (38 mM) NaCl irrigation. In the present experiment, BET

survived with slight leaf burn even under 100 mM NaCl irrigation for 10 weeks. However, PYR was easily damaged by 25 mM NaCl irrigation. Motosugi et al. (1987) examined the salinity tolerance of *Malus prunifolia* and Malling series apple rootstock clones under conditions similar to this study and observed dark-brown leaf burn induced by 20 mM NaCl irrigation after 60 days. The salt tolerance of PYR may be equivalent to that of these apple rootstocks.

The detrimental effects of salinity appeared both on stem elongation and leaf injury in this experiment but stem elongation was not strongly correlated to survival rate (Table 2). Reduction in yield correlates with the degree of leaf injury (Bernstein, 1965). Myers et al. (1995) assessed salinity response of 40-year-old Williams pear with 2.1 dS m^{-1} (approximately 20 mM) sprinkler irrigation and reported severe leaf burn when leaf Na and Cl ion concentrations reached 1–1.9 and 0.8–1.7%, respectively. In the present experiment, leaf burn was observed when leaf ion concentrations were 0.4–0.6% Na and 1.4% Cl in either species. Although age and size of plants are different between these two experiments, salt concentrations resulting in leaf scorch may be equal.

Munns and Termaat (1986) suggested that a larger plant mass provides more space for ion compartmentalisation and assists a plant in avoiding salt toxicity. Contribution of ion compartmentalisation may be clarified by testing pear scions grafted on both BET and PYR and controlling tree vigor. Hayashi (1955) noted that there was no difference between leaf osmotic potential of drought stressed BET and PYR. High survival rate of BET under salinity may also be due to Na and/or Cl ion exclusion at the root level.

In conclusion, BET shows potential as a pear rootstock for cultivation in areas of elevated soil salinity. As BET is grafting-compatible to both European and Asian pear cultivars, it appears to be worthwhile to continue further research at the various locations. Detailed tree growth and yield of grafted plants may be necessary to evaluate economic potential.

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