Effect of Saline Water Irrigation on Growth and Physiological Responses of Three Rose Rootstocks

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Abstract. **Salt-tolerant landscape plants are needed for arid and semiarid regions where the supply of quality water is limited and soil salinization often occurs. This study evaluated growth, chloride (Cl) and sodium (Na) uptake, relative chlorophyll content, and chlorophyll fluorescence of three rose rootstocks [*Rosa ×fortuniana* Lindl., *R. multiflora* Thunb., and *R. odorata* (Andr.) Sweet] irrigated with saline solutions at 1.6 (control), 3.0, 6.0, or 9.0 dS·m^{-1} electrical conductivity in a greenhouse. After 15 weeks, most plants in 9.0 dS·m^{-1} treatment died regardless of rootstock. Significant growth reduction was observed in all rootstocks at 6.0 dS·m^{-1} compared with the control and 3.0 dS·m^{-1}, but the reduction in *R. ×fortuniana* was smaller than in the other two rootstocks. The visual scores of *R. multiflora* at 3.0 and 6.0 dS·m^{-1} were slightly lower than those of the other rootstocks. *Rosa odorata* had the highest shoot Na concentration followed by *R. multiflora*; however, *R. multiflora* had the highest root Na concentration followed by *R. odorata*. All rootstocks had higher Cl accumulation in all plant parts at elevated salinities, and no substantial differences in Cl concentrations in all plant parts existed among the rootstocks, except for leaf Cl concentration in *R. multiflora*, which was higher than those in the other two rootstocks. The elevated salinities of irrigation water reduced the relative chlorophyll concentration, measured as leaf SPAD readings, and maximal photochemical efficiency of photosystem II (PSII) and minimal fluorescence (F$_o$)/maximum fluorescence (F$_v$/F$_m$), but the largest reduction in F$_v$/F$_m$ was only 2.4%. Based on growth and visual quality, *R. ×fortuniana* was relatively more salt-tolerant than the other two rootstocks and *R. odorata* was slightly more salt-tolerant than *R. multiflora*.**

The supply of high-quality water has become increasingly limited in many areas of the world, especially in arid and semiarid regions. With a rapid increase in the urban population, the intense competition for high-quality water among agriculture, industry, and recreational users has promoted the use of alternative water sources for irrigation. These sources include recycled water, treated effluents, and saline ground (well) waters that contain relatively high levels of soluble salts. Soil salinity is already a problem in arid and semiarid areas where irrigation is practiced. Over 50% of all irrigated lands are affected by salinity, yet the water used in these lands is

seldom saline (Pasternak and Malach, 1994). Because low-quality water has been or will be used for irrigation as a result of limited supply of high-quality water, soil salinization will increase in these areas.

Rose (*Rosa* spp.) is one of the most economically important ornamental crops in the world. Rose has been traditionally categorized as a salt-sensitive species with salt injury reported within a range of 0.5 to 3 dS·m^{-1} electrical conductivity (EC) depending on species, cultural medium, leaching fraction, and environmental conditions (Urban, 2003). However, other researchers reported that yield and quality of roses did not decrease when irrigated with drainage recycled water at EC of 3.5 dS·m^{-1}, provided that an appropriate rootstock and aerated medium were used (Cabrera, 2003; Raviv et al., 1998). Although a certain amount of information on salt tolerance is available for greenhouse cut roses (Bernstein et al., 2006; Cabrera, 2003; de Vries, 2003; Fernandez Falcon et al., 1986; Hughes and Hanan, 1978; Wahome et al., 2001), little research has been conducted on garden roses.

Most garden roses are produced by grafting using the T-budding technique (Pemberton, 2003). Different rootstocks are used in vari-

ous areas in the world in accordance with climatic and soil conditions. For example, *R. multiflora* is used in the south–central United States, Canada, and Japan (Pemberton, 2003) and is the most popular rose rootstock in Scandinavia (Stougaard, 1984), where *R. ×fortuniana* is used in areas with year-round temperate climate (Morrell, 1983). In the United States, *R. ×fortuniana* is mainly used in Florida and in the southwestern region (Martin, 2008). *Rosa odorata* is one of the most popular rose rootstocks for greenhouse cut flower, but is also used for garden roses (Cabrera, 2002; Singh and Chitkara, 1982, 1987).

The vigor and yield of flower production of the grafted plants are affected by rootstock selection (Pivetta et al., 2004). Wang (1992) found that *R. ×* 'Queen Elizabeth' budded onto *R. odorata* had a much higher survival rate than when budded onto *R. multiflora* after several years in an alkaline soil and irrigated with moderately saline water in a hot subtropical climate. Similarly, salt tolerance of grafted or budded plants is affected by rootstock selection in many woody plants (Cid et al., 1989). The salt tolerance of 'Bridal White' roses was relatively high when grafted onto *R. manetti* and *R. ×* 'Natal Brial' compared with *R. odorata* (i.e., *R. indica* 'Major'), *R. multiflora* 'Rum 9', and *R. ×* 'Dr. Huey' (Cabrera, 2003). The rootstock–scion relationship may affect the response of the grafted or budded plants to salinity. However, the relative salt tolerance of these rootstocks alone (without grafting) remains unknown. The objectives of this study were: 1) to investigate the relative salt tolerance of three rose rootstocks, *R. ×fortuniana*, *R. multiflora*, and *R. odorata*, by comparing the responses of growth, ion uptake, relative chlorophyll concentration, and chlorophyll fluorescence of these rose rootstocks to a range of salinity of irrigation water; and 2) to understand the general mechanism of salt tolerance.

Materials and Methods

Plant materials and culture. Unrooted cuttings of *R. ×fortuniana*, *R. multiflora*, and *R. odorata* were received from a commercial company on 22 June 2006 and were treated with Hormex (Brooker Chemical Corp., Chatsworth, CA) at 3000 mg·L^{-1} indole-3-butyric acid before being inserted into a 1:1 (by volume) rooting mix of coarse perlite and Sunshine Mix No. 4 (SunGro Hort., Bellevue, WA). Rooted cuttings were transplanted on 11 Aug. to 1.8-L round plastic pots containing a 1:1 mix (by volume) of Sunshine Mix No. 4 and composted mulch (Western Organics, Inc., Tempe, AZ). Plants were grown in a greenhouse from August to the end of October and irrigated with a nutrient solution containing 0.5 g·L^{-1} of 20N–8.6P–16.7K (Peters 20–20–20; Scotts, Allentown, PA). All plants were pruned to two shoots and uniform heights before treatment initiation. During the experimental period, the average air temperature in the

greenhouse was 21 ± 2.0 °C during the day and 17 ± 1.5 °C at night. The average daily light integral (photosynthetically active radiation) was 12.0 ± 1.2 mol·m^{-2}·d^{-1}. The instantaneous light intensity was measured by a quantum sensor (Model QSO-SUN; Apogee Instruments, Logan, UT) and the hourly average was recorded by a 21X data logger (Campbell Scientific, Logan, UT).

Treatments. Saline solutions were prepared by adding sodium chloride (NaCl), magnesium sulfate (MgSO$_4$·7H$_2$O), and calcium chloride (CaCl$_2$) at 87%, 8%, and 5%, respectively, on a weight basis to a nutrient solution. The nutrient solution was made by adding 0.5 g·L^{-1} of 20N–8.6P–16.7K (Peters 20–20–20; Scotts) to tap water. The major ions in the tap water were Na, Ca, Mg, Cl, and SO$_4$ at 184, 52.0, 7.5, 223.6, and 105.6 mg·L^{-1}, respectively. The composition of the treatment saline solutions was similar to that of the reclaimed municipal effluent of the local water utilities. Four salinity levels, EC at 1.6 (nutrient solution, control), 3.0, 6.0, or 9.0 dS·m^{-1}, were created. A 100-L tank of saline solution was prepared each time with confirmed EC for each treatment. The saline solution irrigation was initiated on 1 Nov. 2006 and ended on 15 Feb. 2007 (15 weeks). Rootstocks were randomly placed on greenhouse benches. Plants were irrigated manually with 600 mL treatment solution for all plants in the same treatment, which resulted in a leaching fraction of ≈45%, when the substrate surface started to dry to avoid water stress and overwatering. Irrigation frequency varied with climate, growth stage (biomass), and treatment. All plants were pruned on 13 Dec. to uniform heights when shoots were over 35 cm long and the pruned fresh weights were recorded in the greenhouse immediately.

Measurement. Visual foliar salt damage was assessed on all plants at the end of the experiment. Each plant was given a score of 1 to 5, in which 1 = over 50% foliar damage (salt damage: burning and discoloring) or dead; 2 = moderate (25% to 50%) foliar damage; 3 = slight (less than 25%) foliage damage; 4 = good quality with acceptable growth reduction and little foliar damage (acceptable as landscape performance); and 5 = excellent with no foliar damage.

Leaf greenness or relative chlorophyll concentration (measured as the optical density, SPAD reading) was recorded at the end of the experiment on three leaves per plant at similar middle positions of shoots for all plants in each treatment using a portable SPAD chlorophyll meter (Minolta Camera Co., Osaka, Japan). Although SPAD readings do not give an absolute measure of chlorophyll concentration, they do provide a useful relative index, which is closely related to leaf chlorophyll concentration (Markwell et al., 1995; Wang et al., 2005).

Leaf osmotic potential (ψ_S) was determined according to Ball and Oosterhuis (2005). Specifically, leaves were sampled from the middle section of the shoots in the early morning at the end of the experiment,

sealed in a plastic bag, and immediately stored in a freezer until analysis. Frozen leaves were thawed in a plastic bag at room temperature before sap was pressed with a Markhart leaf press (LP-27; Wescor, Logan, UT) and analyzed using a vapor pressure osmometer (Vapro Model 5520; Wescor). Osmometer readings (mmol·kg^{-1}) were converted to MPa using the van't Hoff equation at 25 °C (Nobel, 1991).

To examine the influence of increased salinity on leaf photosynthetic apparatus among the rootstocks, leaf chlorophyll fluorescence values, minimal fluorescence (F_o), maximum fluorescence (F_m), and the maximal photochemical efficiency of photosystem II (PSII) (F_v/F_m, $F_v = F_m - F_o$) were measured in the morning on young, fully expanded leaves 1 week before the end of the experiment using a Plant Efficiency Analyzer (Hansatech Instruments Ltd., Kings Lynn, UK). Before measuring, the leaves were dark-adapted for 10 min by attaching to the light-exclusion clips.

At the end of the experiment, leaf and stem fresh weights were determined by severing the main stem at the substrate surface

and separating the leaves and stems. Roots were washed free of substrate and fresh weights were recorded. Leaves, stems, and roots were oven-dried at 70 °C to constant weights and dry weights (DW) were determined. To monitor the root zone salinity, leachate was collected every 2 to 3 weeks during the experiment on three containers per treatment per rootstock. The EC of leachate was determined using a salinity meter (Model B-173; Horiba, Ltd., Kyoto, Japan).

To analyze sodium (Na) and chloride (Cl) concentrations, three of the 10 samples of roots, stems, and leaves per treatment were randomly selected. Dried tissue was ground with a stainless Wiley mill and the samples were submitted to the Soil, Water, and Air Testing laboratory (Las Cruces, NM) for Na and Cl analyses. Na concentrations were determined by EPA method 200.7 [U.S. Environmental Protection Agency (EPA, 1983)] and analyzed on an ICAP Trace Analyzer (Thermo Jarrell Ash, Franklin, MA). Cl was determined by EPA method 300.0 (U.S. EPA, 1983) and analyzed using an ion chromatograph (Dionex, Sunnyvale, CA).
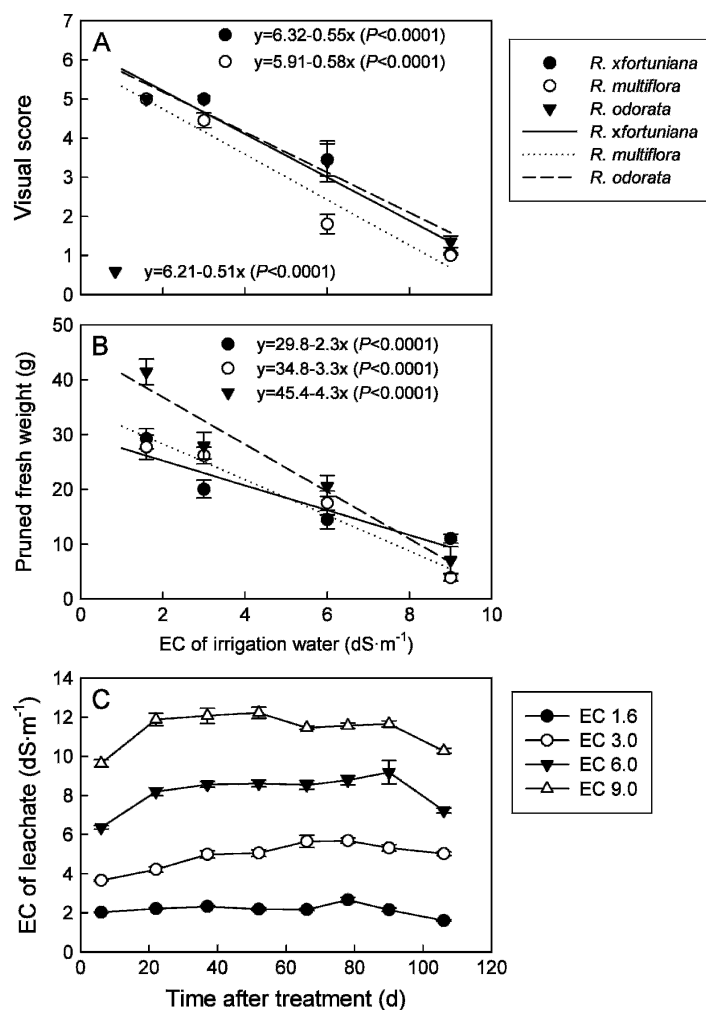

Fig. 1. Visual quality (**A**) and pruned fresh weight (**B**) in the middle of the experiment of rose rootstocks *Rosa ×fortuniana*, *R. multiflora*, and *R. odorata* grown in the greenhouse irrigated with saline solutions at various salinities for 15 weeks and (**C**) the time course of electrical conductivity (EC) of leachate during the experiment. Vertical bars indicate SEs.
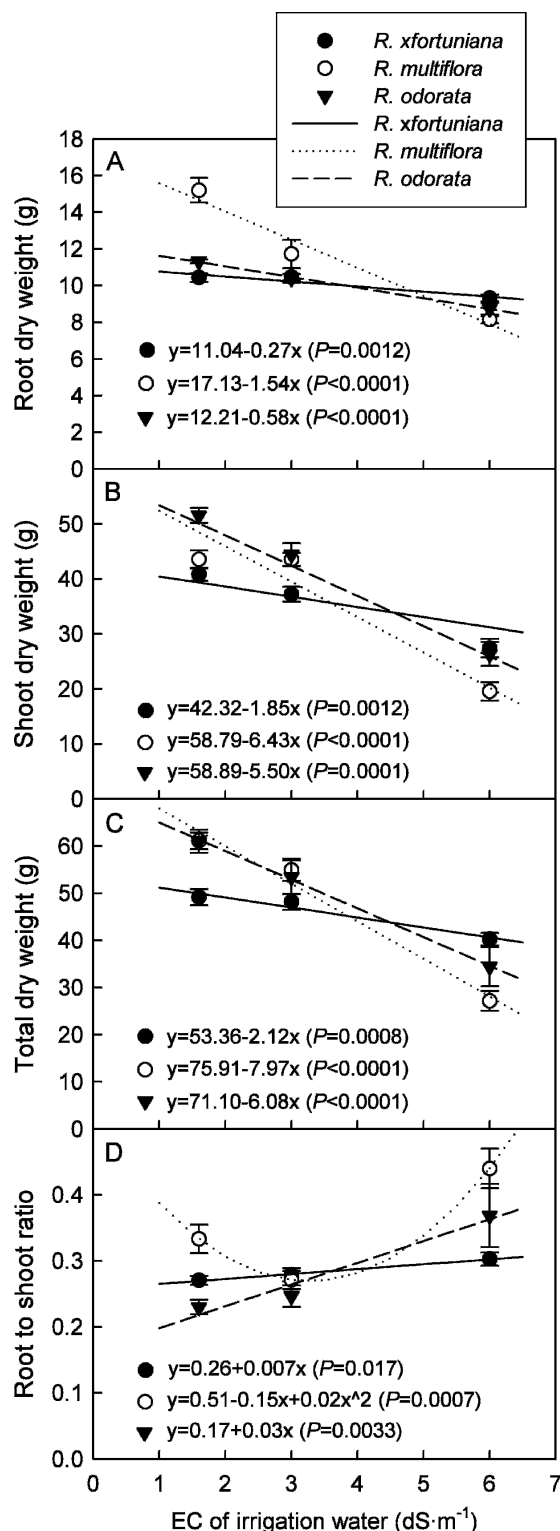
Fig. 2. Dry weight of roots (**A**), shoots (**B**), and total (**C**), and root to shoot ratio (**D**) of rose rootstocks *Rosa ×fortuniana*, *R. multiflora*, and *R. odorata* grown in the greenhouse irrigated with saline solutions at various salinities for 15 weeks. Vertical bars indicate SES.

Experimental design and data analysis. The experiment was a split-plot design with the salinity of the irrigation water as the main plot and rootstock as subplots with 10 replications. All data were analyzed by a two-way analysis of variance using PROC GLM. When main effect (the salinity of irrigation) was significant, linear or quadratic regression was calculated using PROC REG. When the interaction between the salinity of irrigation water and rootstock was not significant, data were pooled across salinity treatments or rootstock. The effect of rootstock was analyzed by Student-Newman-Keuls multiple comparison at $P = 0.05$. All statistical analyses were performed

using SAS (Version 9.1.3; SAS Institute, Cary, NC).

Results and Discussion

Survival rate, visual score, pruned fresh weight, and leachate electrical conductivity. All plants survived at 3.0 dS·m^{-1} and in the control (1.6 dS·m^{-1}) regardless of rootstock (data not shown). The survival rates of *R. ×fortuniana*, *R. multiflora*, and *R. odorata* were 60%, 60%, and 80% at 6.0 dS·m^{-1} and 10%, 0%, and 30% at 9.0 dS·m^{-1}, respectively. All rootstocks in the control had an excellent score without visible foliar salt damage (Fig. 1A). At 3.0 dS·m^{-1}, a few plants of *R. multiflora* had slight salt damage on lower leaves. The foliar salt damage became more severe as salinity of the irrigation water increased. Similar salt damage symptoms were observed on lower leaves of *R. odorata* in the 6.0 dS·m^{-1} and 9.0 dS·m^{-1} treatments as early as 3 weeks after the treatment initiation. However, the survival rate of this rootstock was slightly higher than the other two rootstocks at the end of the experiment. *Rosa multiflora* had lower visual scores than the other two rootstocks at 3.0 and 6.0 dS·m^{-1}. The pruned fresh weight decreased linearly as salinity of the irrigation water increased with sharper reduction slope in *R. odorata* compared with the other two rootstocks (Fig. 1B). The significant reductions in pruned fresh weights at elevated salinities indicate the early negative effect of salinity treatments on these rootstocks.

Rootstock did not affect leachate EC. Therefore, data were pooled across rootstocks (Fig. 1C). The leachate EC was 0.5 to 3.0 dS·m^{-1} higher than that of the irrigation solutions 3 weeks after the initiation of treatment and were stable during the experiment, possibly as a result of the high leaching fraction and well-aerated substrate that prevented excessive salt accumulation. In addition to leaching fraction, type of substrate affected leachate EC when plants were irrigated with saline solutions (Bernstein et al., 2006; Niu and Rodriguez, 2006a). Lower leaching fraction and poor-aerated substrate such as peat-based substrate led to salt accumulation in root zones.

Final growth. There were interactive effects of salinity and rootstock on DW of shoots and roots and root to shoot ratio, indicating that plant growth responses to salinity differed among rootstocks. Because most plants did not survive at 9.0 dS·m^{-1}, this treatment was excluded in data analysis. DW of roots, shoots, and total decreased linearly with salinity of the irrigation water in all rootstocks (Fig. 2A–C). Total DW decreased by 18%, 44%, and 56% and shoot DW decreased by 33%, 49%, and 55% in *R. ×fortuniana*, *R. odorata*, and *R. multiflora*, respectively, when the salinity of the irrigation water increased from 1.6 to 6.0 dS·m^{-1}. The shoot DW of *R. multiflora* was similar at 1.6 and 3.0 dS·m^{-1}. The reductions in DW of roots, shoots, and total were lowest in *R.*

×*fortuniana* and highest in *R. multiflora* at elevated salinities.

Root to shoot ratio increased linearly in *R. ×fortuniana* and *R. odorata* and quadratically in *R. multiflora* as salinity of the irrigation water increased (Fig. 2D). Root to shoot ratio increased by 11% and 60% in *R. ×fortuniana* and *R. odorata*, respectively, when salinity of the irrigation water increased from 1.6 to 6.0 dS·m⁻¹. The increased salinity of irrigation water resulted in more growth reduction in shoots than in roots in *R. ×fortuniana* and *R. odorata*. Root to shoot ratio in *R. multiflora* was lowest at 3.0 dS·m⁻¹ and highest at 6.0 dS·m⁻¹. This suggests that *R. multiflora* grew better shoots at 3.0 dS·m⁻¹.

Plants typically respond to salinity stress by reduced shoot and root growth with shoot growth reduction occurring earlier (Munns, 2002). Most crops tolerate salinity up to a threshold level above which growth or yield decreases as salinity increases (Maas, 1986). This threshold varies with species (Pasternak and Malach, 1994). In this study, *R. ×fortuniana* had smaller growth reduction in roots and shoots compared with *R. multiflora* and *R. odorata* at elevated salinities. Bernstein et al. (2006) reported that growth and cut flower yield did not decrease for *R. hybrida* 'Long Mercedes' grafted on the rootstock *R. indica* when irrigated with treated wastewater at EC of 2.5 dS·m⁻¹ (leachate EC up to 3.5 dS·m⁻¹). As the salinity of irrigation water increased, visible foliar salt damage occurred in rose rootstocks *R. chinensis* 'Major' and *R. rubiginosa* (Wahome et al., 2001), herbaceous perennials (Niu and Rodriguez, 2006a, 2006b), and woody shrubs (Wu et al., 2001) in addition to reducing growth. Similarly, we observed foliar damage in all rootstocks at 6.0 and 9.0 dS·m⁻¹ with more severe damage in *R. multiflora* at 3.0 and 6.0 dS·m⁻¹ compared with the other two rootstocks. For landscape ornamental plants, visual quality is more important than maximum growth. Based on growth and visual quality, *R. ×fortuniana* was more tolerant to salinity followed by *R. odorata*.

Sodium and chloride uptake. There were interactive effects of salinity of the irrigation water and rootstock on tissue Na and Cl concentrations, indicating that salinity effect on Na and Cl uptake varied with rootstock. In *R. ×fortuniana*, no differences in Na concentrations in stems and leaves were found among the salinity treatments (Fig. 3A–B). However, root Na concentrations increased linearly with salinity of the irrigation water in *R. ×fortuniana* (Fig. 3C). In *R. multiflora*, leaf and stem Na concentrations increased linearly with salinity of the irrigation water (Fig. 3A–B). Leaf Na concentration in *R. odorata* increased linearly; Na concentrations at 3.0 and 6.0 dS·m⁻¹ increased by 117% and 520%, respectively compared with that at 1.6 dS·m⁻¹. Stem and root Na concentration in *R. odorata* increased quadratically as salinity of the irrigation water increased. Root Na concentrations in *R. multiflora* were one to two times higher than those in *R.*

×*fortuniana* and *R. odorata*. However, stem Na concentrations in *R. odorata* were 1.5 to 10 times higher than those in *R. multiflora* across the treatments. Also, leaf Na concentration in *R. odorata* at 6.0 dS·m⁻¹ was 2.2 times that in *R. multiflora*.

The concentrations of Cl in plant tissue were much higher than those of Na (Fig. 3D–F). In *R. ×fortuniana*, leaf Cl concentration increased linearly, and Cl concentrations in stems and roots increased quadratically as salinity of the irrigation water increased. In *R. multiflora* and *R. odorata*, Cl concentrations in leaves, stems, and roots increased linearly with increasing salinity of the irrigation water. In leaves, Cl concentrations were higher in *R. multiflora* than in the other two rootstocks in all treatments. There were no substantial differences in Cl concentrations in stems in all treatments among the three rootstocks. However, Cl concentrations in roots at 6.0 dS·m⁻¹ was higher in *R. multiflora* than in the other two rootstocks.

Minimizing the entry of salt in plant (salt exclusion) is an important mechanism of salt

tolerance (Munns, 2002). In this study, *R. ×fortuniana* had higher Na exclusion ability than *R. multiflora* and *R. odorata* evidenced by lower Na concentrations in stems and leaves. *Rosa multiflora* had higher ability than *R. odorata* to restrict Na transport from roots to shoots. However, *R. multiflora* had higher tissue Cl concentrations, especially in the leaves, than the other two rootstocks, which may be the cause of lower visual scores. Wahome et al. (2001) compared the mechanisms of salt tolerance of two rose rootstocks: *R. chinensis* 'Major' and *R. rubiginosa*. They found that the lower leaves of less salt-tolerant *R. chinensis* 'Major' had higher Na concentration than in all other parts, whereas *R. rubiginosa* had higher concentrations of Na in the roots than in all other parts. Wu et al. (2001) also reported that salt-tolerant ornamental shrubs tended to accumulate less Na and Cl in leaves than salt-sensitive plants. Restriction of the uptake of Cl and Na in the roots and retaining these ions in roots thereby preventing the accumulation of these ions in stems and leaves are
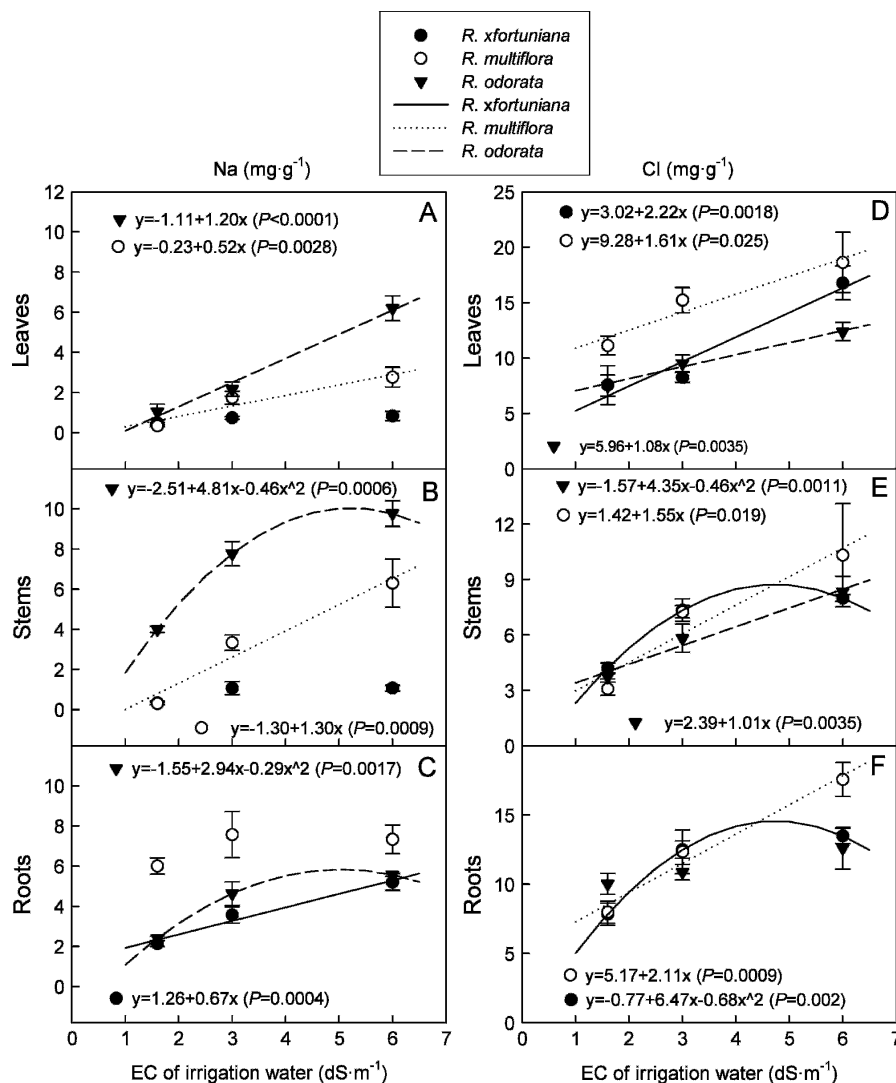
Fig. 3. Sodium (Na) and chloride (Cl) concentrations leaves (**A**, **D**), stems (**B**, **E**) and roots (**C**, **F**) of three rose rootstocks, *Rosa ×fortuniana*, *R. multiflora*, and *R. odorata* grown, in the greenhouse irrigated with saline solutions at various salinities for 15 weeks. Vertical bars indicate SEs.

important mechanisms of salt tolerance. Selection of rose rootstocks affects the salt tolerance of grafted plants (Cabrera, 2003). The accumulation of Na and Cl in leaves of scions is affected by rootstock selection (Cabrera, 2003). For example, the leaf Cl concentrations of 'Bridal White' plants grafted on $R.$ $odorata$ and $R.$ $multiflora$ 'Rum 9' were 1.5 times higher than in the other rootstocks (Cabrera, 2003).

Physiological response. There was no interactive effect between salinity and rootstock on leaf ψ_S. Also, there were no differences in leaf ψ_S among rootstocks. Therefore, data were pooled across rootstocks. The leaf ψ_S at the end of the experiment were -1.6 MPa, -1.9 MPa, and -2.0 MPa for the control, 3.0 $dS \cdot m^{-1}$, and 6.0 $dS \cdot m^{-1}$, respectively (data not shown). No statistical differences in leaf ψ_S were found between the control and 3.0 $dS \cdot m^{-1}$ or between 3.0 and 6.0 $dS \cdot m^{-1}$. However, leaf ψ_S in 6.0 $dS \cdot m^{-1}$ was higher than that in the control, possibly as a result of the accumulation of Na and Cl in leaves. Accumulation of Na and Cl in plant tissues under salinity has been associated with osmotic adaptation (Heuer and Nadler, 1998; Pardossi et al., 1999) and improvement of water status in *Vaccinium ashei* Rehd. (Wright et al., 1995) and *Pistacia* spp. (Picchioni and Miyamoto, 1990).

Salinity and rootstock interactively affected F_m but not F_v/F_m. For *R. ×fortuniana*, F_m decreased quadratically and was $\approx 10\%$ higher in the control than those at 3.0 and 6.0 $dS \cdot m^{-1}$ (Fig. 4A). In *R. multiflora*, F_m decreased linearly as salinity of the irrigation water increased and F_m in *R. odorata* did not change with salinity of the irrigation water. There was no difference in F_v/F_m among rootstocks (Fig. 4B). Although, F_v/F_m decreased quadratically as salinity of the irrigation water increased, the reduction was only 2.4% at 3.0 and 6.0 $dS \cdot m^{-1}$ compared with that in the control. Photochemical damage is reflected in either an increase in F_o or decreases in F_m or F_v/F_m (Thomas and Turner, 2001). In this study, we did observe decreases in F_m and F_v/F_m resulting from elevated salinities, but the magnitude is rather small, especially in F_v/F_m.

There was no interactive effect on leaf SPAD readings between salinity and rootstock. *Rosa ×fortuniana* had higher leaf SPAD readings compared with the other two rootstocks, indicating that *R. ×fortuniana* had greener leaves (Fig. 4C), which agreed with visual observation. Also, SPAD readings were lower at 6.0 $dS \cdot m^{-1}$ compared with 1.6 and 3.0 $dS \cdot m^{-1}$ (Fig. 4D). Leaf discoloration is one of the typical initial foliar salt damage symptoms (Devitt et al., 2005; Wu et al., 2001), which may be reflected by decreased SPAD readings. This is in agreement with our previous study in which leaf SPAD readings were reduced by elevated salinity of irrigation water in some of the herbaceous species (Niu et al., 2007). Although no relationships between chlorophyll concentrations and SPAD readings for these rose species have been previously

established, measuring leaf SPAD readings have been shown to be an efficient method to rapidly and nondestructively quantify the initial or mild salt damage in tomato (Montesano and van Iersel, 2007) and cherry rootstocks (Sotiropoulos et al., 2006).

It is important to note that the results of the relative salt tolerance of the three rose rootstocks obtained from this study may be used as a reference for selecting rose rootstocks. The salinity threshold for acceptable performance when grown in the field or in seasons other than winter needs to be confirmed, because plant response to salinity may be altered by factors such as climate, substrate, or soil conditions and irrigation. Also, further research is needed to investigate if the relative salt tolerance of the scions grafted or budded onto these rose rootstocks would be consistent with that obtained in this study.

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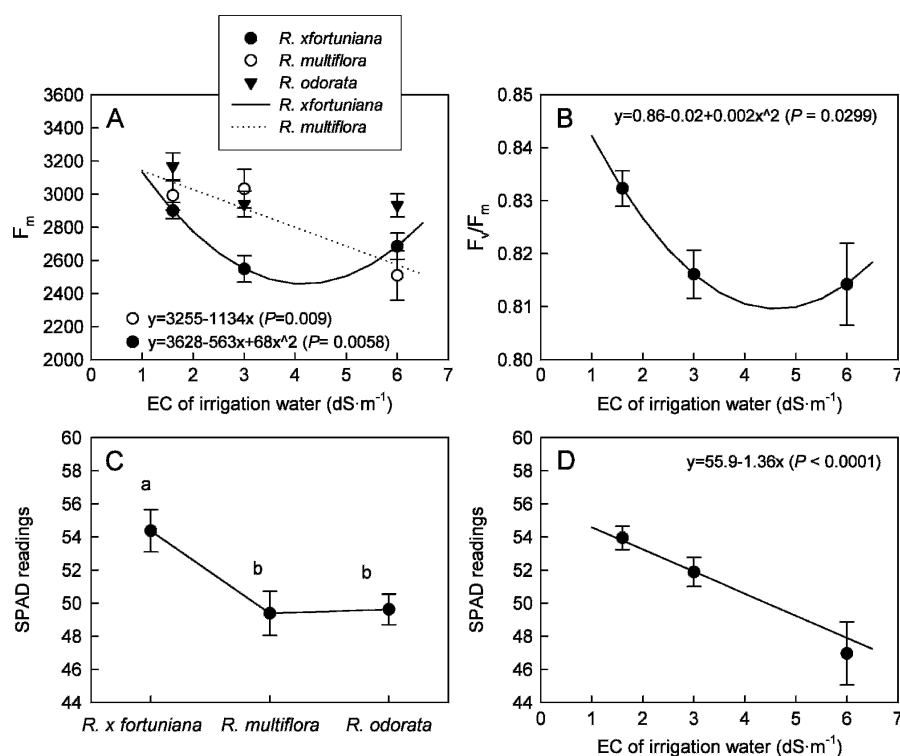Montesano, F. and M. van Iersel. 2007. Calcium can prevent toxic effects of Na+ on tomato leaf

Fig. 4. Chlorophyll fluorescence parameters, maximum fluorescence (F_m) (**A**), maximum photochemical efficiency of PSII (F_v/F_m) (**B**), and leaf SPAD readings (**C**, **D**) of three rose rootstocks, *Rosa ×fortuniana*, *R. multiflora*, and *R. odorata*, grown in the greenhouse irrigated with saline solutions at various salinities for 15 weeks. Vertical bars indicate SES.

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