Evaluating rootzone stresses and the role of the root system on rose crop productivity and fertilizer-water use efficiency:

Tissue nutrient contents, whole plant biomass and quality

Raúl I. Cabrera
Texas A&M University
Research and Extension Center
17360 Coit Road, Dallas, Texas 75252

Now at Rutgers University
Cabrera@aesop.rutgers.edu

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ICFG-HILL, P.O. Box 99, Haslett, MI 48840
ICFG.HILL@yahoo.com

In the last report we commented on the highest EC readings (avg. EC of 8.1 dS/m) observed in the leachates collected from one-half root sections receiving the supplemental urea applications, values even higher than those exposed to the NaCl stress (avg. leachate EC of 7.0 dS/m). We proceeded to analyze the collected leachates for total carbon (C) and nitrogen (N) concentrations (Fig. 1). Regarding leachate C, the root halves exposed to the high pH solutions had significantly higher concentrations (Fig. 1A) compared to the rest of the treatments, albeit those root halves receiving the NaCl stress were second in carbon concentrations. The supplemental bicarbonate (HCO_3-) salts used in the high pH (alkalinity) treatment was likely the main contributor to the high leachate C in this treatment, but a high root carbon exudation activity was also probable in the root sections subjected to high pH and salt stress. The literature indicates that under high pH conditions, dicotyledonous plants like roses release C-containing compounds (like carboxylates and phenolics) to acidify the areas next to the roots as a strategy to enhance the solubility and uptake of micronutrients like iron (Marschner, 1995). The osmotic and nutrient imbalance effects of NaCl stress could have also led to the production of carbon compounds that were exuded or leaked into the soil solution (Henry et al. 2002).

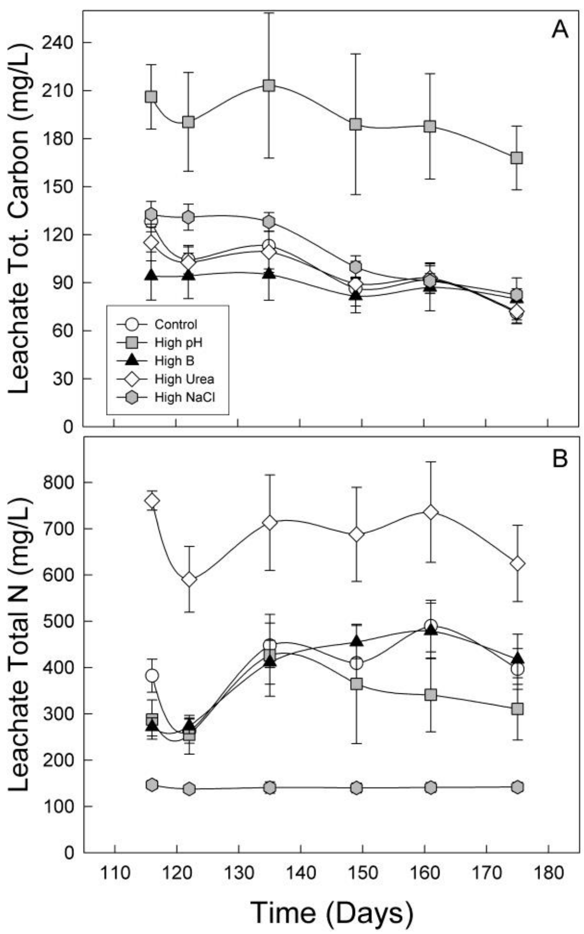

Figure 1. Total carbon (A) and nitrogen (B) concentrations in leachates collected from ‘Revival’ roses (on ‘Natal Briar’) growing on a split-root system fertigated with differential nutrient solutions. Data points are means (±s.e.) of 4 plants.

Regarding the N concentration in leachates, the root halves receiving supplemental urea applications had 85% more N (686 mg/L) than the average observed in those root sections receiving the control, high B and high pH solutions (avg. of 371 mg/L; Fig 1B). These values closely reflected the differences in the applied N concentrations (Cabrera et al., 1993). As a reference point, remember that the urea treatment had 74% more N than in the rest of the treatments (se previous reports). Most of the N in the leachates was in the nitrate form, with less than 1% being in the ammonium form (data not shown), indicating a high degree of nitrification in the substrate, and with the cultural practices, employed in this experiment. The significant nitrification of the supplemental N provided in the urea treatment might explain the lack of NH_4-toxicity symptoms, while at the same time the concomitant increase in leachate EC by the excess N found in the NO_3- form. These observations support the anecdotal reports by growers (in South America) and horticulturists (Cliff Low, personal communication) regarding the potential utilization of urea as a primary N form, particularly in the spring-summer months, without any toxicity effects, but actually enhancing the N status of the plants (see Table 1 below). The root halves exposed to NaCl had rather low total N leachate concentrations. This observation is attributed to a dilution effect associated with reduced plant water and N use caused by this stress (due to reduced growth; see previous reports and Table 2 below), and the production of much higher leachate fractions (average of 68%) compared to the rest of the treatments (average of 26%).

Table 1. Concentration of selected mineral nutrients, chlorophyll indexes and foliage quality ratings in leaves of rose plants (‘Revival’ on ‘Natal Briar’) growing on a split-root system fertigated with differential nutrient solutions. Data corresponds to leaves from flower shoots from harvest 4 (140 DAT). Values are means of 8 plants per treatment.

Treatments		**N**	**K**	**Ca**	**Mg**	**Na**	**B**	**Fe**	**Mn**	**Chlor. Index**	**Plant Quality**
Pot 1	**Pot 2**	(%)	(%)	(%)	(%)	(%)	ppm	ppm	ppm	(SPAD)	**Rating**
Control	**Control**	2.26	2.51	0.89	0.23	0.04	95	62	15	40.7	0.5
Control	**pH**	2.25	3.04	0.63	0.19	0.14	92	48	8	36.8	1.9
Control	**Boron**	2.25	2.77	0.90	0.22	0.05	195	68	12	40.4	1.6
Control	**Urea**	2.44	2.96	1.00	0.23	0.11	95	58	32	41.0	1.2
Control	**NaCl**	2.51	2.18	0.58	0.16	1.53	123	70	12	35.8	3.7

***** NOTE: Quality ratings taken at end of harvest 5. Scale: 0= Clean foliage, good color, no blemishes; 5= Foliage scorching/burn (all leaves), severe chlorosis, dead foliage and/or shoots.

The treatments applied to one-half of the root system not only affected the flower biomass and yield responses (see previous reports), but also the nutrient status and quality of the foliage and plants. On an overall basis, the plants receiving the salinity and high pH (alkalinity) treatments on one-half of their roots had the most distinct nutrient profiles, with the lowest Ca and Mg concentrations in both treatments, the lowest Fe and Mn in the high pH treatment, and the lowest K and highest Na in those plants exposed to salinity (Table 1). Undoubtedly, these nutrient profiles were directly related to the lowest chlorophyll indexes and poor plant quality ratings observed in the plants receiving these treatments (Fig. 2). These observations support our previous contention that even when partially localized, salinity (Cabrera and Perdomo, 2003), and to a lesser degree alkalinity (high pH; Reed et al., 1992), stresses have significant deleterious effects on the growth and quality of rose plants, and that the rest of the non-stressed root system cannot offset those effects (Cabrera et al., 2009). The urea treatment had not only a favorable effect on biomass and flower yields (see previous reports), but also on the overall nutrient profile of these plants (Table 1). These observations support the contention that the judicious utilization of urea as a main source of N during the spring and summer months (when leaf tissues shown in Table 1 were collected and analyzed) can potentially enhance the productivity and quality of the crop, without leading to the often feared NH_4-toxicity effects (Cabrera, 2000; Cabrera et al., 1996; Marschner, 1995).

Figure 2. Representative foliage from ‘Revival’ roses (on ‘Natal Briar’) growing on a split-root system, and fertigated with high pH (top) and high NaCl (bottom) stress solutions in one-half of their root systems. Th

Table 2. Dry weights (and their distribution) in tissues of rose plants ('Revival' on 'Natal Briar') growing on a split-root system fertigated with differential nutrient solutions. Whole plants were harvested at the end of the experiment, divided in organs, dried and weighed. Values are means of 4 plants per treatment.

Treatments		Leaves + New Shoots	Stems	Roots Pot 1	Roots Pot 1	Total Plant	S/R
Pot 1	**Pot 2**	(g/plant)	(g/plant)	(g/plant)	(g/plant)	(g/plant)	**Ratio**
Control	**Control**	40.0 (27)	86.0 (58)	10.5 (7)	11.9 (8)	148.3	5.6
Control	**pH**	18.3 (18)	68.6 (66)	9.5 (9)	7.8 (7)	104.2	5.1
Control	**Boron**	27.9 (22)	81.1 (63)	10.0 (8)	9.4 (7)	128.3	5.9
Control	**Urea**	35.4 (25)	83.1 (58)	11.1 (8)	13.1 (9)	142.7	5.0
Control	**NaCl**	10.3 (10)	68.2 (70)	10.1 (11)	8.5 (9)	97.1	4.3

***** NOTE: The numbers in parentheses denote the fraction (%) of each harvested organ from the total plant weight.

Four plants per treatment were destructively harvested and separated into major organs (leaves plus new shoots, stems and roots from the split pots) at the end of this study. Whole plant biomass was reflective of the cumulative harvested flowers (and biomass) reported before, with significant reductions in those plants having one-half of their root systems irrigated with salt and pH stressing solutions (Table 2). The plants receiving the high NaCl treatment in one-half of their root system had 35% less total biomass than the non-stressed control plants, whereas those receiving the high pH (alkalinity) solution had their total biomass reduced by 30%. On relative terms, the biomass loses in these two treatments were significantly concentrated in leaf and new shoot tissues, accounting for 10-18% of the total plant biomass, compared to the controls and plants receiving the partial boron and urea stresses, where these organs accounted for 22-27% of the total plant biomass (Table 2). On a relative basis the roots of the NaCl stressed plants accounted for 20% of the total plant biomass, compared to 15-17% for the rest of the treatments, and yielded the lowest shoot:root ratios for the salt stressed plants. Interestingly, the plants having one-half of their roots exposed to the high pH and high NaCl treatments had the highest reductions in biomass (19-22%) in these root sectors with respect to the other root halves receiving the non-stressing solutions.

The overall results and observations from these studies indicate that salinity and alkalinity stresses, even when localized only to one-half of the root system, continue to have significant negative effects on rose biomass, flower productivity and quality. What remains to be elucidated is whether the degree of these responses can be modulated by rootstock selection, as we only employed 'Natal Briar' for the studies. Previous results, including some from studies reported in this bulletin (and funded by the J.H. Hill Foundation and ICFGA), have indicated that rose crops responses to salinity (Cabrera and Perdomo, 2003; Cabrera et al., 2009) and alkalinity (Reed et al., 1992) stresses are significantly modulated by rootstock selection, and point to the need to maintain a cadre of rootstocks that can be utilized when dealing with certain environmental, edaphic and biotic stresses. Another major observation from the present studies has been the potential for the effective utilization of significant levels of urea-nitrogen in fertigation programs for roses, particularly during spring /summer months. It should be noted, however, that while the potential for NH_4-toxicity issues can be substantially lessened during these periods (Cabrera et al., 1996), the potential for substantial leaching losses will be high for open, unidirectional drainage, where these effluents are not recirculated or recycled (Cabrera et al., 1993).

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