Optimizing rose crop nutrient status and productivity through balanced cation and anion ratios:

Experimental set-up

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The first study from this project is an experiment that will help to establish the optimum ratios or proportions of cations (Mg^{+2}, K^{+} and Ca^{+2}) in a fertigation solution that are associated with maximum flower and biomass yields and quality in greenhouse roses. An expected additional benefit of such results is an enhancement of fertilizer use efficiency, minimizing its losses to drainage and reducing potential pollution issues.

Background

As we know the production of cut flowers in greenhouses, particularly roses, is a rather intensive activity, requiring the highest inputs of labor, energy, water, fertilizers and agrichemicals (Applied Plant Research, 2001).

Regarding fertilization, a good deal of research has been devoted to the establishment of the essential mineral nutrient concentrations needed to reach sufficiency levels in soils/substrates and leaf tissues (Rehm, 2009; White, 1986). Certain mineral elements, like nitrogen (N), calcium (Ca) and potassium (K), have received extensive attention due to its significant effect on flower productivity, quality and postharvest performance (Cabrera, 2003; Torre et al., 2001), but generally these have been studied in relative isolation. This means that the nutrient of interest is evaluated at different rates of application and the rest of the elements in the fertilization program or fertigation formulation are literally ignored, disregarding the fact that their concentrations and ratios in solution might be significantly changing, and affecting the plants' growth and quality responses. For example, in a recent study we observed that roses exposed to sodium-dominated salinity (276 ppm of Na) responded differentially depending on the ratios or proportions of the companion anions (Solis-Perez and Cabrera, 2007). Interestingly, in 'Natal Briar'-grafted roses, when the Na-companion anion concentrations were dominated by higher ratios of nitrate (NO_3-), the plants were more detrimentally affected by the salt stress, compared when chloride (Cl^-) and sulfate (SO_4=) were the dominant anions in the saline solutions.

The critical nutrient range methodology commonly employed to diagnose nutrient status in substrates and plants (Marschner, 1995; Rehm, 2009) and for fertilization recommendations (Cabrera, 2003; White, 1986), technically considers each element independent of the rest. This disregards nutrient interactions and ratios that can significantly affect the absorption, accumulation and effect of all other companion elements on plant yield and quality (Cadahia et al., 1995). There are other nutrient diagnostic techniques that consider nutrient interactions and ratios, including DRIS and CND (Marschner, 1995). Results from these methods in several agronomic and horticultural crops suggest that even when nutrient analyses of tissues and soil solutions might be considered to be within the recommended ranges of sufficiency, there might be hidden or potential nutrient imbalances that are significantly affecting flower yield and quality without being readily noticed by the growers and consultants. These methods, however, has been limited in commercial crop production, as they require, in addition to large initial datasets, fairly tedious statistical analyses of the data collected later during production to be able to render a useful diagnosis and recommendations for adjustments in the fertilization program.

The identification of optimal or suitable nutrient ratios that are associated with desirable flower yields and quality, in roses or any other crops, could be simplified through the utilization of mixture experiments (Cornell, 2002). These straightforward experiments could be used to help to make predictions of the crops' response (yield and/or quality) to any mixture of nutrients (anions or cations) and to measure the relative influence of each nutrient on the response, and which nutrient combination(s) maximizes the response. These types of studies have been made to establish the optimal nutrient ratios in horticultural crops exposed to alkalinity and salinity stresses (Solis-Perez and Cabrera, 2007; Valdez-Aguilar et al., 2008), but interestingly have not been used in crops growing under standard (normal, non-stressed) conditions.

We will be doing mixture experiments to establish the optimum ratios (proportions) of macronutrients, both cations (Mg^{+2}, K^{+} and Ca^{+2}) and anions (NO_3-, H_2PO_4-, SO_4=), associated with maximum rose flower yield and quality. In this first part we'll concentrate on the cations.

<u>The experiment</u>

A set of rose miniplants, 'Avalanche' grafted on 'Natal Briar', was graciously provided by Eufloria Roses (Nipomo, CA), and transplanted to 1 gallon containers with a peat:sand substrate, and grown for 1.5 months. Thereafter they were transplanted to 5-gallon containers filled with peat-based substrate (3 peat: 1 bark: 1sand), and let them grow and flower through two flushes of flowering to reach a good size. During this time my program with Texas A&M AgriLife Research was transferred from the Dallas to the Uvalde Research and Extension Center. Fortunately, in both locations we have the same type of glass-covered greenhouses (built by same manufacturer) and thus the transition and plant adaptation is going fairly smooth.

Up until now the plants have been fertigated with a standard complete nutrient solution based on a slightly modified 0.5X Hoagland solution (as in all of our previous studies). Within a few weeks of acclimation to the new greenhouses in Uvalde (Fig. 1), nutrient solution treatments will be applied to determine the optimum cation ratios.

There are a total of 7 nutrient solution treatments (T1 to T7) in a mixture matrix arrangement, plus a control solution (T8= 0.5X Hoagland), covering a wide range of cation (Mg^{+2}, K^{+} and Ca^{+2}) ratios (Table 1). The surface response plots generated for biomass (dry weights), flower yield and quality will allow for the establishment of both the optimum cation concentrations and their ratios when ammonium and anion concentrations (NO_3-, H_2PO_4-, SO_4=) are kept constant.

Each plant (container) will be individually irrigated with Roberts spitters (1 per pot) connected thru spaghetti tubing to ½" polyethylene pipes hooked to submersible pumps inside 160-L tanks containing the nutrient solutions listed in Table 1. Irrigation volume to be applied will be based on gravimetrically-determined evapotranspiration (ET) on control plants growing in single containers. Leachate solutions will be collected from each treatment and analyzed for EC, pH and ion concentrations.

Table 1. Solution formulations for study to establish optimum cation (Mg, K, Ca) ratios in roses.

Nutrient	Proportion	Cations (meq/L)				Anions (meq/L)		
Solution	Mg-K-Ca	Mg	K	Ca	NH_4	NO_3	H_2PO_4	SO_4
T1	0.81 - 0.08 - 0.11	7.25	0.75	1.00	1.0	7.0	0.5	2.5
T2	0.06 - 0.83 - 0.11	0.50	7.50	1.00	1.0	7.0	0.5	2.5
T3	0.06 - 0.08 - 0.86	0.50	0.75	7.75	1.0	7.0	0.5	2.5
T4	0.43 - 0.46 - 0.11	3.88	4.12	1.00	1.0	7.0	0.5	2.5
T5	0.06 - 0.46 - 0.48	0.50	4.12	4.38	1.0	7.0	0.5	2.5
T6	0.43 - 0.09 - 0.48	3.87	0.75	4.38	1.0	7.0	0.5	2.5
T7	0.31 - 0.33 - 0.36	2.75	3.00	3.25	1.0	7.0	0.5	2.5
T8 (control)	0.23 - 0.33 - 0.44	2.00	3.00	4.00	1.0	7.0	0.5	2.5

Note: All plants will also receive ½ strength Hoagland micronutrients concentrations and 1 ppm Fe-EDDHA. The calculated EC for the 10 solutions is ~1.7 dS/m (including 0.6 dS/m from the tap water used to prepare them).

Figure 1. Containerized rose plants, 'Avalanche' (on 'Natal Briar rootstock). The plants are being acclimatized for a few weeks in their new location (greenhouse) at the Texas A&M AgriLife Research and Extension Center in Uvalde.

Plant biomass and flower productivity/quality will be measured over several flushes of growth and flowering to assess the long-term crop response to the treatments. Additionally, we will monitor periodically physiological parameters like mineral nutrient and chlorophyll concentrations, stem water potential, leaf transpiration and photosynthesis. The onset of visible physiological and/or nutritional disorders will also be recorded

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