Progress Report

Evaluation of integrated nutrient diagnosis techniques to enhance productivity and quality in greenhouse rose crops

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Summary:

This project intends to generate information on integrated nutrient diagnostic techniques, like DRIS, as tools to enhance fertilizer use efficiency, and predict and correct nutritional imbalances that are affecting rose crop flower productivity and quality. The first part (in progress) deals with the theoretical generation & validation of these norms from currently existing datasets on leaf tissue nutrient status and productivity data, to be followed later by their experimental validation in a commercial rose crop. An additional companion study will evaluate the usefulness of expressing tissue nutrient concentrations on leaf area units compared to the conventional leaf dry mass, and how effective are their relationships (correlations) with flower yield and quality.

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Nutrient use efficiency in most agricultural and horticultural crops rarely exceeds 50%, and in intensively managed greenhouse crops, like roses, this could lead to major fertilizer losses to runoff and leaching/drainage, and undesirable environmental effects, when these are not captured and recycled. In addition, growers and horticulturists often find themselves at a loss when trying to interpret and correct nutrient imbalances and minimize flower productivity and quality loses associated with fertilization practices and crop nutrient status as diagnosed by conventional critical nutrient range (CNR) techniques. Advances in other horticultural crops suggest that integrated nutrient diagnostic techniques like Diagnosis and Recommendation Integrated System (DRIS) and Compositional Nutrient Diagnosis (CND) offer the prediction and correction of nutritional imbalances that significantly affect crop productivity, even when they are not diagnosed by the conventional CNR technique. In few words, these integrated nutrient diagnostic systems are based on the comparison of the results of plant tissue analysis with a norm based on nutrient ratios. The results are presented as indices that quantify, in a hierarchical order, the effect of each nutrient on the crop nutritional balance. The index values could be positive (indicating a possible nutrient excess) or negative (i.e. nutrient deficiency) and are presented on a continuous scale. Studies have demonstrated the advantages of these methods in the prediction of nutritional imbalances that significantly affect crop productivity, even when the plants have individual nutrient levels within the conventional sufficiency (optimum) ranges, and do not show any visual symptoms of deficiency (Fageria, 2001; Lucena, 1997). After conducting an exhaustive literature search we found that there is no information available on DRIS norms for rose crops, and other flower crops for that matter. This task is therefore the major goal of this project, to be carried-out with the assistance from a PhD student (John J. Franco-Hermida) and a colleague (Prof. Miguel Guzman) from the Protected Agriculture Program, University of Almeria, Spain.

For the generation of DRIS norms we had access to a database of almost 2,000 foliar analysis and their associated flower yields, taken from different rose cultivars grafted on the rootstock *R.* × 'Natal Briar'. This dataset was graciously provided by Queen's Flowers (Grupo GRChia S.A.), from their rose growing operations in the Bogota Plateau (Colombia). The DRIS method requires the selection of a high-yield plant population in advance of generating the norms. A flower production threshold of 130 flowers/m^2/yr (about 12 flowers/ft^2/year) was chosen to select the high-yield plant population, based on the upper limits of flower yield expectations for the Bogota Plateau region. The samples not meeting this yield threshold are pooled into a lower yielding plant population. We ran basic comparative statistics (including *F*-tests for differences between variances and *t*-test of mean differences) between these two rose plant populations, as shown in

Table 1. In here we also include information on other datasets that were employed later to do a theoretical calibration of the DRIS norms.

Table 1. Statistics for the high- and low-yielding rose plant populations and datasets used in the establishment and theoretical validation of nutrient diagnostic norms for rose crops, and recommended rose leaf nutrient concentrations from the literature.

Statistical Parameter[x]	**Pn**[y]	**Pn Rel.**[y]	**N**[z]	**P**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**Zn**	**Cu**	**B**
High-yielding population dataset													
Mean	144.2	--	3.84	0.28	2.03	1.48	0.30	0.38	89.3	128	53	8.2	68
Median	141.4	--	3.80	0.28	2.01	1.47	0.29	0.36	83.6	128	53	7.4	67
CV (%)	9.0	--	11.8	16.7	21.9	26.3	19.6	20.9	34.0	45	54	55.1	26
S	167.5	--	0.207	0.002	0.198	0.152	0.003	0.006	921	3280	827	20.3	303
Low-yielding population dataset													
Mean	95.4	--	3.76	0.29	2.00	1.50	0.31	0.37	87.2	110	51	7.7	70
Median	97.8	--	3.72	0.28	1.96	1.46	0.30	0.35	80.5	99	42	6.9	68
CV (%)	21.3	--	12.1	18.6	16.4	30.7	29.5	24.9	49.2	53	50	53.8	29
S	412.0	--	0.207	0.003	0.108	0.212	0.008	0.009	1845	3421	957	17.3	414
Cultivar dataset													
Mean	106.3	83.1	4.00	0.31	2.03	1.97	0.36	0.44	94	112	53	7.2	79
Median	108.8	82.9	4.00	0.31	1.98	1.89	0.35	0.44	87	101	47	6.6	78
CV (%)	17.6	16.8	11.1	12.3	16.3	23.5	20.8	17.5	29	49	42	40.8	17.8
SD	18.7	13.9	0.45	0.04	0.33	0.46	0.08	0.08	27	55	22	2.9	14
Charlotte dataset													
Mean	103.8	--	3.70	0.29	2.22	1.26	0.23	0.37	76	155	101	9.0	56
Median	105.9	--	3.70	0.28	2.20	1.23	0.23	0.34	70	148	95	7.5	58
CV (%)	17.9	--	9.6	12.6	10.8	18.9	19.6	19.9	25.5	39.0	65.9	49.6	20.6
SD	18.6	--	0.36	0.04	0.24	0.24	0.04	0.07	19.3	60.5	66.4	4.4	11.5
Nitrogen dataset													
Mean	--	75.2	3.00	0.34	2.63	0.84	0.25	0.34	70	120	48	18.2	83
Median	--	83.3	3.10	0.33	2.63	0.82	0.24	0.33	70	118	47	18.8	79
CV (%)	--	27.2	19.5	18.4	13.7	16.6	17.9	13.9	18.4	26.1	46.2	33.3	31.6
SD	--	20.4	0.59	0.06	0.36	0.14	0.04	0.05	12.9	31.29	22.2	6.05	26.3
***Recommended values for foliar nutrient concentrations for Rosa* spp.**													
Cabrera, 2003			3.0-4.0	0.2-0.4	1.5-2.5	1.0-2.0	0.2-0.4	0.15-0.25	50-150	50-200	20-50	3-15	30-80
Mills and Jones, 1996			2.8-3.6	0.24-0.33	1.6-2.2	1.0-1.7	0.3-0.43	--	75-384	91-179	20-49	5-8	24-63
Ortega, 1997			3.0-5.0	0.2-0.3	1.6-2.5	1.0-2.0	0.3-0.4	--	80-150	100-300	15-50	7-17	40-80
White, 1986			3.0 - 5.0	0.2-0.3	1.8-3.0	1.0-1.5	0.25-0.35	--	50-150	30-250	15-50	5-15	30-60

[x] CV (%)= coefficient of variation; SD= standard deviation; S= variance; *n:* sample number. The high-yielding population was selected for flower productivities ≥ 130 flowers·m2·yr^{-1}.

[y] Pn= Flower productivity (flowers·m2·yr^{-1}); Pn Rel.= Relative flower productivity.

[z] Macronutrients expressed in % DW and micronutrients in mg·kg^{-1} DW.

It is very interesting to notice that the average nutrient values for the high-yielding rose population do not differ from the optimum ranges reported for roses (Cabrera, 2003, Mills and Jones, 1996; Ortega, 1997; White, 1986), except for Zn, which is slightly higher. The values for Mn, Fe, Cu, B and Zn reported by different authors denote a rather wide range, which concurs with the high coefficients of variation observed for these elements in both the high-yield and low-yield rose plant populations (Table 1). The overall major observation drawn from the data in Table 1 is that the sole application or use of the traditional critical nutrient range (CNR) technique would not have distinguished any potential nutrient imbalances in either of the two plant populations nor predicted their potential flower yield differences.

We established the DRIS norms by initially calculating all the possible ratios (direct and inverse relations) between elements (Table 2). The functions for the element ratios and DRIS indexes were determined according to the methodology of Beaufils (1973). Only one of the two possible combination ratios for a pair of elements was selected (direct or inverse). The first selection criterion was the *F*-test for differences between variances and when none of the two combinations had significant differences, a *t*-test of mean differences was applied. If these procedures did no yield significant differences the nutrient ratio with the highest *F*-test value was chosen. Tissue concentrations for N, P, K, Ca, Mg and S were expressed as percentages of dry matter and the micronutrients in mg/kg. In the ratios involving elements expressed in different units, the elements expressed in percentages were multiplied by 100 to obtain easier to handle numbers, with less decimal places, minimizing the yielding of very low or high variances.

Table 2. Ratios and DRIS norms selected for rose plants, grafted on the rootstock *R.* × 'Natal Briar', obtained from a population with yields ≥130 flowers/m^2/yr.

Ratios ^{v}	**Mean**	**CV (%)**	***F* test** (S_b/S_a) ^{x}	***t* test** ($\mu_a <> \mu_b$) ^{y}
P/N	0.074	17.08	1.19 *	0.2
K/N	0.53	21.65	0.7	0.01 *
Ca/N	0.39	26.79	1.41 *	0.8
Mg/N	0.078	19.27	2.77 *	0.002 *
N/S	10.48	20.51	1.18 *	0.02 *
Fe/100N	3.45	37.47	1.58 *	0.3
Mn/100N	4.88	44.59	1.15 *	0.04 *
Zn/100N	2.03	53.36	1.29 *	0.01 *
100N/Cu	59.44	65.54	0.6	0.0006 *
B/100N	2.62	29.23	1.15 *	0.8
P/K	0.14	20.00	1.15 *	0.5
P/Ca	0.21	38.01	1.26 *	0.8
Mg/P	1.08	22.85	2.38 *	0.4
P/S	0.77	26.16	1.38 *	0.6
Fe/100P	0.25	37.37	2.53 *	0.06 *
100P/Mn	0.29	69.67	1.58 *	0.5
Zn/100P	0.15	54.00	1.3 *	0.1
Cu/100P	0.022	53.67	0.9	0.01 *

Ratios [v]	Mean	CV (%)	*F* test (S_b/S_a) [x]	*t* test ($\mu_a <> \mu_b$) [y]
B/100P	0.19	31.89	1.27 *	0.3
K/Ca	1.46	32.15	1.1	0.2
Mg/K	0.15	22.71	2.38 *	0.7
S/K	0.19	23.18	1.57 *	0.002 *
100K/Fe	2.42	27.40	1.1	0.001 *
Mn/100K	2.61	49.14	1.0	0.08 *
Zn/100K	1.08	59.31	1.18 *	0.3
100K/Cu	31.06	62.68	0.7	0.6
100K/B	3.18	32.21	1.0	0.6
Mg/Ca	0.21	23.63	2.48 *	0.2
S/Ca	0.27	31.27	1.32 *	0.8
Fe/100Ca	1.36	48.52	1.62 *	0.03 *
Mn/100Ca	1.91	52.77	1.17 *	0.6
Zn/100Ca	0.81	65.79	1.16 *	0.4
Cu/100Ca	0.12	66.63	1.0	0.0002 *
B/100Ca	1.03	42.38	1.39 *	0.4
Mg/S	0.81	22.64	2.51 *	0.7
100Mg/Fe	0.35	25.96	2.5 *	0.7
Mn/100Mg	0.38	48.16	1.28 *	0.2
Zn/100Mg	0.16	57.37	1.54 *	0.9
100Mg/B	0.47	35.9	1.5 *	0 *
Fe/100S	0.34	42.2	1.5 *	0.7
100S/Mn	0.39	68.3	1.24 *	0.6
Zn/100S	0.20	61.9	1.1	0.04 *
100S/Cu	5.68	55.5	0.9	0.6
B/100S	0.26	35.7	1.3 *	0.5
Fe/Zn	2.12	53.8	1.8 *	0.3
Fe/Cu	13.41	62.2	1.0	0.04 *
B/Fe	0.81	32.8	1.3 *	0.9
Mn/Zn	2.85	56.6	0.7	0.03 *
Cu/Mn	0.086	91.6	1.5 *	0.9
B/Mn	0.71	78.0	1.1	0.06 *
Cu/Zn	0.19	66.7	1.1	0.5
B/Zn	1.59	49.3	1.2 *	0 *
B/Cu	10.14	52.7	1.0	0.05 *

[v] For the calculation of these ratios, macronutrients were expressed in % of dry weight, and micronutrients in mg·kg^{-1}.

[x] S_a and S_b: Variance of the high-yield and low-yielding populations, respectively.

[y] μ_a and μ_b: Mean of the high-yield and low-yielding populations, respectively.

[z] The values followed by * are significant at α=0.1.

Out of all the possible elemental nutrient ratios (direct and inverse relations) in the high-yielding rose population, 55 were selected as DRIS norms (Table 2). The observation of a large number of norms with significant differences (in variances and/or means) with respect to the low-yielding population suggests these norms are reliable, and furthermore indicate that differences in productivity are likely due to nutritional imbalances (Jones, 1981). When there is a very low variance in a norm from the high-yielding population (high *F* values, >2), and in addition the mean has a small variance (relatively low CV), this leads to the contention that the crop is very responsive to a small change in that balance (norm). In the selected norms (Table 2), the ratios of Mg/N, Mg/P, Mg/K, Mg/Ca, Mg/S, 100Mg/Fe meet these conditions, which suggests that small changes in the concentrations of Mg have a highly significant impact on the flower yields of rose plants. Magnesium is hereby identified as a limiting element. And indeed, one of the most common nutrient deficiencies in rose crops in the Bogotá Plateau is Mg, largely attributed to an antagonistic effect of K (Marschner, 1995), which is very high in the soils from this flower-growing region, averaging over 900 mg/kg (Ortega, 1997). Given these results, it is contended that nutrient imbalances associated with limiting Mg levels significantly affect rose crop productivity in this region.

Theoretical validation of the DRIS norms. The relationships between productivity, expressed as flowers/m^2/yr or in relative terms, and the nutritional balance index (IBN) were significant when the DRIS methodology was applied to the "Cultivars" (shown in Fig. 1A,B) and other datasets (not shown). These results validate the use of these diagnostic norms in the prediction of nutrient imbalances in roses grafted on the 'Natal Briar' rootstock, and concur with similar studies in other crops.

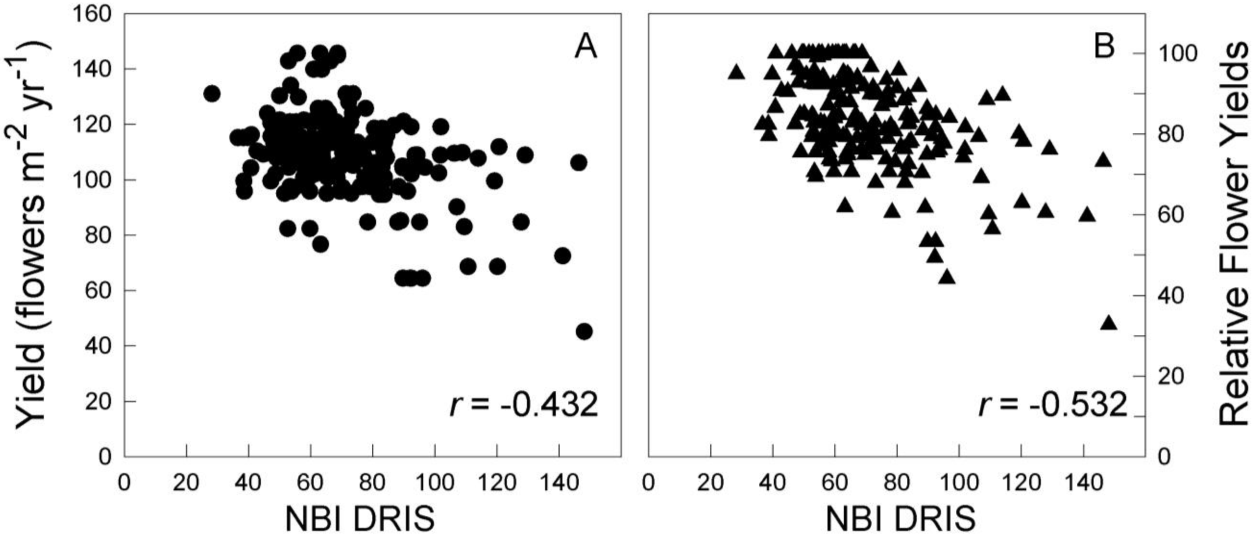

Figure 1. Correlations between absolute and relative rose flower productivities and the DRIS balance indices for a population conformed by plants from 39 rose cultivars grafted on 'Natal Briar' (P<0.001; n=191). NBI = Nutrient Balance Index.

It should be noted that a relevant characteristic of the "Cultivars" dataset is that it was composed with data from 39 rose cultivars grafted 'Natal Briar' and represents several greenhouse locations and soils, and plants aged from one to seven years. In practice, and as observed in other crops, this diversity ensures a broad applicability of the norms across a growing region, encompassing a wide range of cultivars, soils, plant ages and environmental conditions. The use of relative flower productivities from the "Cultivars" dataset allowed for a reduction in the variability given by the inherent genetic potential of each rose cultivar, which is independent of a plant nutrient status, but produced an enhanced correlation (Fig. 1B). This supports the contention that when the potential impact of the plant genetics variable is diminished, the nutrient diagnosis method is likely to predict with more precision the expected productivity response, as this will then depend to a larger extent on environmental variables and production cultural practices, including crop fertilization (Hoog, 2001). The use of relative flower and/or biomass yields has been previously employed to establish critical leaf tissue chloride values in greenhouse roses, and salinity thresholds in garden roses and other horticultural and agronomic crops, employing datasets that spanned over time and space scales.

We are experimentally testing the practical use of these preliminary nutrient diagnostic (DRIS) norms, to fine tune fertilization recommendations and practices to correct any rose crop imbalances and disorders predicted by the application of these norms. In future reports we will also share with you about our companion study that will evaluate the usefulness of employing rose leaf tissue nutrient status expressed on a leaf area basis versus the conventional dry weight basis.

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