J. Hort. Sci.
Vol. 1 (1): 28-32, 2006

Development of diagnostic leaf nutrient norms and identification of yield limiting nutrients using DRIS in rose grown under protected conditions

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ABSTRACT

Leaf samples collected from protected cultivation units of rose around Bangalore (Karnataka) and Hosur (Tamil Nadu), when flower buds were at pea size, were processed and analyzed for various nutrients and thus, the data bank was established. By using Diagnosis and Recommendation Integrated System (DRIS), nutrient expressions, which have shown higher variance and lower coefficient of variation, were selected as norms viz. N/P(13.02), K/N(0.85), N/S(11.10), P/S(0.853), K/P(11.0), N/Ca(2.18), N/Mg(7.18) etc. In addition, five nutrient ranges have been derived using mean and standard deviation as low, deficient, optimum, high and excess for each nutrient to serve as a guide for diagnostic purpose. The optimum N ranged from 2.53 to 2.96% , P from 0.19 to 0.23%, K from 2.23 to 2.72%, Ca from 1.15 to 1.59%, Mg from 0.41 to 0.55% and S from 0.21 to 0.27%. Among the micronutrients, the optimum Zn ranged from 28 to 64 ppm, Fe from 176 to 240 ppm, Mn from 107 to 175 ppm and Cu from 13 to 21 ppm for roses under protected conditions. The diagnosis of nutrient imbalance (DRIS indices) indicated that the most common yield limiting nutrients were potassium and magnesium among the macronutrients and iron and zinc among the micronutrients in protected cultivation units of rose.

Key words: Nutrients, norms, DRIS indices, rose, protected conditions

INTRODUCTION

With the introduction of liberalization policy in agriculture, rose cultivation in poly-houses became popular in India especially in Karnataka and Tamil Nadu for the export of quality cut flowers. As the nutrient removal is very high under protected cultivation due to removal of long stalks/stems for export purpose, its nutrient requirements have to be carefully monitored through plant/leaf analysis for high productivity and quality. For efficient fertilizer programme, leaf nutrient standards are required to be developed, as no established norms are available for roses grown under protected conditions. There are a few reports in the literature on the use of Diagnosis and Recommendation Integrated System (DRIS) in ornamental plants (Mourao Filho, 2004). Therefore, an investigation was carried out to develop leaf nutrient norms using DRIS, which in addition predicts the yield-limiting nutrients in the order of importance (Beaufils, 1973).

MATERIAL AND METHODS

Establishment of Data bank

Leaf Sampling

In a survey conducted in Karnataka and Tamil Nadu, 320 leaf samples were collected from various protected cultivation units of rose during the years 2002 and 2003. At each site, composite samples of recently matured 5thleaflets (Jones *et al*, 1991) were collected from 50 plants to develop leaf nutrient norms/standards. It is essential to select a specific part of the same physiological age at a definite location on the plant at definite stage of growth (when flower buds were at pea size).

Decontamination and Analysis of Samples

Tissue samples were decontaminated by washing first with tap water to remove the dirt or soil, then in 0.2% detergent solution and in N/10 HCl solution to remove residues of chemical spray materials on the leaf surface followed by washing in single and double distilled water (Bhargava and Raghupathi, 1993). Excess water on the surface of the leaves was removed by pressing between the folds of blotting paper and the leaves were dried in an oven at 70-75°C for 48 h. After complete drying, the samples were powdered in a Cyclotec Mill. and were stored in polycarbyl containers for analysis. The samples were analyzed for different nutrients (except nitrogen) by digesting 1g tissue in di-acid mixture (9:4 ratio of nitric acid and perchloric acid) by using standard analytical methods (Jackson,1973). Nitrogen was estimated by micro-kjeldhal method whereas phosphorus, potassium and sulphur by vanado-molybdate, flame-photometer and turbidity methods, respectively. Calcium, magnesium and the micronutrients Fe, Mn, Cu and Zn were analyzed by using Atomic Absorption Spectrophotometer (Perkin-Elmer-A-Analyst-200). Thus, the data bank was established for the whole population.

Computation of DRIS norms

By using DRIS, the whole population was divided into two sub-groups namely low and high yielding (Beaufils, 1973; Bailey *et al*, 1997; Walworth and Sumner, 1987) based on the production of number of flowers/plant/year. From the experience of the growers, 175 flowers/plant/year was considered as the cut off yield between low and high performing gardens. The cut off yield was positioned in such a way that the high yielding sub-population reflects conditions that are deemed desirable (Beaufils, 1973). However, Letzsch and Sumner (1984) have shown that the actual cut off value used has little effect on the norms developed as long as it is not too low. Each parameter was expressed in as many forms as possible, e.g. N/P, P/N, NxP etc. A X^2-test was run for each form of expression to ensure that each sub-population is normally distributed after which the mean, variance, standard deviation for all forms of expressions were calculated together with the coefficient of variation. Expressions having comparable means (by T-test) and significant variance ratios between the two sub-populations were retained as being discriminatory. Among different forms of expressions, the one showing higher variance ratio (Variance of low yielding / variance of high yielding) was selected as norm (Letzsch, 1985; Walworth and Sumner, 1987).

DRIS indices

DRIS provides a means of ordering nutrient ratios into meaningful expressions in the form of indices. The DRIS indices were calculated as described by Walworth and Sumner (1987) by using the following formula, as an example for one nutrient is shown below:

$$N = 1/10[-f(P/N)-f(K/N)+f(N/Ca)+f(N/Mg)-f(S/N)-f(Fe/N)+f(N/Mn)+f(N/Zn)-f(Cu/N)+f(N/dw)]$$

$$\text{Where, } f(N/P) = \left|\frac{N/P}{n/p} - 1\right| \left|\frac{1000}{CV}\right| \text{ hen } N/P > n/p$$

$$\text{and } f(N/P) = \left|1 - \frac{n/p}{N/P}\right| \left|\frac{1000}{CV}\right| \text{ when } N/P < n/p$$

where N/P, the actual value of the ratio of N and P in the plant under diagnosis;

n/p, the value of the norm (which is the mean value of the high yielding unit);

CV, coefficient of variation for population of high yielding units.

Similarly, the indices for other nutrients have been calculated using appropriate formulae. The absolute sum values of the nutrient indices generate an additional index called NBI, the nutritional balance index (Walworth and Sumner, 1987).

Leaf nutrient guides/ranges derived from mean and standard deviation

Five leaf nutrient guides/ranges have been derived using mean and standard deviation as deficient, low, optimum, high and excess for each nutrient. The optimum nutrient range is the value derived from "mean -4/3SD (standard deviation) to mean + 4/3SD". The range "low" was obtained by calculating "mean - 4/3 SD to mean - 8/3SD" and the value below "mean - 8/3 SD" was considered as deficient. The value from "mean + 4/3 SD to mean + 8/3 SD" was taken as high and the value above "mean + 8/3 SD" was taken as excessive (Bhargava and Chadha, 1993).

RESULTS AND DISCUSSION

Leaf nutrient concentrations

The leaf nutrient status under different protected cultivation units varied differently. For the entire population of roses, the leaf N concentration varied from 2.16 to 3.11% indicating that the nitrogen content was low at least in some of the low yielding gardens when compared to optimum value. P ranged from 0.138 to 0.266% whereas potassium varied from 1.15 to 2.80% for the entire population (Table 1). Among the micronutrients, Fe ranged from 110 to 268 ppm and was generally considered high but was not high under protected cultivation as most of the plants were showing deficiency symptoms in the low yielding gardens though the lowest iron concentration recorded was 110 ppm in a garden, which is normal for many crops.

DRIS ratio norms

Forty-five nutrient expressions chosen as diagnostic norms from high yielding population are presented in

Table 1. Mean and range of leaf nutrient concentrations for the whole population

Nutrient	Unit	Range	Mean
N	%	2.16-3.110	2.558
P	%	0.14-0.266	0.198
K	%	1.15-2.800	2.194
Ca	%	0.68-1.770	1.179
Mg	%	0.22-0.560	0.358
S	%	0.17-0.320	0.229
Fe	ppm	110-268	174
Mn	ppm	38-193	97
Zn	ppm	18-136	43
Cu	ppm	02-022	10

Table 2. DRIS ratio norms for rose grown under protected conditions

Selected Ratios	Norms	CV (%)	Selected Ratios	Norms	CV (%)
N/P	13.020	14	K/Fe	0.013	35
K/N	0.853	16	K/Mn	0.026	44
N/Ca	2.182	24	K/Zn	0.059	51
N/Mg	7.183	28	K/Cu	0.293	39
N/S	11.110	19	Ca/Mg	3.324	20
N/Fe	0.015	29	S/Ca	0.201	29
N/Mn	0.030	45	Ca/Fe	0.007	27
N/Zn	0.069	48	Mn/Ca	83.120	40
Cu/N	4.304	47	Ca/Zn	0.031	41
K/P	11.000	15	Cu/Ca	8.850	42
P/Ca	0.170	29	S/Mg	0.657	30
P/Mg	0.556	27	Fe/Mg	483.800	22
P/S	0.853	12	Mn/Mg	262.200	28
P/Fe	0.001	29	Mg/Zn	0.009	37
P/Mn	0.002	42	Cu/Mg	28.260	38
P/Zn	0.005	46	S/Fe	0.004	28
Cu/P	56.070	47	Mn/S	438.400	43
K/Ca	1.873	32	S/Zn	0.006	44
K/Mg	6.155	31	Cu/S	46.800	44
K/S	9.467	23	Mn/Fe	0.552	28
Fe/Zn	4.505	45	Cu/Fe	0.059	39
Mn/Zn	2.397	48	Cu/Mn	0.112	42
Cu/Zn	0.252	35	—	—	—

Table 2. It was established that a particular nutrient expression should have a high variance and low coefficient of variation, to be chosen as diagnostic norm between high and low yielding population, for greater diagnostic precision (Walworth and Sumner, 1987 and Angeles *et al,* 1993). Based on this principle, these 45 nutrient expressions were chosen as diagnostic norms *viz.* N/P (13.02), K/N(0.85), N/S(11.10), P/S(0.853), K/P(11.0), N/Ca(2.18), N/Mg(7.18) etc. and have shown lower CV values compared to others and may have greater physiological rationale (Raghupathi *et al,* 2004). Maintaining the ratios of some expressions at optimum when they were with large coefficient of variation was much less critical for the performance of the crop. Therefore, the nutrients considered as yield building components, need to be kept in a state of relative balance for maximum efficiency of dry matter production (Raghupathi *et al,* 2004).

Identification of yield limiting nutrients by DRIS indices

The nutrient imbalance in plants was diagnosed through DRIS indices. DRIS provides a means of ordering nutrient ratios into meaningful expressions in the form of indices. A DRIS index is a mean of the deviations of ratios containing a given nutrient from their respective normal or optimum values. Thus, the relative abundance of each nutrient was evaluated by comparing all ratios containing that nutrient (N/P, NxK, Ca/N etc.) with the DRIS norms. As the value of each ratio function was added to one index sub-total and subtracted from another prior to averaging, all indices were balanced around zero (Table 3). Thus, the nutrient indices sum to zero indicating an optimum level, negative values a relative deficiency and positive values a relative excess of that nutrient (Beverly, 1991). The yield limiting nutrients were differing from garden to garden though some of the nutrients were more prominent. The order in which the nutrients were limiting the yield indicated that most often more than one nutrient was limiting the yield (Table 3). However, the diagnosis of nutrient imbalance indicated that the most common yield limiting nutrients are found to be potassium and magnesium among the macronutrients and zinc and iron among the micronutrients in the protected cultivation units growing rose crop.

Nutritional balance index (NBI)

The absolute sum values of the nutrient indices generate an additional index called nutritional balance index (Walworth and Sumner, 1987). The overall imbalance of the nutrient was assessed based on the sum of indices irrespective of sign (Table 3). Higher the sum value, larger will be the plant nutritional imbalance and, therefore, the lower will be the yield. However, the yield cannot be predicted from sum of indices irrespective of the sign because of the influence of unmeasured factors that affect the yield but not included in the calculation of DRIS indices (Sumner, 1977).

Leaf nutrient guide and classification of gardens

Five leaf nutrient guides/ranges have been derived using mean and standard deviation as deficient, low, optimum, high and excess for each nutrient and presented (Table 4). The optimum leaf N for rose ranged from 2.53 to 2.96% but the variation in the range was not wide. However, Jones *et al,* (1991) reported a wider range (3 to 5%) for roses grown outside. The classification of the gardens

Table 3: DRIS indices for various nutrients in selected low yielding rose gardens

S.No	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	Sum order of limiting nutrients
1	166	109	-101	-72	-78	227	-179	9	-89	8	1038Fe>K>Zn>Mg
2	-89	151	-16	-22	-152	-60	-23	2	88	121	724Mg>N>S>Fe
3	9	46	-109	23	-10	33	-18	52	-51	25	376K>Zn>Fe>Mg
4	-27	26	-174	24	-10	35	125	32	-146	115	714K>Zn>N>Mg
5	38	64	28	15	-116	-64	-72	178	-217	146	938Zn>Mg>Fe>S
6	4	-17	135	184	-154	10	-18	5	-155	6	688Zn>Mg>Fe>P

Table 4. Leaf nutrients guide for rose under protected conditions

Nutrient	Unit	Deficient	Low	Optimum	High	Excess
N	%	<2.08	2.09-2.52	2.53-2.96	2.97-3.39	>3.40
P	%	<0.13	0.14-0.18	0.19-0.23	0.24-0.27	>0.28
K	%	<1.75	1.76-2.22	2.23-2.72	2.73-3.17	>3.18
Ca	%	<0.69	0.70-1.14	1.15-1.59	1.60-2.03	>2.04
Mg	%	<0.25	0.26-0.40	0.41-0.55	0.56-0.69	>0.70
S	%	<0.15	0.16-0.20	0.21-0.27	0.28-0.33	>0.34
Fe	ppm	<111.00	112.00-175.00	176.00-240.00	241.00-304.00	>305.00
Mn	ppm	<38.00	39.00-106.00	107.00-175.00	176.00-244.00	>244.00
Zn	ppm	<11.00	12.00-027.00	28.00-064.00	65.00-092.00	>93.00
Cu	ppm	<4.00	5.00-012.00	13.00-021.00	22.00-030.00	>31.00

surveyed indicated that nitrogen was at optimum in 85% of the gardens whereas it was limiting only in 9% of the gardens (Table 5). The optimum P ranged from 0.19 to 0.23% indicating a lower requirement of P compared to N (Table 4). It was observed that P was rarely a limiting factor for flower production in roses. Thus, the P concentration was at optimum in 86% of the gardens and was higher in 11% of the gardens. The optimum K ranged from 2.23 to 2.72%. The requirement of K is always next only to nitrogen for roses as it is involved not only in the production of flowers but also in improving the quality. Potassium was found to be low in 21% of the gardens indicating that K was a yield-limiting factor. The optimum concentration range for calcium was from 1.15 to 1.59% and was similar to the results reported by Jones *et al* (1991). Among the gardens surveyed, 25% of the gardens were low in magnesium. Thus, magnesium status of many individual gardens was low when compared to optimum range (Table 4). Only 6% of the gardens had recorded lower sulphur content indicating that sulphur was not a yield- limiting factor in most of the gardens. Jones *et al* (1991) reported a wider optimum ranges for many nutrients for roses grown outside. Among the micronutrients, zinc was found to be low in 30% of the gardens whereas iron was low only in 23%of the gardens. The optimum zinc concentration ranged from 28 to 64 ppm whereas iron ranged from 176 to 240 ppm. Thus, zinc was found to be the most yield- limiting factor in most of the protected cultivation units followed by iron. Most of the gardens recorded optimum levels for manganese and copper. It can be concluded that the leaf nutrient standards developed can be used for efficient fertilizer programming and to correct the nutrients in question for obtaining optimum flower yield and quality in rose crop grown under protected conditions.

Table 5. Classification of rose gardens into various nutrient categories

Nutrient	Deficient	Low	Optimum	High	Excess
N	0	9%	85%	6%	0
P	0	3%	86%	11%	0
K	2%	21%	74%	3%	0
Ca	0	8%	78%	14%	0
Mg	0	25%	72%	3%	0
S	0	6%	77%	14%	3%
Fe	5%	23%	66%	6%	0
Mn	0	0	91%	9%	0
Zn	5%	30%	62%	3%	0
Cu	0	0	88%	7%	5%

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(MS Received 3 April, 2006 Revised 24 May, 2006)