Distribution of Nutrients in Cut-flower Roses and the Quantities of Biomass and Nutrients Removed during Harvest

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Additional index words. nutrient uptake, fertilization, sustainable production, groundwater, *Rosa* sp.

Abstract. Pollution of the environment, especially groundwater, may be reduced by proper fertilizer management, based in part on crop removal. The weights and concentrations of nutrients in tissue components of cut-flower roses (*Rosa hybrida* L.) were determined to assist in developing a fertilizer management system that sustains a high level of production but also is environmentally friendly. Harvested flower stalks of the cv. Royalty were cut to 45-cm length, and sectioned into 15-cm units, from which blossom, leaf, and stem components were separated, weighed, and analyzed for nutrients. The flower represented 28.5%, leaves 46.0%, and stem 25.5% of the total weight of the stalk. Upper leaves had the highest levels (g·kg⁻¹) of N (29.3), Ca (21.8), and Mg (3.0), and (mg·kg⁻¹) Fe (74) and Mn (71). The flower was highest in K (18.4 g·kg⁻¹), P (3.0 g·kg⁻¹), Zn (29 mg·kg⁻¹), and B (23 mg·kg⁻¹). Annual removal of nutrients by 45-cm flower stalks totaled: 256.2, 187.5, 116.3, 30.0, 26.0, and 21.1 kg·ha⁻¹ of N, K, Ca, P, Mg, and S, respectively. Micronutrients removed per annum totaled 700, 470, 260, 200, and 190 g·ha⁻¹ of Fe, Mn, Zn, Cu, and B, respectively. Assuming 50% recovery of applied N and 80% of K, a total annual application of N at 512 kg·ha⁻¹ and K at 234 kg·ha⁻¹ may replace the amounts removed. However, actual rates of N and K, as well as other nutrients applied, should be adjusted based on soil and tissue analysis results. Removal of nutrients will be greater if stalks harvested are >45 cm in length, which may necessitate additional nutrient application, depending on soil conditions.

Rose harvesting in Hawaii is a year-round activity. The farm-gate value of cut-flower roses for the state of Hawaii in 1993 was nearly \$4 million U.S. (Statistics of Hawaiian Agriculture, 1994). Intensive production of cut flowers demands high levels of fertilization as well as ample water. Improper fertilization in combination with excessive irrigation may contribute to environmental pollution, especially of groundwater, waste valuable re-

sources, and reduce the profit margin. In the past, some growers reportedly applied 2880 kg·ha⁻¹ of N annually. In part, sustaining productivity depends on the amounts, forms, and frequency of application of plant nutrients. The quantities of nutrients that are absorbed by a plant at any time are dependent upon its rate of growth. Leaching of soluble nutrients beyond the reach of plant roots, volatilization of certain elements, such as nitrogen, and

immobilization of nutrients by soil minerals or by soil microbiological activities must be factored in when a total nutrient budget for sustainable production is formulated.

Most of the data in the literature on mineral content of roses are limited to leaf analyses for diagnostic purposes (Boodley and White, 1969; Carlson, 1966; Oertli, 1966; Owen and Massey, 1953; Post and Fischer, 1951; Sadasivaiah and Holley, 1973; Seely and Davidson, 1939). Carlson and Bergman (1965) reported elemental concentrations of components of cut-flower roses, including blossoms, leaves, and stems, but did not address total nutrient uptake. Bagatto et al. (1991) found significant changes in the concentrations of several nutrients in leaves and stems as a result of stem gall formation. No information is available on the removal of nutrients by cut-flower roses. If we are to seriously protect our environment from pollution, we must develop fertilizer application strategies that allow for optimum crop production without contributing to the pollution of groundwater. An accurate and balanced nutrient budget for roses and other crops based on actual field data is essential to prevent further pollution of our environment. The objectives of this study with cut-flower roses were to determine: 1) the total biomass removed when harvesting stems, 2) the distribution of nutrient elements in them, and 3) the quantity of nutrients that are removed with each harvest in order to formulate a nutrient budget that meets the requirement for optimum production, yet reduces the risk of overapplication.

Materials and Methods

Cut-flower roses were obtained from Watanabe Floral, located in Lalamilo on the island of Hawaii at an elevation of 900 m. The cultivar Royalty was established in Summer 1990 with cv. Odorata as the rootstock. Planting was in beds 1.2 m wide with a density of 10 plants/m², giving a population of 61,775 plants/ha with mean annual production of 30 stems/plant. This figure was used to calculate annual nutrient removal in kg·ha⁻¹. The soil at this location belongs to the Waimea series (silty clay loam, a Mollic Haplustand of the order Andisol). Analysis of the soil prior to initiation of the study gave: pH 6.7; organic carbon, 8.23%; P, 45 mg·kg⁻¹ (modified Truog method), neutral ammonium acetate extractable cat-

Table 1. Fertilizers applied to rose plants by the grower during the time of the study.

Fertilizer	Element	% In fertilizer	Total applied/year (kg·ha ⁻¹)
Calcium nitrate	N	15.5	448
	Ca	22.2	642
Ammonium nitrate	N	33	345
Diammonium phosphate	N	21	103
	P	22.5	112
Iron chelate	Fe	13	11.2
Zinc chelate	Zn	13.2	5.6
Solubor	B	20.5	11.2
Potassium-magnesium sulfate	K	18.3	168
	Mg	10.8	100

Received for publication 9 Dec. 1997. Accepted for publication 10 Aug. 1998. This research was supported in part by a grant from the Research and Development Dept. of the County of Hawaii and Watanabe Floral of Kamuela, Hawaii. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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Table 2. Biomass of components in 45-cm cut-flower roses² (n = 126).

Tissue	Weight (g)		Dry weight (% of total)
	Fresh	Dry	
Flower	10.47	1.88 a	28.5
Section, 0–15cm			
Leaves	1.66	0.43 f	6.5
Stem	1.64	0.32 g	4.9
Section, 15–30cm			
Leaves	4.39	1.24 c	18.8
Stem	1.95	0.55 e	8.4
Section, 30–45cm			
Leaves	4.82	1.36 b	20.6
Stem	2.70	0.81 d	12.3
Total	27.61	6.59	100.0

²Mean separation within columns by LSD at $P \leq 0.05$.

ions; K, 1738 mg·kg⁻¹; Ca, 5270 mg·kg⁻¹, Mg 770 mg·kg⁻¹. Current fertilization practices (Table 1) were based on Cooperative Extension Service recommendations. All fertilizers were applied through drip irrigation, which was scheduled according to pan evaporation with an average of 253,960 L·ha⁻¹ being applied weekly.

Cut flowers with stalks >45 cm were shipped to our laboratory in Hilo at biweekly intervals starting 8 Apr. and ending 14 June 1993, for a total of six sampling dates (considered as replications in time). Each bundle consisted of 20 stems picked at random, with three bundles per sampling date. Each bundle was considered a subsample within replicates. All bundles were harvested from the same greenhouse, then packed and chilled before shipment. On arrival, stems were measured for length and weighed fresh, trimmed to 45 cm, then rinsed in deionized water and blotted dry. Each stalk was divided into three 15-cm sections and the top section was separated into flower, leaves, and stem, while the bottom two were separated into leaves and stem. Each portion was weighed fresh, then oven dried at 55 °C to a constant weight. All samples were ground in a stainless steel Wiley mill. Sections of stalks from an individual bundle were composited by section and treated as a composite sample.

Tissue samples were analyzed by the College of Tropical Agriculture and Human Resources Agricultural Diagnostic Service Center at the Univ. of Hawaii at Manoa. Total N

was analyzed according to Nelson and Sommers (1972) and Isaac and Johnson (1976). The concentrations of P, K, Ca, Mg, Fe, Mn, Zn, and Cu were determined by inductively coupled plasma emission spectrometry (Isaac and Johnson, 1985); S according to Harlin and Soltanpour (1980), Novozarnsky et al. (1986), and Wall et al. (1980); and B by the azomethine method (Wolf, 1974). Quantitative nutrient uptake by components of the 45-cm sections was calculated. All data were subjected to PROC GLM statistical analysis using SAS (SAS Institute, 1985), and means were separated using least significant difference (LSD), which was based on the Rep (sampling dates) × Tissue mean square.

Growers in Hawaii may harvest blossoms for leis only, or for cut flowers of various lengths. Therefore, sectioning the stalk and analyzing the components allows the grower to calculate nutrient removal in accordance with the harvesting mode.

Results

Biomass production. Cut-flower roses ranged in length from 53.3 to 80.0 cm with a mean length of 64.0 cm. Stem fresh weight (FW) ranged from 21.0 to 58.0 g, with a mean of 37.2 g/stalk prior to trimming. When trimmed to 45 cm, the mean FW was 27.6 g and the dry weight (DW) was 6.6 g (Table 2). Flowers constituted 28.5%, leaves 46.0%, and stems 25.5% of the total DW.

Elemental concentrations of components.
A. Macronutrients. Flowers, when contrasted with leaf and stem components, had the highest concentrations of P and K, intermediate levels of N, Mg, and S, and the lowest levels of Ca (Table 3). Leaves were higher than other tissues in N, Ca, Mg, and S, while stem tissue was the lowest in nearly all of the macronutrients. Leaf concentrations of N, Ca, and Mg decreased with increasing age and K was higher in older leaves, but levels of P and S did not vary with age. In the stem, older tissue contained lower concentrations of N, K, and Ca, while age had little effect on levels of P and S; however, Mg was slightly higher in older tissue (Table 3). A statistically significant effect of sampling date ($P \leq 0.01$) was found for P, K, Ca, Mg, and S, but no meaningful pattern over time was apparent for any tissue.

The ranges recorded for each element are reported in Table 3. The sampling date × tissue interaction term was significant only for N. This interaction was not due to any substantial change in ranking of the tissues, but rather to the magnitude of the differences between tissues varying somewhat over time.

B. Micronutrients. Tissue concentrations of Zn and B were higher in flowers than in leaves or stems (Table 3). Concentrations of Fe and Mn were higher in leaves than in flowers or stems, and concentrations of Cu were highest in stems. Youngest leaves contained slightly higher concentrations of Fe and Mn than did older leaves, while age had little effect on concentrations of Zn, Cu, or B. Older stem tissue had higher concentrations of Zn and Cu, while Mn content was not influenced by age; B was slightly higher in younger stem tissue (Table 3). A statistically significant effect of sampling date ($P \leq 0.01$) was found for Cu and Zn, but no meaningful pattern over time was apparent. The sampling date × tissue interaction was significant for Fe, Zn, and Cu. This interaction may be due to the magnitude of the differences between tissues varying over time, rather than any substantial change in ranking of the tissues. The overlap of statistical differences in the means reflects changes in ranking of the tissues over time.

Uptake of nutrients.
A. Macronutrients. The amounts of N, P, K, and Mg removed by cut-flower roses were highest in the flowers, intermediate in the lowest leaves, and least in the stems (Table 4). Calcium was highest in the middle leaves, with less in the lowest and upper leaves, followed by the flowers, and least in the stem sections. The lowest leaves removed the largest quantities of S, followed by the flower, and then the middle and upper leaves. As with other nutrients, the amount of S was lowest in the stem portions of the stalk (Table 4).

B. Micronutrients. The amounts of micronutrients removed by cut-flower roses were extremely small in comparison with the macronutrients (Table 4). Among all tissues tested, the flower removed the highest amounts of Fe, Zn, and B, but Cu was removed equally by the flowers and the bottom leaves. Among leaves, basal ones removed the highest amounts of most micronutrients, followed by the middle and then the apical ones, except for Mn where

Table 3. Levels of nutrients in tissue components of cut-flower roses² (n = 126).

Tissue	Element										
	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B
	g kg ⁻¹						mg kg ⁻¹				
Flower	20.9 c	3.0 a	18.4 a	3.8 e	2.2 d	1.6 b	63 ab	29 c	29 a	13 c	23 a
Stem section, 0–15 cm											
Leaf	29.3 a	2.3 b	14.3 d	21.8 a	3.0 a	2.4 a	74 a	71 a	22 b	16 bc	13 c
Stem	10.5 d	1.9 d	15.3 c	7.2 d	0.8 f	0.8 c	42 d	17 d	18 c	18 b	18 b
Stem section, 15–30 cm											
Leaf	27.6 b	2.3 b	16.1 c	16.0 b	2.6 b	2.4 a	56 b	59 b	19 c	15 bc	15 bc
Stem	10.1 d	2.2 c	9.3 e	4.2 e	1.3 e	0.8 c	55 bc	18 d	26 a	28 a	16 bc
Stem section, 30–45 cm											
Leaf	27.1 b	2.4 b	17.0 b	14.2 c	2.4 c	2.4 a	57 b	54 b	19 c	17 bc	15 bc
Stem	8.4 e	2.0 d	9.2 e	3.3 f	1.4 e	0.6 d	44 cd	18 d	26 a	27 a	13 c

²Mean separation within columns by LSD at $P \leq 0.05$.

Table 4. Nutrients removed annually by cut-flower roses^a (n = 126).

Tissue	Element										
	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B
	kg ha ⁻¹						g ha ⁻¹				
Flower	72.9 a	10.4 a	64.1 a	13.2 c	7.7 a	5.6 b	220 a	100 b	100 a	40 a	80 a
Stem section, 0–15 cm											
Leaf	23.1 d	1.8 e	11.3 de	17.2 b	2.4 c	1.9 c	60 c	60 c	20 c	10 c	10 c
Stem	6.2 f	1.1 f	9.1 e	4.3 d	0.5 e	0.5 d	20 d	10 e	10 c	10 c	10 c
Stem section, 15–30 cm											
Leaf	63.2 c	5.3 c	36.9 c	36.6 a	6.0 b	5.5 b	120 b	130 a	40 b	30 b	30 b
Stem	10.3 ef	2.2 e	9.5 e	4.3 d	1.3 d	0.7 d	60 c	20 de	20 c	30 b	10 c
Stem section, 30–45 cm											
Leaf	68.1 b	6.0 b	42.7 b	35.7 a	6.0 b	6.0 a	150 b	130 a	40 b	40 a	30 b
Stem	12.6 e	3.1 d	13.9 d	5.0 d	22.1 c	0.9 d	70 c	20 de	30 b	40 a	20 c
Total	256.2	30.0	187.5	116.3	26.0	21.1	700	470	260	200	190

^aMean separation within columns by LSD at $P \leq 0.05$.

quantities for the bottom and middle were equal. Similarly, the basal part of the stem removed the most micronutrients, followed by the middle, then the upper section.

Nutrient removal by the three major tissue components was calculated by totaling the amounts present in each tissue. The leaves had the highest proportion of all macro and micro-nutrients (the range was 38.1% for Zn to 77.0% for Ca), the flower ranked second, except for calcium and copper (11.4% for Ca to 38.1% for B), and the stem contained the least amount of most nutrients (10.1% for S to 36.9% for Cu).

Discussion

The data presented here make it possible to calculate the amounts of the various nutrients removed by the harvested rose biomass. A nutrient replacement program can be formulated in order to sustain production and avoid overapplication of fertilizers. The harvested biomass had a mean additional length of 19 cm with a FW of 9 g, which is 35% more than the stalk that was trimmed to 45 cm. For a harvested length of 45 cm, 256 kg ha⁻¹ N and 187 kg ha⁻¹ K were removed annually (Table 4). These are by far the most heavily utilized nutrients. Annual removal (kg ha⁻¹) of the other macronutrients was as follows: Ca, 116; P, 30; Mg, 26; and S, 21. The amounts of micronutrients removed per annum were very small, ranging from 700 g ha⁻¹ for Fe to 190 g ha⁻¹ for B (Table 4). All these amounts may be increased by ≈35% to compensate for the discarded biomass.

Nitrogen fertilizer recovery by plants is influenced by many factors. These include: the nature of the plant and its root system; the form, amount, and frequency of application of nitrogen; soil physical and chemical properties, including soil organic matter, and cation and anion exchange capacities; biological, chemical, and physical immobilization; rate of water percolation; amount of irrigation or rain frequency and intensity; and volatilization.

Existing publications on rose nutrition con-

tain no data on the efficiency of utilization of nutrients by the plant. Using the data collected in this study, we attempted to calculate the efficiency of utilization of nitrogen fertilizer. An annual N application of 896 kg ha⁻¹ and removal by biomass of 346 kg ha⁻¹ give an utilization efficiency of 39%. In contrast, recovery of fertilizer N by maize in the above-ground portion of the plant, with optimum yield, over 13 consecutive crops was 50% to 60% (unpublished data by Y.N. Tamimi and D.T. Matsuyama). Similar data reported by Hill et al. (1983) showed a recovery of 57% of applied N. If we were to consider 50% to 60% recovery by roses, then an annual rate of N at 577 to 692 kg ha⁻¹ would be required. The timing and quantities of N fertilizer to be applied in split increments can be adjusted by taking into consideration tissue analysis, seasonality of demand for flowers, and cultural practices.

In a similar manner, annual K removal by the harvested biomass was calculated at 253 kg ha⁻¹. Potassium can be applied as soil analysis dictates. If a 75% to 80% recovery is assumed, an annual rate of 316 to 337 kg ha⁻¹ will replace what is removed. Removal rates of other nutrients may be determined by considering the nutrient uptake reported in Table 4. We suggest that periodic soil and tissue tests be used to determine the need for application of all nutrients.

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