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Accumulation of Nutrients by Strawberry Plants and Fruit Grown in Annual Hill Culture[1]

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Abstract. **The accumulation of N, P, K, Ca, Mg, Fe, Mn, Zn, and B were determined at transplanting, first flowering, first harvest, middle of harvest season, and end of harvest season to ascertain the extent and the pattern of plant nutrient uptake in strawberry (*Fragaria* X *ananassa* Duch.). The plants were grown with the annual hill cultural system and mulched with polyethylene. More accumulation of each element occurred during harvest than before that time. Excluding harvested fruit, leaves accumulated the most N, P, K, and Mg; the roots and crown the most Fe and Zn, while the dead material accumulated the most Ca. Harvested fruit accumulated more N, P, K, and B than did the plant. The caluclated average seasonal accumulation of the 9 elements in the plant and in the harvested fruit during the 2 seasons in kg/ha were: K 63.1, N 58.6, Ca 30.8, P 9.4, Mg 7.8, Fe 0.456, Mn 0.161, Zn 0.088, and B 0.077.**

Only limited data are available on elemental accumulation by the strawberry plant (3, 5) during a cropping season. Data are available on fruit elemental composition and accumulation during a long harvest season (2). Similar information is needed for the plant in order to determine the total needs of the crop at various times during the growing and fruiting season. Information on nutrient accumulation is very useful for the management of the fertilizer needs of the crop. This study was undertaken on a well fertilized soil to determine elemental accumulation throughout the growing and harvest season by strawberry plants set in polyethylene mulched beds using the annual hill cultural system.

Materials and Methods

This research was conducted on a Scranton (adjunct) fine sand during 2 seasons, 1976-1978, at the Agricultural Research Center, Dover, FL. September 1976 soil test values of the saturated paste extract (4) in ppm were: total soluble salts 100, K 15, Ca 17, and NO_3 11 with a pH of 6.5. Plots were fertilized each year with 224, 186, and 49 kg/ha of N, P, and K, respectively. In September 1976 and 1977, 50 kg/ha of a complete, soluble micronutrient mix (3% B and Cu, 18% Fe, 7.5% Mn, 7% Zn, and 0.2% Mo) was applied. Each year, plant beds were fumigated with a methyl bromide and chloropicrin mixture and then mulched with 1-mil black polyethylene. Plants of the clones 'Tioga', 'Florida Belle', and 71-729 were taken from a well fertilized local summer nursery and established in the plant beds at a density of about 59,000 plants/ha. The statistical design was a randomized complete block with 5 replicates. Plant samples were taken at transplanting, and when most plants were beginning to flower, in December 1976 only. Further samples were taken at first harvest, in January 1977 and 1978: at the middle of the harvest season, in early March 1977 and 1978: and at the end of the harvest season, which was in early May of each year. The plant samples were rinsed in tap and distilled water and air-dried. The plants were divided into leaves, petioles, roots and crown, flowers and flower stalks, unharvested fruit, and dead foliage. These samples were weighed, dried at 60°C, and ground by mortar and pestle. Samples were wet-ashed, and N was determined by the Kjeldahl method, B by the quinalizarin procedure, P was determined colorimetrically, and all other elements by atomic absorption spectroscopy.

To determine the elemental accumulation by the harvested fruit at the middle and the end of the harvest season, the average concentration of the element in the fruit for each harvest period in a previous study (1) was multiplied by the yields in the same harvest period in the present study. The average values in the previous study were believed to be valid for use in this study since adjacent plots were used and cultivars, fertilization, soil type, and cultural practices were the same. Fruit were harvested twice weekly, graded, counted, and weighed. Data on Mn were available for the first season only.

Results and Discussion

To determine the total accumulation by the plant, the data from the plant and the calculated data of the fruit were combined (Table 1). These combined data indicate that most of the elemental accumulation occurred after the plant began to fruit. This was the result of some accumulation in the plant, since the dry weight increased from an average 15.4 g at first fruiting to an average 27.1 g at the end of the harvest season, and to the accumulation in the harvested fruit. More N, P, K, and B were accumulated in the harvested fruit than in the plant. After midseason, nearly all of the N, P, K, Mg, Zn, Mn, and B accumulated in the harvested fruit. For some elements their accumulation in the plant decreased between the two last sampling dates. This was mostly the result of the immature fruit ripening and being harvested. The total Ca accumulating doubled and the total K accumulation almost doubled between the last 2 sampling dates with the Ca accumulation mostly in plant organs other than the fruit and the K accumulating mostly in the harvested fruit. The total accumulation of the elements in plant and harvested fruit for the season in decreasing order was as follows: K, N, Ca, P, Mg, Fe, Mn, Zn, and B.

The total dry matter and elemental accumulation by the 3 strawberry clones at the end of each harvest season are given in Table 2. The dry matter, and the N, P, K, and Zn accumulation varied among clones in 1977, and the Ca and Fe accumulation varied among clones in 1978. The elemental accumulation differences among the clones were related fairly well to the dry matter content. Since plant dry matter contents varied somewhat from year to year (as they do in growers fields) and no clone was consistently the highest, all other varietal data were pooled for subsequent study. Total marketable yields averaged 20,300 kg/ha per season. The concentration of the elements in the plant organs at the end of the harvest season varied with the element (Table 3). Leaves had high concentrations of N, Mg, and Mn; the roots and crowns had high concentrations Fe, Zn, and Mg; the dead material had high concentrations of Ca, B, Mn, and Fe, and the petioles had high

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Table 1. Average accumulation of elements by strawberry at 5 sampling dates for plants and harvested fruit.

Element	Plant contents					Fruit contents				Plant and fruit totals	
						Mid-season		End of season			
	Transplanting[z]	First[y] flower	First harvest	Mid-season	End of season	Mkt. fruit	Cull fruit	Mkt. fruit	Cull fruit	Mid-season	End of season
					kg/ha						
N	2.4	10.7[x]	21.8	26.9	27.3	8.3	2.1	24.4	6.9	37.3	58.6
P	0.5	0.8	2.7	3.8	3.8	1.6	0.4	4.4	1.2	5.8	9.4
K	1.7	4.3	14.6	18.9	22.7	11.0	2.7	31.7	8.8	32.6	63.1
Ca	1.7	4.7	7.3	14.0	26.9	0.9	0.2	3.1	0.8	15.1	30.8
Mg	0.4	1.5	2.9	5.0	4.7	0.8	0.2	2.4	0.7	6.0	7.8
					g/ha						
Fe	24.8	45.6	103.6	201.9	369.4	26.6	6.5	67.5	18.9	235.0	455.8
Zn	5.6	17.6	32.7	63.6	53.6	10.5	2.4	27.1	7.4	76.5	88.1
Mn[w]	4.4	27.5	58.5	98.5	113.6	12.7	2.8	37.1	10.2	114.0	160.9
B	5.8	9.6	22.6	43.7	32.5	12.2	3.1	34.5	9.6	59.0	76.6

[z]Date of sampling.

[y]Date 2 values were for 1976-77 only.

[x]All plant and total values for dates other than at transplanting have the transplanting values subtracted from them.

[w]Mn data were for 1976-77 only.

Table 2. Effect of strawberry clone on dry matter yield and elemental accumulation in plants[z] at end of harvest season.

Clone	Dry matter (%)	Element accumulation (g/plant)					Element accumulation (mg/plant)			
		N	P	K	Ca	Mg	Fe	Zn	Mn	B
					1977					
Florida Belle	31.0ab[y]	.62a	.086a	.44b	.49a	.100a	9.4a	1.5a	2.0a	0.74a
Tioga	22.4b	.45b	.056b	.40b	.40a	.074a	7.4a	0.8b	1.8a	0.51a
71-729	37.5a	.73a	.093a	.62a	.56a	.115a	9.7a	1.3a	2.4a	0.78a
					1978					
Florida Belle	22.9a	.39a	.074a	.30a	.41c	.069a	5.2a	0.9a		0.56a
Tioga	25.6a	.43a	.066a	.38a	.58a	.086a	4.7ab	0.7a		0.66a
71-729	22.0a	.39a	.062a	.34a	.47b	.074a	3.6b	0.8a		0.58a

[z]For all plant organs except harvested fruit.

[y]Mean separation in columns for each year by Duncan's multiple range test, 5% level.

Table 3. Elemental concentration (dry weight basis) of various plant organs at end of harvest season.

Plant organ	Element composition (%)					Element composition (ppm)			
	N	P	K	Ca	Mg	Fe	Zn	Mn	B
				1977					
Roots & crown	1.57c[z]	0.24c	1.07d	1.51b	0.33a	562a	93a	63b	25ab
Petioles	1.16d	0.25c	3.18a	1.27c	0.33a	84c	26b	28d	19b
Leaves	3.07a	0.31b	1.91c	1.58b	0.36a	130c	24b	76a	20b
Flower & stalk	2.00b	0.38a	2.53b	0.71d	0.26b	109c	29b	46c	17bc
Fruit[y]	1.90b	0.31b	2.12c	0.57d	0.23b	64c	18b	41c	13c
Dead foliage	1.40c	0.17d	0.79d	2.22a	0.30ab	345b	18b	78a	28a
				1978					
Roots & crown	1.17d	0.20d	0.66d	1.58c	0.33ab	279a	58a		23b
Petioles	1.21d	0.30b	3.23a	1.51c	0.29b	74b	28b		22b
Leaves	2.70a	0.31b	1.55c	2.22b	0.38a	154b	27b		27b
Flower & stalk	1.71c	0.26c	1.58c	1.20d	0.29b	98b	33b		25b
Fruit[y]	1.89b	0.39a	2.05b	0.76e	0.26b	72b	25b		15c
Dead foliage	1.20d	0.25c	0.24e	2.93a	0.29b	317a	28b		33a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

[y]All unharvested fruit remaining on plant.

Table 4. Accumulation of elements in plant organs at end of harvest season (2 season data except for Mn).

Plant organs	Element accumulation (kg/ha) N	P	K	Ca	Mg	Element accumulation (g/ha) Fe	Zn	Mn	B
Roots & crown	5.2	0.8	3.4	5.7	1.2	164	29	27	9
Petioles	2.5	0.6	7.1	3.0	0.7	17	6	6	4
Leaves	14.4	1.5	8.7	9.2	1.8	69	12	43	11
Flower & stalk	0.8	0.2	1.0	0.4	0.1	5	1	3	1
Fruit[z]	1.7	0.4	2.1	0.7	0.2	7	2	3	1
Dead foliage	5.1	0.8	2.0	9.6	1.1	132	8	36	11

[z]All unharvested fruit.

concentrations of K. P concentrations did not vary consistently among plant organs during the 2 seasons.

The amount of each element accumulated in each plant organ (excluding harvested fruit) is given in Table 4. The amount is the product of the elemental concentration and the dry matter content. At the end of the season, the dry matter content of the various plant organs as a percent of the total dry matter content of the plant was: leaves 31, dead material 24, roots and crown 23, petioles 13, immature fruit 6, and flower and flower stalks 3. Leaves accumulated the greatest amounts of N, P, K, Mg, and Mn; the roots and crown accumulated the most Fe and Zn while Ca was accumulated in greatest amounts by the dead material.

Variation in either the plant size or the fruit yield will alter the total elemental accumulation but should not appreciatively change the pattern of nutrient accumulation. The data indicate that most of the elemental accumulation occurs during the fruit harvest, and most of the N, P, K, Mg, Zn, and B accumulated during that time were in the fruit. For maximum fruit yield, these elements must be available in greatest amounts during fruiting. Strawberries are generally grown on coarse-textured soils and fertilizer leaching can be serious even under full-bed mulch (1). To reduce the leaching problem, controlled-release fertilizer is applied in Florida and elsewhere. However, the release characteristics of these fertilizers vary greatly (6) and should be carefully evaluated so that the nutrients are released to meet the needs of the plant without being subject to excessive leaching. The amount of fertilizer to apply will vary with the fruit yields and the soil. Only small amounts are needed to replace that contained in the harvested fruit. Amounts applied in excess of this either buildup the soil fertility or are lost by leaching and volatization. Since strawberries are generally grown on porous soils, leaching is probably the ultimate fate of the excess fertilizer.

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Factors Affecting the Marketability of Roses[1]

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Abstract. **Marketability of arrangements of rose (*Rosa hybrida* L.) was evaluated on the basis of unit size, stem length, cultivar, flower condition including openness, bentneck and discoloration, and price using conjoint analysis. Long stemmed, 12 unit red hybrid tea roses lost competitive position in favor of shorter 9 and 5 unit rose arrangements. Price was the major determinant for the favorable consumer acceptance of the smaller sized, short stemmed roses in arrangements. The cultivar of rose marketed and the degree of flower openness were important factors influencing the consumer's purchase decision. Low priced short stemmed roses (40 cm) in a tight bud-stage were the most highly valued, however, 'Sonia' roses evoked strong consumer appeal regardless of price or stage of bud openness.**

Roses are the major cut flower crop in the U.S., representing about 39% of the wholesale value of cut flower production (1). However, market growth has been slowed due to seasonal supply and demand imbalances (10). Market expansion could be enhanced if roses were merchandised in mixed bouquets and arrangements rather than exclusively on a homogeneous basis (6).

Another factor affecting market growth has been consumer price resistance to the 12 units in which roses are commonly merchandised (10). Recently high prices have represented a barrier to consumer spending. Efforts by the industry to eliminate the 12 unit package have met with resistance due to a

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