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Using Plant Uptake to Determine Optimum Values for Soil Tests[1]

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Abstract. Plants of *Chrysanthemum morifolium* Ramat. grown on a constant fertilization program were analyzed for elemental content, and the growing mix was analyzed by 3 different soil test methods. Optimum values for the nutrients reported by each of the soil tests were determined by using plant uptake data.

Soil tests are used to determine the nutritional status of a growing mix so that adjustments can be made to obtain maximum crop production. Soil tests vary in their method of extraction. In the ornamentals area soil tests range from an attempt to simply remove the bulk solution (saturated paste extract) through removal of bulk solution ions plus a minimal quantity of exchangeable ions (Spurway test) and finally to extensive removal of exchangeable ions (NH_4 replacement). The ionic composition of the soil solution is measured using a distilled water extractant, and a saturation extract procedure. The distilled water will dissolve soluble salts in the soil and remove the salts and any ions in solution (5). Ions that are on the exchange sites will remain in the soil. A dilute acid extractant is employed in the Spurway test where acetic acid simulates the natural soil solution processes (11). In this test all soluble ions and soluble salts will be removed in addition to some ions on the exchange sites. An exchange extractant, the NH_4 ion, replaces ions on the exchange sites thus the ammonium acetate is used in the Penn State soil test which measures total ions [those on exchange sites plus soluble ions (10)]. These 3 tests remove different quantities and balances of nutrients from the growing mix, but they all have been related to plant growth. Several workers (8, 14, 15) have related soil test levels to plant uptake as well as to plant growth in order to avoid unnecessary luxury consumption of some nutrients.

The objective of this research was to determine an optimum soil test level for N, P, K, Ca, and Mg based on plant uptake data.

Materials and Methods

'#4 Improved Indianapolis White' chrysanthemum was used because as a test crop because of its known response to different irrigation-fertilization regimes. The pasteurized growing mix was composed of equal parts by volume of a Bedford silt loam soil, sphagnum moss peat, and sand grade lelite. Each treatment consisted of 120 12.5 cm standard clay pots which were irrigated with a fertilizer solution through a trickle irrigation system. The statistical design was a randomized complete block with 12 replications, 4 treatments, and 2 observations with 5 pots per observation. The irrigation-fertilization regime was initiated on the planting data, August 7, with daily applications of 240 ml of fertilizer solution per pot. The naturally long days at that time of year prevented flower bud initiation during the 4 weeks of the experiment. On August 12, the irrigation frequency was increased to twice per day and on August 19 to 3 times per day for the remainder of the experiment. The nutrient level and balance suggested by Baker (1) was taken as the basis for the fertilizer solutions (Table 1). Each nutrient level was increased by the calculated amount of that element which the plant could remove during 4 weeks of vegetative growth.

Whole plants were harvested September 4 by cutting them off at soil level. Five plants from each observation were combined into one sample, dried, ground in a Wiley mill, and analyzed with a No. 8900 Applied Research Laboratories Spectrometer for elemental content by a modified method of Kenworthy (6) as described by Baker et al. (2).

Soil from the 5 pots making up each observation was combined, mixed, and 3 soil samples were removed. One sample was tested by a Spurway soil test method conducted by the Robert B. Peters Co. of Allentown, Pa. Another sample was sent to the Merkle Soil and Forage Testing Laboratory of The Pennsylvania State University which uses an ammonium acetate extractant for a routine greenhouse soil test (Analytical

Table 1. Composition of fertilizer solutions applied to chrysanthemums at each irrigation.

Treatment	Element (ppm)				
	N	P	K	Ca	Mg
1. (0.25 x)	47	5	16	54	7
2. (0.5 x)	94	9	32	107	14
3. (1 x)	188	18	64	214	28
4. (2 x)	378	36	128	428	56

Table 2. Nutrient concentration of '#4 Improved Indianapolis White' chrysanthemums grown at 4 levels of continuous fertilization (means of 24 replications).

| Treatment | Nutrient concentration (dry wt) | | | | | | | | | | |
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Al (ppm)	Zn (ppm)
1. (0.25 ×)	4.3	0.36	3.3	1.5	0.78	92	134	9	23	113	49
2. (0.5 ×)	4.7	0.46	3.8	1.6	0.74	98	137	9	22	110	40
3. (1 ×)	5.0	0.67	4.8	1.4	0.56	96	138	10	21	106	43
4. (2 ×)	5.5	0.88	5.4	1.2	0.40	111	120	8	20	95	49
CV (%)	5	10	6	8	8	15	17	14	9	23	20

Table 3. Spurway soil test values for each item reported and each treatment (means of 24 values).

Treatment	pH	SS ($\times 10^5$ mhos)	NO_3 (ppm)	N (ppm)	P (ppm)	K (ppm)
1. (0.25 ×)	7.0	27	22	32	2.4	17.3
2. (0.5 ×)	6.8	46	55	62	4.1	19.3
3. (1 ×)	6.6	60	82	90	6.4	21.5
4. (2 ×)	6.2	107	102	138	15.3	38.3
CV (%)	2	27	44	42	57	29

Methods for Merkle Soil Testing Laboratory Mimeo, 1967). The 3rd sample was used for an Intensity-Balance (saturation extract) soil test.

The Intensity-Balance soil test procedure suggested by NeSmith et al. (7) was modified to the following procedure. A 250 g air-dried soil sample was placed in a plastic beaker and distilled water added in small increments until the soil was saturated (9). The soil was permitted to remain saturated for 4 hr before it was filtered through a Buchner funnel for one-half hour. The filtrate was used for NO_3-N, soluble salt (SS) and pH determinations. A 25 ml aliquot of filtrate was dried at 100°C. The residue was dissolved in 5 ml of lithium buffer and the sample analyzed spectrometrically for P, K, Ca, and Mg.

Results and Discussion

The uptake of N, P, and K increased with increasing concentrations of each nutrient in the fertilizer solution (Table 2). Calcium and Mg, however, decreased even though the concentrations of these nutrients were also increased in the fertilizer solution. This demonstrated the existance of the K-Mg and K-Ca antagonism described by Van Itallic (12). It must be concluded that although there was a reduction in uptake of Ca and Mg, neither had reached a low enough level to reduce plant growth because there was an increase in fresh and dry weight from treatment 3 to treatment 4 (Data not included).

The levels of total N, P, and K, as reported by the Spurway soil test, increased as expected since the fertilizer solution contained increasing concentration of these elements (Table 3).

The increasing levels of NO_3, P, K, Ca, and Mg reported by the Penn State test would be expected since the level of each element was increased in each fertilizer treatment (Table 4). The K percent saturation of the exchange capacity increased as the level of K increased. The % saturation of Ca and Mg decreased even though the level of exchangeable Ca and Mg as reported by the soil test increased. This provided a good indication that the % saturation for Ca and Mg was a measure of balance and was related to Ca and Mg uptake by the plant.

The N, P, K, Ca, and Mg reported by the Intensity-Balance soil test increased as expected (Table 5). The ratio of N, P, K, or Ca to SS increased with increasing fertilizer levels while that of Mg:SS decreased slightly. The Ca:Mg and K:Mg ratios increased with each fertilizer addition.

The optimum nutrient range was defined as the range where the uptake of a nutrient began to level off even though the amount supplied continued to increase. When an element was at a low level and the supply was increased, uptake rose quite sharply until the level was near the optimum. At that point it leveled off even though the supply continued to increase.

Under these conditions a second degree equation should describe the curve and the second derivative of that equation will give the maximum (4). The calculated maxima are reported in Table 6. The optimum range was then determined as the range from the mean of the highest treatment to the maximum value (Table 7).

For some nutrients the second degree equation was not statistically better than the first degree equation. When this occurred no maximum could be calculated. The probable optimum range was determined as the highest mean value plus or minus two standard deviations (Table 7).

Boodley (3) recommended a nitrate level of 25-50 ppm in solution (Spurway) which is much lower than what was obtained in this experiment. White (16) recommended 50-250 ppm N based on soil weight according to the Penn State soil test. Geraldson (5) did not recommend as high N levels for

Table 4. Penn State soil test values (mean of 24 values).

| Treatment | pH | SS ($\times 10^5$ mhos) | N (ppm) | P (ppm) | Element level (meq/100g soil) | | | | % saturation | | |
					K	Mg	Ca	CEC	K	Mg	Ca
1. (0.25 ×)	7.2	54	48	56	0.24	2.0	10.8	13.1	1.8	15	82
2. (0.5 ×)	7.0	93	168	77	0.26	2.0	11.5	14.2	1.8	14	81
3. (1 ×)	6.9	123	255	94	0.32	2.1	11.8	15.0	2.1	14	79
4. (2 ×)	6.4	232	391	155	0.62	2.3	12.4	17.3	3.5	13	71
CV (%)	2	29	33	44	24	10	9	10	22	6	5

Table 5. Intensity and balance soil test values (means of 24 values).

Treatment	pH	SS (ppm)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Ca:Mg	K:Mg	Element balance (% of total salts)				
										N	P	K	Ca	Mg
1. (0.25 x)	7.8	1076	71	3	22	192	53	3.6	0.4	6	0.30	2	18	5
2. (0.5 x)	7.6	2222	281	7	47	376	94	4.0	0.5	12	0.32	2	17	4
3. (1 x)	7.6	3008	474	11	68	542	129	4.2	0.5	15	0.35	2	18	4
4. (2 x)	7.3	5935	1091	21	194	1193	244	4.8	0.8	18	0.36	3	20	4
CV (%)	3	25	31	38	48	32	26	2	52	19	44	59	10	10

Table 6. Optimum nutrient levels as determined by the second derivative of a second degree equation for each soil test.

Element	Spurway	Penn State	I + B
N (NO$_3$)	132	423	1667
Total N (ppm)	166	---	---
P (ppm)	23.6	None[z]	None
K (ppm)	53.3	None	278
Ca	---	None	None
Mg	---	None	None
N (%)	---	---	None
P (%)	---	---	0.426
K (%)	---	None	3.03
Ca (%)	---	82	None
Mg (%)	---	None	None
Ca:Mg	---	---	None
Ca:Mg	---	---	None
K:Mg	---	---	0.78
K:Mg	---	---	None

[z]Indicates that no value could be calculated from data.

Table 7. Optimum nutrient range in the Spurway, Penn State, and Intensity-Balance soil tests.

Element	Spurway	Penn State	I − B
N (NO$_3$) (ppm)	102-132	391-423	1091-1667
Total N (ppm)	138-166	---	---
P (ppm)	15.3-23.6	115-195	13-29
K	38.3-53.3 ppm	0.40-0.84 meq/100 g[z]	194-278 ppm
Ca	---	10.0-14.0 meq/100 g[z]	855-1519 ppm[z]
Mg	---	1.7-2.9 meq/100 g[z]	143-343 ppm[z]
N (%)	---	---	17-19[z]
P (%)	---	---	0.36-0.43
K (%)	---	2.5-4.5[z]	2.00-3.03
Ca (%)	---	80-82	17.6-22.0[z]
Mg(%)	---	13-17	14-16[z]
Ca:Mg	---	---	3.8-5.8[z]
K:Mg	---	---	0.2-0.6[z]

[z]Probable optimum range.

vegetables in Florida as appeared optimum for chrysanthemums in the greenhouse. The interpretation provided by Geraldson (5) will be used even though it is for vegetables. Warncke (13) recommended with a saturation extract a nitrate level of 80-150 ppm for greenhouse crops. The advantage of the Intensity-Balance test for greenhouse crops lies in testing the balance among the nutrients in the solution rather than testing ions on the exchange sites.

The explanation for the difference between these results and the recommended N level by Boodley, White and Warncke is that these plants were fertilized with each irrigation. Due to frequent irrigations the plants dried out very little between irrigations hence the water stress was minimal. The amount of fertilizer solution applied at each irrigation was sufficient to leach pots; therefore, soluble salts did not build up in the soil and since growth increased with each increase in soluble salts it was not detrimental. The fertilizer supply was relatively constant and fluctuations of nutrients were frequent but small. These data would indicate that the standard recommendations for N are not optimum for vegetative chrysanthemums produced with a constant fertilization program. There was a great difference in the recommendation for the Intensity-Balance and the level Warncke recommends for the saturation extract for greenhouse crops; however, there is no explanation for this difference.

Boodley (3) recommended 4-6 ppm P on the basis of the Spurway soil test, and White (16) recommended 125-450 ppm P if the Penn State soil test is used. Warncke (13) recommended a P level of 6-12 ppm for greenhouse crops. The optimum level for P in the Spurway test from this work was much higher than that of Boodley (3). A most probable explanation could be that since the levels of other nutrients were high, P was absorbed rapidly and the levels of P had to be increased also otherwise

it would have been a limiting factor. These optimum levels were only slightly lower than White (16) recommended. Because the P was being applied constantly, there was no need to have a large storage of P in the soil and the level was adequate. It is also possible that a higher level than used in this experiment would promote a greater P uptake. The optimum for the Intensity-Balance was only slightly higher than Warncke (13) recommended.

Boodley (3) recommended 25-50 ppm K when based on the Spurway soil test. White (16) suggested 0.75-1.50 meq/100 g K and 3 to 7.5% saturation of the exchange capacity if the Penn State test is used. Warncke (13) recommended a concentration of 120-200 ppm K for the saturation extract greenhouse test. The range determined in this experiment agreed very well with Boodley's recommendation, it is lower than that recommended by White and slightly higher than recommended by Warncke. The probable reason was that K was continually applied and there was no need to maintain a high K capacity in the soil. This again emphasizes the need for different interpretations of soil test results when a constant fertilization program is used. Geraldson (5) indicated that a range of 1−12% K:SS was optimum, but under constant fertilization conditions the ratio does not need to be greater than 3%. The explanation is again related to the constant application of K.

Calcium was not determined by the Spurway soil test. White (16) recommended 8-13 meq/100 g and 52−85% saturation. The results for Ca in the Penn State test of this experiment agreed very well with those of White. Geraldson (5) suggested 10−15% for the Ca:SS ratio. The ratio determined in this experiment was higher. Warncke (13) recommended a Ca level of greater than 150 ppm and the results of this experiment indicate a substantially higher level.

J. Amer. Soc. Hort. Sci. 104(3):365−368. 1979.

367

The % saturation of Ca is an indication of balance, and it decreased with each increase in fertilizer K. Plant weight increased with each increment of K so Ca had not been reduced sufficiently to reduce growth (data not included). These trends make it evident that continuing to increase K will cause Ca to become the limiting factor and eventually depress growth.

The Ca:Mg ratio was calculated for the Intensity-Balance soil test and was found to be in the range suggested by Geraldson (5).

Magnesium was not determined for the Spurway soil test. White recommended a Mg level of 1.2-3.5 meq/100 g or 7.5 to 21% saturation. Geraldson (5) determined a 3 to 5% Mg:SS ratio as being optimum. Warncke (13) recommended a Mg level of greater than 60 ppm. The results of this experiment were similar to those of White and higher than Warncke.

The results for Mg were difficult to interpret because of the strong K-Mg antagonism. As the K fertilization increased, the uptake of Mg was depressed. For this reason the derivative of the second degree equation should provide the minimum value hence this technique could not be used.

The % saturation by Mg should provide an index of balance. Since the % Mg taken up by the plant falls with each increment of K fertilization, it is possible that additional K fertilization could cause a depression in growth. The K:Mg ratio was calculated and should give an indication of the balance. Treatment 4 had a mean K:Mg ratio of 0.8 and the maximum value was 0.78 indicating that if the ratio was greater there would be a depression in growth due to a low level of Mg.

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Effect of Seeding Rate, Pattern, Row Position, and Clipping on Size Uniformity of Field-grown Tomato Transplants[1]

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Abstract. Coated seed of tomato (*Lycopersicon esculentum* Mill.) were precision seeded at 4 rates and 3 patterns to determine the effects on size variation of field-grown transplants. No significant differences in the number of marketable or cull transplants were obtained with the 3 planting patterns. Seeding rates greater than 63 seeds/m usually increased the number of cull transplants with no significant increase in the number of marketable transplants. About 20% more marketable transplants were produced in the 2 inside rows than in the 2 outside rows on 4 row beds.

Southern Georgia is a major production area for tomato transplants to be shipped to northern areas of the United States and southern Canada. Field seeding occurs from late February through mid-April. Transplants are harvested, packed bare-root, and shipped to northern growing areas for replanting (6).

Hand labor is used for pulling, bundling, and packing. Mechanically lifting and field-packing transplants has progressed to where it will become an accepted practice (8). Machinery now used lifts and field packs transplants on a non-selective basis. Cultural techniques are needed which promote transplant

368

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