ABSTRACT

EFFECT OF NITROGEN AND POTASSIUM LEVELS ON GROWTH AND COMPOSITION OF LEAVES OF 'ICEBERG' CHRYSANTHEMUM UNDER GREENHOUSE CONDITIONS

By

Reynaldo Catublas Rodriguez

Rooted cuttings of 'Iceberg' chrysanthemum were planted in glazed crocks containing quartz sand. Three cuttings were planted in each of 90 two-gallon containers. The cuttings were watered with nutrient solutions containing varying levels of N and K. Ten treatment solutions were prepared to contain 56, 112, 224, 448 and 896 ppm N with 312 and 624 ppm K.

Leaf samples were collected after 9 weeks of growth. The samples were collected to represent leaf position of successive pairs of leaves starting with a sample of tip tissue. Height and weight of 10 plants in each treatment were recorded.

Best growth resulted from 224 ppm N with 312 ppm K. When K was increased to 624 ppm, the greatest amount of growth, as measured by weight occurred with 448 ppm N.

Each leaf sample was analyzed for N, K, P, Ca, Mg, Mn, Fe, Cu, B, Zn, Al, and Na. Several instances of interactions resulting from N level, K level, and leaf position were found.

Reynaldo Catublas Rodriguez

Considering composition values, growth measurements and values from the literature, leaf sampling positions 3, 4, and 5 as a combined sample, appeared satisfactory as a location for sampling to determine nutrient status of chrysanthemum. These positions represented leaf numbers 3 to 8 below the tip.

Composition values found in this study are not suggested as "standard" values. It is recommended that such values be confirmed with further studies that would involve flowering and studies of flower quality.

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Reynaldo Catublas Rodriguez

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INTRODUCTION

Chrysanthemum has been one of the largest of the greenhouse floriculture crops and has become the flower of the people. At present the chrysanthemum industry has a wholesale value of 61.3 million dollars in the 23 states included in the U. S. Crop Reporting Services survey of 1966. This included standards, pompons, and potted plants. Chrysanthemum ranked as first among the four main cut flower crops produced. Of the 61.3 million dollar value, the standard chrysanthemum had a total wholesale value of 23.2 million dollars. In Michigan the wholesale value of chrysanthemum was 1.35 million dollars with the standards being 0.3 million dollars.

Post, 1952, stated that chrysanthemums were grown by a greater number of greenhouse producers than any other commercial crop in the U.S. and in several countries of the world. With proper manipulation of daylength and temperature, the chrysanthemum can be made to flower the year round. The great number of chrysanthemum varieties available and their good keeping quality make chrysanthemum a popular cut flower for home use and for commercial flower arrangement.

In order to obtain good keeping and storage qualities, and marketability, a good cultural management program in the greenhouse is mandatory. Usually the accepted practice is to use a soil mix that provides good drainage and aeration.

However, this may not supply the necessary nutrients for the normal growth of the plants. Furthermore, growers do not change the soil in benches from year to year. This necessitates fertilizer amendments.

Although there has been some work conducted on the nutrition of chrysanthemum there is little information on the effects of N and K.

This study was conducted in order to provide additional information on the effects of various concentration of N and K in the nutrient medium on leaf composition and growth of Iceberg chrysanthemum and to relate these effects to position on the plant where the leaf sample was taken.

REVIEW OF LITERATURE

Foliar analysis has been used for over 100 years. Weinhold (1862), Hellriegell (1867), and Wolff (1868) were among the first workers who used plant tissue analysis as a diagnostic tool to confirm visual symptoms which indicate deficiency or toxicity of a nutrient element. Ulrich (18) mentioned de Sausure in 1804 as the earliest work on plant analysis. Today plant analysis has become widely used as a tool for determining fertilizer needs of perennial crops like fruit trees, and, also, in some vegetable and floriculture crops.

Bould (2) stated that in order to be effective as a diagnostic tool, factors such as age and position of leaves, the species or varieties of crop, the climate, time of the year, stage of development of the crop, damage by pests and diseases, and geographical location should be taken into account. Lunt, et al. (11) stated that a background of detailed information as to the requirement of the crop would be essential in order for tissue analysis to be effective as a diagnostic tool. Leaf analysis is based on the functioning and assimilating leaves as the central laboratories of nutrition according to Lundegard has mentioned by Shear, et al. (14). Leaf analysis, also may reveal the direction and extent of nutrient inbalance in the plant.

Since a great deal of work had been done in tree crops and other economic crops, a compilation on the position of leaf, the tissue best for sampling, and the range best for a plant of a particular nutrient element had been listed by Childers (4), Chapman (3), and Goodall and Gregory (5), so that only literature pertaining to chrysanthemum will be cited here.

Messing, *et al*. (12) reported that the omission of any element from a nutrient solution frequently induced different effects in different varieties of the same species. The nutrient requirement of chrysanthemum depended on the variety. In particular, slow growing varieties with small hard foliage needed higher levels of N.

Waters (19) stated that increased K had little effect on plant responses other than K-content of leaf and flower tissue. When N rates were increased, yield responses and postharvest keeping quality decreased and the susceptibility to *Botrytis cinerea* Perc. ex. Fr. increased markedly. In general, optimum yields were obtained when young mature leaves contained 3.5% to 4.5% and 3.5% to 6.0% K; and flowers contained 1.5% to 2.5% of N and K. He also observed that, for good quality yields of flowers, 20 to 30 lbs. of N and K per acre per week should be applied under field conditions in Florida.

Lunt, et al. (11) proposed the following leaf composition and sampling positions as representative of desirable growth of 'Good News' Chrysanthemum.

Element	Adequate Range	Plant Part Effectively Reflecting Mineral Deficiencies
N %	4.5 - 6.0	Upper leaves
P %	0.26 - 1.15	Upper or lower leaves
K %	3.5 - 10.0	Lower leaves
Ca %	0.50 - 4.6	Upper leaves
Mg %	0.14 - 1.50	Lower leaves
Mn ppm	195 - 260	Upper or lower leaves
B ppm	25 - 200	Upper leaves
Cu ppm	10 (?)	Middle leaves from lower axillary growth
Zn ppm	7-26 (?)	Lower leaves

Boodley (1) observed that potted chrysanthemum, grown in spring and summer, had a greater nutrient content than those grown in winter.

Lunt and Kofranek (10) reported that the K requirement of Chrysanthemum (var. Albatross, Dark Orchid, Queen and Good News) was high. Leaf K content of plants adequately fertilized contained about 100 me./100 grams (3.90%) and upward while the leaves of plants containing 12-15 me./100 grams (0.47-0.59%) developed necrosis, typical K deficiency, were delayed in blooming and shoots were crooked.

The N requirement of these 4 varieties was also high. Plants adequately fertilized had leaf N levels of about 4.0 to 4.5%. Levels of about 2.25 to 2.75% were considered slightly deficient. They felt it was important that N levels should be maintained for the first 7 weeks of growth. If moderate N deficiency developed subsequently, N fertilization did not bring back the flower quality. Sustained high N levels until blooming time led to a condition of "brittle leaf". Thus lower N levels in the growing medium would be desirable during the last 3 or 4 weeks before bloom.

Joiner and Smith (9) used 'Bluechip' Chrysanthemum and observed detrimental effects of high N and low K during high temperature, although the injurious effects were less marked and were finally overcome as K was increased. Vigorous, productive plants were produced when 100 ppm N and 166 ppm K were used or a ratio of 1:1.6 N to K. Chemical analysis of the foliage revealed ionic antagonism between K and Mg whereas N had a synergistic effect on the absorption of Ca, Mg, and P. Increased N lowered flower keeping quality while intensity of flower color decreased with high N and low K.

Woltz (21) with 'Forty Niner' and 'Goldsmith' Chrysanthemum proposed the following as approximate desirable levels for solution concentration (sand culture) and leaf analysis.

Element	Nutrient Sol. Sand Culture ppm	Leaves
N %	100 - 200	4.5 - 5.0
P %	40	0.3 - 0.4
K %	100 - 200	4.0 - 6.0
Mg %	25 - 50	0.3
B ppm	0.1	75
Cu ppm	0.1	35
Fe ppm	1.0	200
Mn ppm	0.25	200
Zn ppm	0.5	150

Stevens, et al. (17) with potted Chrysanthemum observed the first symptoms of injury due to excessive soluble salts as a reduction in plant growth followed by a wilting of the foliage.

Joiner (7) stated that generally at a low P level, each increment of K, decreased tissue content of P, Ca, and Mg. But as P was increased in the substrate a larger increase of K was necessary to cause a decrease in the absorption of these elements in 'Indianapolis White No. 3'.

Pawlowski (13) observed that flower development in Chrysanthemum was delayed by ammonium nitrate in concentrations exceeding 200 ppm N, and this effect was independent of the K concentration in the nutrient solution or the K content of the plant. Increasing K concentration in the nutrient solution, decreased the content of the total N in the plant, whereas the nitrate and relative protein N content increased. In the K stimulating range, increasing yields were accomapnied by a decrease in the content of organic bond non-protein N.

Waters (19) observed that generally N content of leaves and flowers increased linearly in response to additional K. The K content of leaves and flowers increased linearly in response to additional K fertilizers and varied slightly in response to additional N. Excessive N was more injurious than excessive K.

Waters (20), using 14-14-14 fertilizer at the rate of 2400-7200 lbs/A/season, reported the following leaf composition values at the different rates of fertilizers. He used 'Iceberg' Chrysanthemum.

Fertilizer	% Chemical Content of Leaves at Harvest			
lbs/A/Season	N	P	K	Ca
900	3.12	.39	1.40	1.26
1200	3.31	.41	1.48	1.55
1500	3.59	.35	2.97	1.30
1800	3.55	.47	2.05	1.56
2100	3.48	.38	2.40	1.58
2400	3.45	.40	2.68	1.53
		N.S.		N.S.

MATERIALS AND METHODS

The research was carried out in the Plant Science Greenhouse of the Department of Horticulture, Michigan State University, East Lansing, Michigan.

Materials

Rooted cuttings of *Chrysanthemum morifolium* var. Iceberg* were placed in 2-gallon containers filled with number 7 fine quartz sand and then covered with an inch of number 4 coarse grade sand.

One-gallon containers were used to hold and collect the nutrient solution used for the culture.

Treatments

The quartz sand used was rinsed several times with deionized water until the washings were clear before the cuttings were planted.

The 2-gallon containers were cleaned with a solution of 50 cc. chlorox to 1 gallon of water. The 2-gallon containers were provided with a side drain hole where a single-holed rubber stopper was fitted and a rubber tubing connected the 2-gallon container to the 1-gallon container fitted with a 2-holed rubber stopper.

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*Obtained from Yoder Brothers, Barberton, Ohio.

A watch glass was placed over the drain hole inside the 2-gallon container and covered with glass wool to minimize loss of sand during watering. This did not interfere with the drainage.

The rooted cuttings were washed carefully to remove any soil or rooting medium which might contaminate the culture. Three plants were placed in each container on June 16, 1967. Three 2-gallon containers corresponded to one treatment and a total of nine 2-gallon containers made up a single treatment with three replications. The plants were watered with deionized water for three days before the treatments were started. A modified Hoagland solution was used as standard.

The nutrient solutions contained all the elements in the standard solution of Hoagland and Arnon (6). Nitrogen and potassium were supplied at varying concentrations as shown in Table 1.

The pH of the solutions was adjusted to 6.0 prior to use and the nutrient solutions were changed once a week. The frequency of watering was based on the needs of the plants as determined by growth or climatic conditions.

The 2-gallon containers were placed on top of the benches and a support was built for the 1-gallon containers so that they were just below their respective 2-gallon containers. The containers were labelled with their respective treatment numbers and were completely randomized.

Table 1. N and K Concentrations in Each Treatment[a]

Treatment No.	Nitrogen Conc. ppm	Potassium Conc. ppm
1	56	312
2	112	312
3	224	312
4	448	312
5	896	312
6	56	624
7	112	624
8	224	624
9	448	624
10	896	624

[a]See Appendix Table 1 for chemicals used in preparation of each solution.

Saran cloth was placed above the plants to prevent leaf burn from the intense sunlight and, also, to minimize dust on the medium and on the leaves. Additional lights were used from 4:00 p.m. to 11:00 p.m. to extend daylength and to insure vegetative growth during the experimental period. Insects and diseases were controlled by spraying the appropriate insecticide and fungicide during the experimental period.

The plants were observed very closely for any signs of deficiency or toxicity. The plants grown under treatment 1 (56 ppm N and 312 ppm K) and treatment 6 (56 ppm N and 624 ppm K) showed signs of chlorosis and stunted growth. By the ninth week, the plants from these two treatments were completely different from the 224 ppm N and 312 ppm K so that on August 18, 1967 the plants final observations were made regarding symptoms of nutrient disorders.

The height and fresh weight were taken and recorded for ten plants from each treatment. The following leaf samples were taken from each treatment by compositing the 3 plants in each container.

Sample No. 1 - The growing tip included the first expanded leaf.

Sample No. 2 - The next two leaves below sample 1.

Sample No. 3 - The next two leaves below sample 2.

Sample No. 4 - The next two leaves below sample 3.

Sample No. 5 - The next two leaves below sample 4.

Sample No. 6 - The next two leaves below sample 5.

Sample No. 7 - The next two leaves below sample 6.

Sample No. 8 - The next two leaves below sample 7.

Sample No. 9 - The next two leaves below sample 8.

Sample No. 10 - The next two leaves below sample 9.

Leaf sample 10 was also the bottom leaves in treatments using 56 ppm N. The leaf samples were cleaned with cheesecloth moistened with deionized water. Each leaf sample from one treatment in each replicate was placed in a perforated bag. They were immediately placed in a drying oven for 48 hours at 150 to 170F.

The oven-dried samples were ground in an intermediate Wiley mill to pass through a 20-mesh screen. The ground samples were collected in separate bottles, covered, numbered correspondingly and stored for analysis.

For nitrogen determination, a 0.25 gram aliquot was weighed and placed in a Kjeldahl flask and analyzed by a standard Kjeldahl method.

For potassium determination, a 0.25 gram aliquot of the ground sample was weighed and extracted in 50 ml. of distilled water for 2 hours with occasional shaking. The filtrate was used for potash determination in the flame photometer.

For phosphorus, sodium, calcium, magnesium, manganese, iron, copper, boron, zinc, and aluminum spectrophotometric analysis was used. All analyses were made in the Plant Analysis Laboratory, Horticulture Department, Michigan State University.

Statistical Analysis

Analysis of variance was done by use of the computer. Tukey's (16) honestly significant difference (HSD) was used in determining significant differences among the means. A significant difference at the .01 level was used unless otherwise specified.

A simple correlation was also run through the computer to determine the effects of the N and K interaction on the various elements included in the analysis except Na.

RESULTS

Growth

Growth of the plants was affected by the concentration of nitrogen and potassium, Table 2. Greatest amount of growth, as measured by either height or dry weight, resulted from the use of 224 ppm N and 312 or 624 ppm K. Solutions containing 896 ppm N reduced growth only when combined with 624 ppm K.

The least amount of linear growth resulted from the solution containing 56 ppm N with 312 ppm K. The solution containing 56 ppm N with 624 ppm K did result in significantly greater height of plants than the 56 ppm N with 312 ppm K. Fresh weight of tops was significantly reduced when 56 ppm N was used as compared to all other N concentrations with 312 ppm K. However, with 624 ppm K, 56 ppm N significantly reduced growth as compared with 224 ppm N and above. With both 312 and 624 ppm K there was no difference in fresh weight of tops for N concentrations above 112 ppm.

Observations

Plants in treatments receiving 56 ppm N with 312 and 624 ppm K respectively, were stunted, no side shoots developed, stems were thin, leaves were smaller and yellowish green compared to the other treatments; and after removing 10 leaf samples practically no leaves were left. These were the only 2 treatments that showed N deficiency.

Table 2. Growth of Chrysanthemum Plants as Influenced By Solution Concentrations of Nitrogen and Potassium

Nitrogen	Potassium	Ht. of Tops	Fresh Wt. of Tops
ppm	ppm	cm	g
56	312	46.8	38.0
112	312	78.4	99.9
224	312	92.8	112.2
448	312	77.2	98.1
896	312	74.7	106.8
56	624	58.1	40.3
112	624	72.9	68.5
224	624	85.7	83.9
448	624	84.7	90.5
896	624	66.7	73.2

Required for significant difference

		.05 - 11.4	.05 - 27.4
		.01 - 13.0	.01 - 31.3

With 112 ppm N and 312 ppm K, the plants were not very different from the 224 ppm N with 312 ppm K, although the leaves were not as large, plants were not as tall, and side shoots were present. Using 112 ppm N with 624 ppm K, resulted in plants that were somewhat shorter and with thinner shoots thinner as compared to its counterpart above. This was shown by the average height of 72.9 cm compared to 78.4 cm, and average weight was 68.5 g compared to 99.9 g. The plants with 112 ppm N with 624 ppm K were woody and the leaves difficult to remove from the stems with petioles attached.

The solution with 224 ppm N and 312 ppm K was considered as a standard. This treatment resulted in plants that were tallest with an average height of 92.8 cm and heaviest with an average weight of 112.2 g. The leaves were large and bright green. Side shoots were present. Solutions with 224 ppm N but with 624 ppm K, resulted in an average height of 85.7 cm and 83.9 g average weight. The plants looked normal.

Solutions with 448 ppm N and 312 ppm K, resulted in plants with few side shoots but looked normal. The plants had an average height of 77.2 cm and 98.1 g average weight. Plants receiving 448 ppm N and 624 ppm K, averaged 84.8 cm in height and 90.5 g average weight.

Solutions with 896 ppm N and 312 ppm K, produced plants that were quite brittle. The plants looked normal. The average height was 74.7 cm and 106.8 g average weight. Solutions containing 896 ppm and 624 ppm K resulted in plants with an average height of 66.7 cm and 73.2 g average weight. However, the plants in both treatments looked normal.

Nitrogen

As shown in Table 3, each increment in nitrogen concentration above 112 ppm resulted in a significant increase in leaf N. The use of 56 ppm N did not significantly reduce leaf N below that resulting from 112 ppm N.

The use of 624 ppm K resulted in a significant increase in leaf N as compared to 312 ppm K.

Leaf N was lower in older leaves. Although there was a stepwise reduction in leaf N with age, not all leaf positions were significantly different from each other. However, significant differences were present if the data for even or odd numbered leaf positions were compared.

Table 4 shows leaf N as influenced by K concentration in relation to varying concentrations of N. Increasing the K concentration from 312 to 624 ppm resulted in an increase in leaf N when the nitrogen concentration was 56, 112 or 224 ppm. However, when N concentration was 448 or 896 ppm, an increase in K concentration resulted in a decrease in leaf N.

Leaf N content increased as the N concentration in the medium was increased regardless of leaf position (Table 5).

Table 3. Nitrogen in Chrysanthemum Leaves in Relation to Nutrient Solution Concentration of Nitrogen and Potassium and to Leaf Position

N - ppm	Leaf N - % dry wt
56	3.27
112	3.40
224	3.90
448	4.90
896	5.91
Req. for sign. diff.: 5% - .14, 1% - .16	
K - ppm	
312	4.21
624	4.34
Req. for sign. diff.: 5% - .08, 1% - .10	
Leaf position	
1	4.91
2	4.71
3	4.60
4	4.47
5	4.26
6	4.15
7	4.07
8	3.95
9	3.87
10	3.73
Req. for sign. diff.: 5% - .20, 1% - .23	

Table 4. Nitrogen in Chrysanthemum Leaves as Influenced by Combinations of Nitrogen and Potassium Solution Concentrations

Nitrogen Con.	Potassium Conc.	Nitrogen
ppm	ppm	% dry wt.
56	312	3.18
112	312	3.03
224	312	3.78
448	312	5.01
896	312	6.05
56	624	3.35
112	624	3.77
224	624	4.02
448	624	4.78
896	624	5.77

Req. for sign. diff.: 5% - .20; 1% - .23

Table 5. Nitrogen Content of Chrysanthemum Leaves in Relation to Leaf Position as Influenced by Solution Concentration of Nitrogen

Leaf Position	Nitrogen Concentration ppm				
	56	112	224	448	896
	Nitrogen - % dry wt.				
1	4.31	4.42	4.62	5.33	5.89
2	3.97	4.05	4.15	5.22	6.16
3	3.59	3.82	4.09	5.31	6.21
4	3.21	3.61	4.04	5.24	6.26
5	3.09	3.30	3.74	5.02	6.15
6	2.99	3.14	3.79	4.87	5.97
7	3.03	2.97	3.73	4.68	5.93
8	2.97	2.89	3.62	4.55	5.72
9	2.87	2.89	3.62	4.45	5.53
10	2.62	2.90	3.59	4.30	5.22

Req. for sign. diff.: 5% - .44; 1% - .51

A significant difference in the younger leaf tissues occurred when 448 and 896 ppm N was used. In the older leaf tissues a significant difference occurred when 224, 448 and 896 ppm N were used in the medium. There was no significant difference between the first two leaf samples when the N concentration in the medium was 56, 112, or 224 ppm. However, in the medium where 448 ppm N was used there was no significant difference from the first down to the sixth leaf sample. Similarly where 896 ppm N was used there was a gradual increase in leaf N from the first leaf sample to the fourth and then a decrease for the leaf samples below the fourth sample. The increase in leaf N from the first to the fourth leaf sample was not significant. However, leaf position 8 and below were significantly below the N concentration for leaf position 4.

The nitrogen content of leaves still followed the general trend of having the greatest concentration in the upper-most leaf position (Table 6) when the potassium concentration was increased from 312 to 624 ppm. However, the two uppermost leaf samples had a higher N content as compared to 312 ppm K, when 624 ppm K was used in the medium. There was no significant difference between 312 and 624 ppm K for the other leaf positions.

As shown in Table 7, there was a decrease in leaf N with leaf age for all N concentrations with either K concentrations except for 448 and 896 ppm N with 312 ppm K, in which

Table 6. Nitrogen Content of Chrysanthemum Leaves in Relation to Leaf Position and Solution Concentration of Potassium

Leaf Position	Potassium Concentration	
	312 ppm	624 ppm
	Nitrogen - % dry wt.	
1	4.64	5.19
2	4.51	4.91
3	4.49	4.71
4	4.44	4.51
5	4.21	4.32
6	4.17	4.14
7	4.08	4.06
8	3.98	3.92
9	3.86	3.88
10	3.71	3.74

Req. for Sign. Diff.: .05 = .28
.01 = .32

Table 7. Nitrogen Content of Chrysanthemum Leaves as Influenced by Potassium and Nitrogen Solution Concentration and by Leaf Position

Leaf Position	N. Conc. ppm 56		112		224		448		896	
	K. Conc. ppm 312	624	312	624	312	624	312	624	312	624
1	4.24	4.38	4.00	4.83	4.47	4.77	5.11	5.55	5.39	6.40
2	3.94	4.00	3.52	4.58	3.99	4.31	5.13	5.30	5.94	6.37
3	3.43	3.75	3.39	4.24	3.95	4.23	5.45	5.17	6.26	6.16
4	3.00	3.42	3.29	3.93	3.89	4.19	5.49	5.00	6.54	5.98
5	2.84	3.33	2.95	3.65	3.61	3.88	5.27	4.77	6.36	5.95
6	2.87	3.12	2.77	3.52	3.73	3.86	5.13	4.60	6.34	5.60
7	3.02	3.04	2.58	3.37	3.60	3.87	4.88	4.48	6.33	5.55
8	3.04	2.90	2.56	3.21	3.54	3.70	4.67	4.44	6.10	5.33
9	2.90	2.84	2.58	3.21	3.51	3.73	4.60	4.29	5.71	5.34
10	2.53	2.71	2.65	3.16	3.52	3.67	4.38	4.22	5.48	4.06

Required for significant difference: 5% = .62; 1% = .71

case leaf N content tended to increase from the first to the fourth leaf samples before it decreased with age. With 624 ppm K, the above did not occur but instead followed the trend of leaf N which decreased with leaf age.

The data showed that for 56 ppm N with 312 ppm K, leaf N was lowest for leaf position 10 and significantly increased when leaf position 3 was reached. For 56 ppm N with 624 ppm K, the lowest leaf N was for position 10 with a significant increase occurring at position 4. Lowest leaf N for 112 ppm N with 312 ppm K was for leaf position 8 and significantly increased at position 4. The combination of 112 ppm N with 624 ppm K had the lowest leaf N at leaf position 10 with a significant increase occuring at position 4. For 224 ppm N with 312 ppm K, the lowest leaf N was at position 9 and significance occurred at the first leaf sample. For 224 ppm N with 624 ppm K, the lowest leaf N was at leaf position 10 and a significant increase was reached at leaf position 1. When 448 ppm N was used, the lowest leaf N occurred at position 10 for both 312 and 624 ppm K. However, a significant increase occurred at position 6, for 312 ppm K and position 4 for 624 ppm K. Also, the highest leaf N content occurred at leaf position 4 and there was no significant difference between samples 4 and 1. Using 896 ppm N resulted in the lowest leaf N at position 10 with either 312 or 624 ppm K. However, a significant increase occurred at leaf position 7 with 312 ppm K and at position 9 with the 624 ppm K. There was no significant increase until position 3 was reached. Also note that the highest leaf N with 312 ppm K was highest at position 4 and a significant difference from position 1. In all cases 624 ppm K increased leaf N content compared to 312 ppm.

Potassium

Nitrogen concentrations below and above 112 ppm in the medium resultedin an increased K content of leaves as shown in Table 8. The increase was significant with the 56, 448, and 896 ppm N. The lowest N concentration (56 ppm) resulted in the highest K content but was not significant when compared to the 448 or 896 ppm N.

Table 8 shows that leaf K content was significantly increased when 624 ppm K was used in the medium.

Leaf K was higher for the lower leaf samples as shown in Table 8. The first six leaf samples had K content that was significantly different from each other. Below position 6, there was not a significant increase for each leaf position but significance occurred for every other leaf position.

Various combinations of N and K concentrations altered the main effects of N and K concentrations, Table 9. Increasing the K concentration from 312 ppm to 624 ppm increased leaf K

Table 8. Potassium Content of Chrysanthemum Leaves in Relation to Concentrations of Nitrogen and Potassium and to Leaf Position

N - ppm	Leaf K - % dry wt
56	7.01
112	6.42
224	6.43
448	6.78
896	6.94
Req. for sign. diff.: 5% - .26, 1% - .30	
K - ppm	
312	5.96
624	7.47
Req. for sign. diff.: 5% - .16, 1% - .19	
Leaf Position	
1	4.18
2	4.92
3	5.75
4	6.29
5	6.82
6	7.20
7	7.50
8	7.86
9	8.21
10	8.43
Req. for sign. diff.: 5% - .36, 1% - .42	

Table 9. Potassium Content of Chrysanthemum Leaves as Influenced by Nitrogen and Potassium Solution Concentrations

Nitrogen Conc.	Potassium Conc.	Potassium
ppm	ppm	% dry wt.
56	312	6.84
112	312	5.45
224	312	5.76
448	312	5.88
896	312	5.89
56	624	7.18
112	624	7.39
224	624	7.10
448	624	7.68
896	624	8.00

Req. for sign. diff.: 5% - .36, 1% - .42

when the N concentration was 112 ppm or higher. The increase was not significant when 56 ppm N was used. With 312 ppm K, increasing the N concentration from 56 to 112 ppm reduced leaf K. Further increases in N concentration increased leaf K with significance occurring when 448 or 896 ppm N was used. When 624 ppm K was used there was no significant increase in leaf K until 448 or 896 ppm N was used.

As shown in Table 10, leaf K increased with lower leaf positions regardless of N concentration. However, the increase between leaf position 1 and 2 was significant for a N concentration of 56 ppm. For all other N concentrations the increase was not significant until leaf position 3. Conversely, the decrease in leaf K below that for leaf position 10 was significant for leaf position 7 when 56, 112 or 448 ppm N was used. For 224 and 896 ppm N, the decrease was significant for leaf position 6. The over-all increase in leaf K, from position 1 to 10, was greatest for 56 ppm N and lowest for 112 ppm N. This over-all increase was about equal for 112 and 224 ppm N and for 448 and 896 ppm N.

Using 624 ppm K in the medium increased leaf K content significantly for all leaf positions as shown in Table 11. Leaf K content increased with leaf age in both K concentrations. The highest value was significantly different from the lowest.

Table 10. Potassium Content of Leaves as Influenced by Nitrogen Concentration and Leaf Positions

Leaf Position	Nitrogen Concentration				
	ppm				
	56	112	224	448	896
	Nitrogen - % dry wt.				
1	3.90	4.16	4.20	4.31	4.31
2	4.94	4.83	4.83	4.95	5.06
3	6.18	5.66	5.52	5.68	5.73
4	6.48	6.27	6.13	6.20	6.39
5	6.81	6.66	6.50	6.95	7.17
6	7.26	6.90	7.03	7.35	7.46
7	7.76	6.96	7.31	7.57	7.90
8	8.56	7.30	7.26	7.87	8.30
9	8.99	7.69	7.61	8.30	8.45
10	9.19	7.78	7.88	8.63	8.67

Req. for Sign. Diff.: 5% - .81, 1% - .93

Table 11. Potassium Content of Chrysanthemum Leaves in Relation to Potassium Concentration and Leaf Position

Leaf Position	Potassium - ppm	
	312	624
	K - % dry wt.	
1	3.87	4.48
2	4.45	5.39
3	5.11	6.39
4	5.60	6.98
5	5.82	7.82
6	6.27	8.12
7	6.63	8.37
8	7.04	8.67
9	7.27	9.15
10	7.56	9.30

Req. for Sign. Diff.: 5% - .36, 1% - .42

Phosphorus

The leaf P content (Table 12) was significantly higher when 56 ppm N was used in the medium compared to higher concentrations. N concentrations above 112 ppm did not significantly change leaf P.

Using 624 ppm K significantly increased leaf P content above that found for 312 ppm K as shown in Table 12.

There was higher leaf P content with older leaf positions. There was not a significant increase for each leaf position. However, significance occurred when every other or every third leaf position was compared.

Using 312 ppm K with N concentrations below and above 224 ppm N tended to increase leaf P content (Table 13). The increment was not significant except in the 56 ppm N which was also the highest value obtained. Applying twice as much K (624 ppm) in the medium did not change the effect of N concentration on leaf P. Except the lowest value was for 112 ppm N and 448 ppm N significantly increased leaf P. When 56 ppm N was used, leaf P was significantly higher than all other N concentrations.

The interaction of nitrogen concentration with leaf position on leaf P was significant (Table 14). The significant increase in leaf P associated with leaf position varied in significance with different concentrations of N. For example:

Table 12. Phosphorus Content of Chrysanthemum Leaves in Relation to Nitrogen and Potassium Solution Concentration and to Leaf Position

N - ppm	P - % dry wt
56	1.73
112	1.34
224	1.31
448	1.39
896	1.37
Req. for sign. diff.: 5% - .11, 1% - .12	
K - ppm	
312	1.21
624	1.65
Req. for sign. diff.: 5% - .06, 1% - .07	
Leaf Position	
1	1.02
2	1.11
3	1.17
4	1.22
5	1.29
6	1.43
7	1.58
8	1.71
9	1.81
10	1.95
Req. for sign. diff.: 5% - .14, 1% - .16	

Table 13. Phosphorus Content of Chrysanthemum Leaves as Influenced by Nitrogen and Potassium Concentrations in the Solution

Nitrogen Conc.	Potassium Conc.	Phosphorus
ppm	ppm	% dry wt.
56	312	1.54
112	312	1.15
224	312	1.09
448	312	1.13
896	312	1.14
56	624	1.92
112	624	1.52
224	624	1.54
448	624	1.67
896	624	1.61

Req. for Sign. Diff.: 5% - .14, 1% - .16

Table 14. Phosphorus Content of Chrysanthemum Leaves as Influenced by Nitrogen Concentration and Leaf Position

Leaf Position	Nitrogen Concentration				
	56	112	224	448	896
			P - % dry wt.		
1	0.97	1.06	1.07	1.11	0.91
2	1.08	1.08	1.17	1.20	1.02
3	1.23	1.14	1.14	1.25	1.08
4	1.33	1.17	1.14	1.29	1.16
5	1.43	1.19	1.21	1.30	1.30
6	1.78	1.33	1.28	1.37	1.41
7	2.07	1.46	1.34	1.48	1.56
8	2.32	1.52	1.49	1.58	1.64
9	2.40	1.64	1.60	1.64	1.77
10	2.66	1.79	1.69	1.75	1.87

Req. for Sign. Diff.: 5% - .32, 1% - .37

with N at 56 ppm leaf positions 1 to 3 were not significantly different in leaf P; with N at 112 ppm leaf positions 1 to 6 were not significantly different; with N at 224 ppm leaf positions 1 to 7 were not different; with N at 448 or 896 ppm, leaf positions 1 to 6 were not different. Also, with N at 56 ppm leaf positions, 4, 5, 6, 7, and 8 were significantly different from leaf positions 1 or 10. With N at 112 ppm, leaf position 7 was significantly different from leaf positions 1 or 10. However, with N at 448 or 896 ppm there were no leaf positions significantly different from either positions 1 and 10.

As shown in Table 15, the interaction of leaf position with K concentration was significant for leaf P. The significant increase in leaf P did not occur for leaf positions 1 and 2 but for all other positions when K was increased from 312 to 624 ppm. Leaf P did not increase from position 1 until leaf position 5 when 312 ppm K was used while when 624 ppm K was used the increase occurred when leaf position 3 was reached. Moving upward from leaf position 10, a significant decrease in leaf P occurred at position 7 when 312 ppm K was used and at position 8 when 624 ppm K was used.

Table 15. Phosphorus Content of Chrysanthemum Leaves in Relation to Potassium Concentration and Leaf Position

Leaf Position	Potassium - ppm	
	312	624
	P - % dry wt.	
1	0.93	1.12
2	0.96	1.27
3	0.98	1.35
4	1.03	1.40
5	1.09	1.49
6	1.21	1.65
7	1.34	1.83
8	1.44	1.98
9	1.50	2.12
10	1.62	2.29

Req. for Sign. Diff.: 5% - .20, 1% - .23

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Calcium

N concentration below and above 224 ppm significantly decreased leaf Ca (Table 16). Increasing K concentration to 624 ppm in the medium significantly decreased leaf Ca. Leaf Ca increased with age. There was twice as much leaf Ca in the older leaf position compared to the youngest one. Significant differences occurred between each leaf position for the first 4 positions. Below position 4, significance always occurred for alternate leaf positions.

The use of 624 ppm K, as compared to 312 ppm K, reduced leaf Ca at all nitrogen concentrations (Table 17). However, the pattern of change associated with N concentrations varied with the K concentration. With 312 ppm K, there was not a significant difference in leaf Ca between 56 and 112 ppm N. When 624 ppm K was used, leaf Ca did not change significantly when N was increased from 448 to 896 ppm.

The general pattern of an increase in leaf Ca with lower leaf positions was found for all N concentrations (Table 18). However, the rate of increase varied with N concentration. The first two leaf positions were not significantly different for all concentrations of N. Starting from leaf position 3, there was not a significant increase in leaf Ca until position 8 for 56 ppm N. For 112, 448, and 896 ppm N, leaf position 5

Table 16. Calcium Content of Chrysanthemum Leaves as Influenced by Nitrogen and Potassium Concentration in Solution and by Leaf Position

N - ppm	Ca - % dry wt
56	1.33
112	1.41
224	1.60
448	1.45
896	1.25
Req. for sign. diff.: 5% - .06, 1% - .07	
K - ppm	
312	1.62
624	1.19
Req. for sign. diff.: 5% - .04, 1% - .05	
Leaf Position	
1	0.88
2	1.03
3	1.20
4	1.32
5	1.39
6	1.53
7	1.59
8	1.65
9	1.72
10	1.79
Req. for sign. diff.: 5% - .08, 1% - .09	

Table 17. Calcium Content of Chrysanthemum Leaves as Influenced by Solution Concentrations of Nitrogen and Potassium

Nitrogen Conc.	Potassium Conc.	Calcium
ppm	ppm	% dry wt.
56	312	1.57
112	312	1.58
224	312	1.83
448	312	1.73
896	312	1.39
56	624	1.09
112	624	1.24
224	624	1.36
448	624	1.17
896	624	1.11

Req. for Sign. Diff.: 5% - .08, 1% - .09

Table 18. Calcium Content of Chrysanthemum Leaves as Influenced by Nitrogen Concentration and Leaf Position

Leaf Position	Nitrogen Concentration ppm				
	56	112	224	448	896
1	0.98	0.89	0.91	0.86	0.74
2	1.13	0.95	1.12	1.06	0.87
3	1.24	1.18	1.26	1.25	1.05
4	1.22	1.32	1.49	1.43	1.15
5	1.20	1.41	1.58	1.47	1.27
6	1.37	1.58	1.78	1.58	1.35
7	1.41	1.62	1.81	1.67	1.43
8	1.45	1.67	1.94	1.69	1.51
9	1.56	1.73	2.02	1.71	1.56
10	1.71	1.79	2.06	1.76	1.62

Req. for Sign. Diff.: 5% - .18, 1% - .21

was significantly higher in leaf Ca than position 3. Starting with leaf position 10, a difference existed between N concentrations as to how soon a significant reduction occurred.

As shown in Table 19, the increase in leaf Ca in relation to leaf position was found for both concentrations of K. However, the rate or extent of change in leaf Ca was greater for 312 ppm K than for 624 ppm K. This rate of change resulted in more instances of adjacent leaf positions not being significantly different for 624 ppm K than for 312 ppm K.

Magnesium

N concentrations below and above 224 ppm in the medium decreased significantly the leaf Mg content (Table 20). However, 56 and 112 ppm N did not differ significantly as regards leaf Mg.

K concentration of 624 ppm in the medium significantly decreased the leaf Mg.

Mg was more concentrated in the lower leaf positions. However, adjacent leaf positions did not differ significantly. Moving 2 or 3 leaf positions was necessary for significance.

Table 21 shows that with both 312 and 624 ppm K, the highest level of leaf Mg was found for 224 ppm N. However, with 624 ppm K, the change in leaf Mg was signficant only for 896 ppm N. With 312 ppm K, the change in leaf Mg was significant for all N concentrations except 56 and 112 ppm N did not result in a significant change in leaf Mg.

Table 19. Calcium Content of Chrysanthemum Leaves in Relation to Potassium Concentration and Leaf Position

Leaf Position	Potassium - ppm	
	312	624
	Ca - % dry wt.	
1	0.98	0.77
2	1.16	0.89
3	1.36	1.03
4	1.52	1.12
5	1.62	1.15
6	1.79	1.27
7	1.85	1.32
8	1.92	1.39
9	1.97	1.46
10	2.04	1.53

Req. for Sign. Diff.: 5% - .12, 1% - .13

Table 20. Magnesium Content of Chrysanthemum Leaves in Relation to Nitrogen and Potassium Concentration in Solution and to Leaf Position

N - ppm	Mg - % dry wt
56	0.39
112	0.39
224	0.44
448	0.41
896	0.32
Req. for sign. diff.: 5% - .019, 1% - .021	
K - ppm	
312	0.47
624	0.31
Req. for sign. diff.: 5% - .012, 1% - .014	
Leaf Position	
1	0.33
2	0.33
3	0.36
4	0.38
5	0.39
6	0.41
7	0.42
8	0.42
9	0.42
10	0.44
Req. for sign. diff.: 5% - .027, 1% - .031	

Table 21. Magnesium Content of Chrysanthemum Leaves as Influenced by Nitrogen and Potassium Concentrations

Nitrogen Conc.	Potassium Conc.	Magnesium
ppm	ppm	% dry wt.
56	312	0.47
112	312	0.45
224	312	0.54
448	312	0.49
896	312	0.38
56	624	0.32
112	624	0.33
224	624	0.34
448	624	0.32
896	624	0.26

Req. for Sign. Diff.: 5% - .027, 1% - .031

Leaf Mg was highest for all leaf positions when 224 ppm N was used, Table 22, and lowest when 896 ppm N was used. There was a significant reduction in leaf Mg with 56 ppm N, as compared to 224 ppm N, for leaf positions 1, 2, 3, 4, and 10 but not for leaf positions 5, 6, 7, 8, and 9. Comparing 56 ppm N with 896 ppm N showed that there was a significant difference in leaf Mg for all leaf positions except 1, 2, 4, 5. The level of N also influenced the significance between leaf positions. The greatest change was for 224 and 56 ppm N and the least for 896 ppm N. The number of leaf positions not differing significantly in leaf Mg varied according to N concentration.

As shown in Table 23, the increase in leaf Mg was found for 312 ppm K. This was not true when 624 ppm K was used. With 624 ppm K there was no significant difference between leaf positions. However, with 312 ppm K there was a consistent increase in leaf Mg with leaf position with the lower leaf positions (7,8,9, and 10) not differing significantly.

Manganese

N concentration did not have a significant influence on leaf Mn (Table 24).

Increasing the K concentration in the medium from 312 to 624 ppm did not significantly increase leaf Mn.

Table 22. Magnesium Content of Chrysanthemum Leaves as Influenced by Nitrogen Concentration and Leaf Position

Leaf Position	Nitrogen Concentration ppm				
	56	112	224	448	896
	Mg - % dry wt.				
1	0.33	0.34	0.36	0.33	0.28
2	0.36	0.32	0.36	0.35	0.28
3	0.38	0.34	0.37	0.38	0.31
4	0.37	0.37	0.42	0.40	0.33
5	0.36	0.38	0.44	0.41	0.34
6	0.42	0.42	0.48	0.43	0.33
7	0.41	0.42	0.47	0.44	0.33
8	0.41	0.42	0.49	0.44	0.34
9	0.42	0.42	0.51	0.43	0.34
10	0.47	0.44	0.51	0.44	0.34

Req. for Sign. Diff.: 5% - .06, 1% - .07

Table 23. Magnesium Content of Chrysanthemum Leaves in Relation to Potassium Concentration and Leaf Position

Leaf Position	Potassium - ppm	
	312	624
	Mg - % dry wt.	
1	0.34	0.31
2	0.37	0.30
3	0.40	0.31
4	0.45	0.31
5	0.47	0.30
6	0.51	0.32
7	0.52	0.31
8	0.52	0.32
9	0.53	0.32
10	0.55	0.33

Req. for Sign. Diff.: 5% - 0.38, 1% - 0.44

Table 24. Manganese Content of Chrysanthemum Leaves as Influenced by Nitrogen and Potassium Concentration in Solution and by Leaf Position

N - ppm	Mn - ppm dry wt
56	119
112	120
224	120
448	125
896	122
Req. for sign. diff.: 5% - 9.8, 1% - 11.3	
K - ppm	
312	118
624	124
Req. for sign. diff.: 5% - 6.2, 1% - 7.1	
Leaf Position	
1	85
2	88
3	95
4	99
5	107
6	121
7	130
8	142
9	166
10	178
Req. for sign. diff.: 5% - 13.9, 1% - 16.1	

Mn was more concentrated in the lower leaf samples. This difference became significant when leaf position 4 was reached. This increase repeated its significance for leaf positions 6, 8, and 9.

Using 312 ppm K with N levels below and above 224 ppm tended to increase the leaf Mn content (Table 25). The difference was not significant except for 56 ppm N. Increasing the K level to 624 ppm in the medium leaf Mn was lowest with the lowest N concentration. Increasing N to 112 ppm increased leaf Mn content significantly. Further increases in N had no marked effect. It might be of interest to note that using 624 ppm K with 56 ppm N resulted in the lowest leaf Mn while 312 ppm K with 56 ppm N produced the highest leaf Mn values.

The effect of N concentrations on leaf Mn was not significant for all but 2 leaf positions - 5 and 10 (Table 26). Leaf Mn increased with leaf position for all N concentrations. The greatest increase occurred with 56 ppm N. Starting with position 1, all N levels resulted in a significant increase in leaf Mn at leaf position 5 or 6. Starting at leaf position 10, there was a significant decrease in leaf Mn at position 7 and 8 for all N concentrations.

As shown in Table 27, increasing the K concentration from 312 to 624 ppm did not increase leaf Mn for any of the leaf positions. Starting with the first leaf position, there was

Table 25. Manganese Content of Chrysanthemum Leaves as Influenced by Nitrogen and Potassium Concentration

Nitrogen Conc.	Potassium Conc.	Manganese
ppm	ppm	ppm dry wt
56	312	130
112	312	112
224	312	111
448	312	122
896	312	114
56	624	107
112	624	128
224	624	129
448	624	128
896	624	129

Req. for Sign. Diff.: 5% - 14, 1% - 16

Table 26. Manganese Content of Chrysanthemum Leaves as Influenced by Nitrogen Concentration and Leaf Position

Leaf Position	Nitrogen Concentration				
	ppm				
	56	112	224	448	896
	Leaf Mn - ppm dry wt.				
1	83	86	80	97	78
2	84	84	88	96	90
3	87	97	97	99	94
4	87	96	107	105	102
5	84	103	120	117	112
6	116	118	124	128	119
7	120	134	125	137	135
8	143	141	139	142	145
9	183	159	158	161	168
10	201	181	162	172	174

Req. for Sign. Diff.: 5% - 31, 1% - 36

Table 27. Manganese Content of Chrysanthemum Leaves in Relation to Potassium Concentration and Leaf Position

Leaf Position	Potassium - ppm	
	312	624
	Leaf Mn - ppm dry wt.	
1	82	88
2	83	94
3	91	99
4	93	106
5	100	114
6	117	125
7	127	134
8	139	145
9	168	164
10	179	176

Req. for Sign. Diff.: 5% - 19, 1% - 22

a significant increase in leaf Mn at leaf position 6 for 312 ppm K and position 5 at 624 ppm K. Leaf position 8 was significantly lower in leaf Mn than position 10 for both K concentrations.

Iron

N concentration of 56 ppm resulted in the lowest leaf Fe content (Table 28). N levels of 448 and 896 significantly increased leaf Fe. Leaf Fe was significantly higher for 448 and 896 ppm N than for 112 ppm N. Other comparisons did not show significant differences.

K concentration of 624 ppm in the medium significantly increased the leaf Fe content. Leaf Fe was more concentrated in the lower leaf samples. A significant increase occurred at leaf position 4. Additional significant increases occurred at leaf positions 7 and 10.

Leaf Fe was lowest for 56 ppm N when 312 ppm K was used (Table 29). When 624 ppm K was used, leaf Fe was lowest for 224 ppm N and significantly higher for 56 and 896 ppm N. Leaf Fe was significantly lower for 56 ppm N with 312 ppm K than all other N concentrations.

Leaf Fe increased significantly with leaf position for all N concentrations, except for 112 ppm (Table 30). For all N concentrations, except 112 ppm, there was a significant

Table 28. Iron Content of Chrysanthemum Leaves as Influenced by Nitrogen and Potassium Concentration and Leaf Position

N - ppm	Fe - ppm dry wt
56	240
112	250
224	263
448	288
896	282
Req. for sign. diff.: 5% - 27, 1% - 31	
K - ppm	
312	243
624	287
Req. for sign. diff.: 5% - 17, 1% - 20	
Leaf Position	
1	200
2	221
3	225
4	249
5	252
6	274
7	278
8	293
9	311
10	344
Req. for sign. diff.: 5% - 38, 1% - 44	

Table 29. Iron Content of Chrysanthemum Leaves as Influenced by Nitrogen and Potassium Interaction

Nitrogen Conc.	Potassium Conc.	Iron
ppm	ppm	ppm dry wt
56	312	173
112	312	230
224	312	267
448	312	281
896	312	263
56	624	308
112	624	270
224	624	259
448	624	295
896	624	301

Req. for Sign. Diff.: 5% - 38, 1% - 44

Table 30. Iron Content of Chrysanthemum Leaves as Influenced by Nitrogen Concentration and Leaf Position

Leaf Position	Nitrogen Concentration ppm				
	56	112	224	448	896
	Leaf Fe - ppm dry wt.				
1	186	201	176	218	217
2	184	219	206	248	246
3	165	231	227	256	247
4	176	244	269	274	281
5	177	246	286	278	274
6	258	275	271	288	279
7	242	275	264	302	309
8	293	264	288	318	300
9	332	264	325	327	307
10	391	283	318	371	357

Req. for Sign. Diff.: 5% - 86, 1% - 100

increase in Fe when leaf position 7 or 8 was reached. Starting with leaf position 10, there was a significant reduction in leaf Fe at position 8 for 56 ppm N, position 3 for 224 ppm N, position 5 for 448 and 896 ppm N. Varying the N concentration resulted in significant variation in leaf Fe for leaf positions 3, 4, and 10.

Leaf Fe was increased for all leaf positions by increasing K concentration from 312 to 624 ppm (Table 31). This increase was significant for leaf positions 4, 8, 9 and 10. With 312 ppm K, there was a significant increase in leaf Fe when leaf position 6 was reached. Starting with leaf position 10, 312 ppm K resulted in a significant decrease at leaf position 5. When 624 ppm K was used, leaf Fe was significantly higher for leaf position 4 than for position 1 and significantly lower for leaf position 8 than for position 10.

Copper

Using varying concentrations of N below and above 112 ppm tended to decrease the leaf Cu content (Table 32). The difference was not significant except for 896 ppm N.

Using 624 ppm K in the medium significantly increaed the leaf Cu.

Leaf Cu content decreased with leaf age. The difference between the first and third leaf positions was significant. However, leaf positions 2 through 10 did not differ significantly.

Table 31. Iron Content of Chrysanthemum Leaves in Relation to Potassium Concentration and Leaf Position

Leaf Position	K - ppm	
	312	624
	Fe - ppm dry wt	
1	191	208
2	202	239
3	215	235
4	221	277
5	235	269
6	257	292
7	259	298
8	258	327
9	284	338
10	305	383

Req. for Sign. Diff.: 5% - 54, 1% - 63

Table 32. Copper Content of Chrysanthemum Leaves as Influenced by Nitrogen and Potassium Concentration and Leaf Position

N - ppm	Cu - ppm dry wt
56	19
112	20
224	17
448	16
896	15
Req. for sign. diff.: 5% - 4.3, 1% - 5.0	
K - ppm	
312	14
624	21
Req. for sign. diff.: 5% - 2.7, 1% - 3.2	
Leaf Position	
1	25
2	20
3	18
4	16
5	15
6	16
7	18
8	14
9	14
10	17
Req. for sign. diff.: 5% - 6.1, 1% - 7.1	

Using 624 ppm K as compared to 312 ppm, increased leaf Cu with all N concentrations except 224 and 896 ppm (Table 33). N concentrations did not significantly decrease leaf Cu.

Leaf Cu content decreased with age regardless of N levels (Table 34). The differences were significant for 56 and 112 ppm N; N concentrations did not have a significant influence on leaf Cu at any of the leaf positions.

Using 624 ppm K significantly decreased leaf Cu for leaf positions 4, 5, 6, 8, 9, and 10 as compared to that for leaf positions 1 (Table 35). When 312 ppm K was used, leaf Cu was significantly lower for leaf position 5 than for position 1. Comparing 624 ppm K with 312 ppm K showed that leaf Cu was significantly increased at leaf position 1, 2, 3, and 7.

Boron

Leaf B was decreased with increasing N concentrations (Table 36). A significant decrease occurred with 448 and 896 ppm N.

As K level was increased to 624 ppm, leaf B was increased significantly.

Leaf B increased with age. Only leaf positions 7, 8, and 9 were not significantly different from the adjacent leaf position.

Table 33. Copper Content of Chrysanthemum Leaves as Influenced by Nitrogen and Potassium Concentrations

Nitrogen Conc.	Potassium Conc.	Copper
ppm	ppm	ppm
56	312	15
112	312	14
224	312	15
448	312	12
896	312	12
56	624	23
112	624	26
224	624	19
448	624	19
896	624	18

Req. Sign. Diff.: 5% - 6.1, 1% - 7.1

Table 34. Copper Content of Chrysanthemum Leaves as Influenced by Nitrogen Concentration and Leaf Position

Leaf Position	Nitrogen Concentration ppm				
	56	112	224	448	896
	Leaf Cu - ppm dry wt.				
1	32	29	22	20	24
2	23	25	16	18	20
3	19	22	16	15	19
4	18	17	16	15	12
5	15	16	18	15	12
6	19	17	15	15	13
7	16	19	27	15	13
8	15	15	13	15	12
9	15	16	15	15	11
10	18	25	14	15	14

Req. for Sign. Diff.: 5% - 14, 1% - 16

Table 35. Copper Content of Chrysanthemum Leaves in Relation to Potassium Concentration and Leaf Position

Leaf Position	K - ppm	
	312	624
	Leaf Cu - ppm dry wt	
1	20	31
2	15	26
3	13	23
4	12	19
5	11	19
6	13	19
7	13	23
8	12	16
9	12	16
10	15	19

Req. for Sign. Diff.: 5% - 9, 1% - 10

Table 36. Boron Content of Chrysanthemum Leaves in Relation to Nitrogen and Potassium Concentration and Leaf Position

N - ppm	B - ppm dry wt
56	67
112	68
224	65
448	58
896	55
Req. for sign. diff.: 5% - 3.1, 1% - 3.6	
K - ppm	
312	60
624	65
Req. for sign. diff.: 5% - 1.9, 1% - 2.2	
Leaf Position	
1	31
2	42
3	51
4	58
5	62
6	70
7	74
8	75
9	78
10	83
Req. for sign. diff.: 5% - 4.2, 1% - 5.1	

Leaf B was decreased significantly when 448 and 896 ppm N was used with 312 ppm K (Table 37). With 624 ppm K, leaf B was significantly higher for 112 ppm N than other levels of N. Increasing K to 624 ppm resulted in significantly higher leaf B for 112, 448, and 896 ppm N.

Leaf B was highest at leaf position 1 with 896 ppm N, for position 2, 3, 4, 5, 6, and 7 with 56 ppm N, and for positions 8, 9, and 10 with 112 ppm N (Table 38). As compared to the highest value for each leaf position, varying N concentrations resulted in a significant decrease for all leaf positions except 1 and 2. Starting with leaf position 1, there was a significant increase in leaf B at position 2 for all N concentrations, except for 896 ppm N where the increase was significant at position 3. Starting at leaf position 10, there was a significant decrease in leaf B at position 5 with 56 ppm N, at position 7 with 112 and 896 ppm N, and at position 8 with 224 and 448 ppm N.

The increase in leaf B with increasing leaf positions was significant at position 2 for both 312 and 624 ppm (Table 39). Starting with leaf position 10, there was a significant decrease in leaf B at position 8 with 312 ppm K and at position 9 with 624 ppm K. Significant differences in leaf B for adjacent leaf positions was not consistent for the K concentrations.

Table 37. Boron Content of Chrysanthemum Leaves as Influenced by Nitrogen and Potassium Concentrations

Nitrogen Conc.	Potassium Conc.	Boron
ppm	ppm	ppm dry wt
56	312	68
112	312	65
224	312	63
448	312	54
896	312	51
56	624	65
112	624	70
224	624	66
448	624	63
896	624	59

Req. for Sign. Diff.: 5% - 4, 1% - 5

Table 38. Boron Content of Chrysanthemum Leaves as Influenced by Nitrogen Concentration and Leaf Position

Leaf Position	Nitrogen Concentration ppm				
	56	112	224	448	896
1	29	31	31	31	33
2	44	41	44	42	40
3	57	53	53	49	46
4	66	60	61	54	50
5	69	65	67	57	55
6	83	76	72	61	58
7	84	82	73	67	63
8	82	85	76	69	65
9	75	90	83	74	68
10	81	94	86	79	73

Req. for Sign. Diff.: 5% - 10, 1% - 12

Table 39. Boron Content of Chrysanthemum Leaves as Influenced by Potassium Concentration and Leaf Position

Leaf Position	K - ppm	
	312	624
	Leaf B - ppm dry wt	
1	30	32
2	39	45
3	49	54
4	56	60
5	61	64
6	70	70
7	72	75
8	73	78
9	75	81
10	78	88

Req. for Sign. Diff.: 5% - 6, 1% - 7

Zinc

There was no consistent effect of N concentration on leaf Zn (Table 40). Leaf Zn was significantly higher with 112 ppm N. AlsO, 56 and 448 ppm N resulted in higher leaf Zn than found for 224 or 896 ppm N.

Increasing K level to 624 ppm in the medium increased the Zn content of leaves significantly.

The Zn content of leaves at positions 9 and 10 (Table 40) was significantly higher than for positions 2 and 3. All other comparisons of leaf position were not significant.

The highest Zn content of leaves obtained with 312 ppm K was with 56 ppm N (Table 41). The lowest with 312 ppm K was with 896 ppm N. The difference was not significant. With 624 ppm K the highest Zn content was obtained with 112 ppm N and the lowest with 224 ppm N. The difference was highly significant. The increase in K level to 624 ppm significantly increased the Zn content of leaves regardless of N concentration.

Increasing the N concentration did not significantly affect leaf Zn at any leaf position (Table 42).

Increasing the K concentration to 624 ppm significantly increase leaf Zn for all positions (Table 43). With 312 ppm K there were no significant differences between leaf positions. With 624 ppm K, leaf positions 6, 7, 8, 9 and 10 were significantly higher in leaf Zn than positions 1 and 2. Leaf Zn

Table 40. Zinc Content of Chrysanthemum Leaves in Relation to Nitrogen and Potassium Concentration and Leaf Position

N - ppm	Leaf Zn - ppm dry wt
56	43
112	51
224	33
448	42
896	32
Req. for sign. diff.: 5% - 8, 1% - 10	
K - ppm	
312	22
624	58
Req. for sign. diff.: 5% - 5, 1% - 6	
Leaf Position	
1	37
2	34
3	34
4	37
5	38
6	42
7	42
8	44
9	47
10	47
Req. for sign. diff.: 5% - 12, 1% - 14	

Table 41. **Zinc Content of Chrysanthemum Leaves** as Influenced by the Interaction of Nitrogen and Potassium Concentrations

Nitrogen Conc.	Potassium Conc.	Zinc
ppm	ppm	ppm dry wt
56	312	26
112	312	22
224	312	25
448	312	22
896	312	18
56	624	61
112	624	80
224	624	41
448	624	62
896	624	46

Req. for Sign. Diff.: 5% - 12, 1% - 14

Table 42. Zinc Content of Chrysanthemum Leaves in Relation to Nitrogen Concentration and Leaf Position

Leaf Position	Nitrogen Concentration ppm 56	112	224	448	896
	Leaf Zn - ppm dry wt				
1	43	42	30	38	32
2	35	42	28	34	31
3	32	49	28	32	30
4	40	47	31	40	27
5	35	50	36	41	27
6	42	57	34	45	34
7	49	52	32	46	32
8	51	55	33	46	35
9	51	57	40	51	37
10	54	57	39	50	37

Req. for Sign. Diff.: 5% - 26, 1% - 30

Table 43. Zinc Content of Chrysanthemum Leaves in Relation to the Interaction of Potassium Concentration and Leaf Position

Leaf Position	Potassium - ppm	
	312	624
	Leaf Zn - ppm dry wt	
1	28	45
2	21	46
3	20	48
4	19	54
5	18	57
6	22	63
7	22	62
8	23	64
9	23	72
10	27	68

Req. for Sign. Diff.: 5% - 17, 1% - 19

was significantly higher for leaf position 10 than for position 3 with 624 ppm K.

Aluminum

Leaf Al was significantly increased with 224, 448, and 896 ppm N (Table 44).

Increasing K level to 624 ppm did not significantly increase the leaf Al.

Leaf Al increased with age and the increase was significant for every third leaf position.

Leaf Al was significantly higher for 56 and 112 ppm N with 624 ppm K than for 312 ppm K (Table 45). For 224 ppm N, leaf Al was significantly higher for 312 ppm K than for 624 ppm K. With 448 and 896 ppm N, the K concentration did not affect leaf Al. Leaf Al was significantly higher for 224 and 448 ppm N than for 56 ppm N when 312 ppm K was used. When 624 ppm K was used, there were no significant differences as related to N concentration.

Increasing the concentration of N did not significantly affect leaf Al at any leaf position (Table 46). However, with 56 ppm N there was a significant increase in leaf Al at leaf position 8. With 112 ppm N, the increase was significant at position 6, at position 4 with 224 and 448 ppm N and at position 7 with 896 ppm N. Starting at leaf position 10,

Table 44. Aluminum Content of Chrysanthemum Leaves in Relation to Nitrogen and Potassium Concentration and Leaf Position

N - ppm	Al - ppm dry wt
56	140
112	160
224	189
448	187
896	170
Req. for sign. diff.: 5% - 24, 1% - 29	
K - ppm	
312	164
624	175
Req. for sign. diff.: 5% - 16, 1% - 18	
Leaf Position	
1	93
2	108
3	131
4	154
5	162
6	182
7	190
8	204
9	217
10	251
Req. for sign. diff.: 5% - 35, 1% - 41	

Table 45. Aluminum Content of Chrysanthemum Leaves as Influenced by the Interaction of Nitrogen and Potassium Concentration

Nitrogen Conc.	Potassium Conc.	Aluminum
ppm	ppm	ppm dry wt
56	312	121
112	312	139
224	312	208
448	312	187
896	312	163
56	624	159
112	624	180
224	624	170
448	624	187
896	624	178

Req. for Sign. Diff.: 5% - 35, 1% - 41

Table 46. Aluminum Content of Chrysanthemum Leaves as Influenced by Nitrogen Concentration and Leaf Position

Leaf Position	Nitrogen - ppm				
	56	112	ppm 224	448	896
	Leaf Al - ppm dry wt.				
1	82	101	95	86	103
2	97	99	116	112	116
3	101	126	135	156	137
4	107	145	194	166	158
5	116	168	187	177	162
6	141	183	213	198	177
7	141	183	200	221	206
8	170	187	202	257	202
9	183	192	276	232	202
10	261	213	276	265	242

Req. for Sign. Diff.: 5% - 79, 1% - 98

there was a significant decrease in leaf Al at position 7 with 56 ppm N, position 3 with 112 ppm N, position 4 with 224 and 448 ppm N, and position 5 with 896 ppm N.

Leaf Al was not increased at any leaf position when the K concentration was increased to 624 ppm (Table 47). Starting at leaf position 1, there was a significant increase in leaf Al at position 3 with 312 ppm K and at position 4 with 624 ppm K. Starting at leaf position 10, there was a significant decrease in leaf Al at position 8 with 312 ppm K and position 7 with 624 ppm K.

As nitrogen changes there is a negative correlation of the following elements: K, P, Ca, Mg, Mn, and B. (Table 48)

As potassium changes there is a positive correlation of the following elements: P, Na, Ca, Mn, Fe, B, Zn, and Al.

Table 47. Aluminum Content of Chrysanthemum Leaves as Influenced by Potassium Concentration and Leaf Position

Leaf Position	K - ppm	
	312	624
	Leaf Al - ppm dry wt	
1	68	98
2	103	113
3	135	127
4	151	157
5	163	161
6	181	184
7	189	192
8	183	225
9	209	225
10	237	266

Req. for Sign. Diff.: 5% - 50, 1%-58

Table 48. Effects of Changes in Concentration of Nitrogen and Potassium on Other Elements. Correlation Coefficients (r at 1% = 0.182)

Elements	Correlation Coefficients	
	Nitrogen	Potassium
N	1.00000	
K	-0.20074	1.00000
P	-0.31411	0.80691
Na	-0.02711	0.33664
Ca	-0.33280	0.28904
Mg	-0.33215	-0.11173
Mn	-0.21337	0.74115
Fe	0.05306	0.54994
Cu	-0.00617	-0.06288
B	-0.55352	0.74991
Zn	-0.17977	0.46751
Al	-0.08493	0.58401

DISCUSSION

Varying the level of N with different levels of K resulted in significant changes in growth as indexed by height and/or weight of plants. As regard height of plants, the greatest height resulted with a combination of 224 ppm N with 312 ppm K. Height of plants with this treatment was significantly greater than that obtained with 56, 112, 448, or 896 ppm N and 312 ppm K. When 624 ppm K was used, the 224 ppm N resulted in height being significantly greater than with 56, 112, or 896 ppm N but not with 448 ppm N. However, increasing the level of K to 624 ppm did not increase the height of plants beyond that obtained with 224 or 448 ppm N. This would indicate that the level of N was critical and may have been either too low or too high for maximum growth. The level of K may be lower without significantly reducing the height of plants.

When plant weight was used as an index of performance, the heaviest plants were obtained with 224 ppm N with 312 ppm K. When 624 ppm K was used the greatest weight was obtained with 448 ppm N thus indicating that an increase in K should be accompanied with an increase in N if plant weight is used as a criteria of growth. However, the plant weight was not significantly altered until N was decreased to 56 ppm with either 312 or 624 ppm K. Increasing N to 896 ppm with 624 ppm K also significantly reduced growth.

These responses suggest that the relationship of N to K in the growing media is not extremely specific when plant weight is used as a criteria of response.

If a ratio of height to weight was used as a criteria of response, this ratio was less than 1.0 when the N/K ratio was higher (N increased) and more than 1.0 when the N/K ratio was lower (N decreased). In this experiment, the N/K ratio of 0.715 (224 ppm N/312 ppm K or 448 ppm N/624 ppm K) resulted in the greatest level of growth as measured by either plant height or weight. Responses to other treatments, however, suggests that the ratio of N/K in the growing media may not be as specific as suggested by the value of 0.715 but may vary, possibly, over a wide range (perhaps 0.5 to 1.0) without significantly altering plant performance.

Of equal importance to the possibility of having N too low for best performance is the possibility of having N too high and the suggestion that if the N level should be too high, an increase in K may overcome the detrimental effect of the high N.

When growing Chrysanthemum in soil, it may not be possible to accurately determine the level of N and K. The use of soil tests would be helpful but the use of plant (leaf) analysis may be more reliable. Lunt, et al., 1963, reported the range in composition of Chrysanthemum leaves necessary for desirable growth. Table 49 shows the composition of leaves from sample positions 3, 4, and 5 (leaves 3 to 8 below tip) from plants grown with 224 ppm N and 312 ppm K.

The composition of leaf positions 3, 4, and 5 (leaves 3 to 8 from tip) did not fall below or exceed the range proposed by Lunt, *et al.*, except for N and Mn.

Nutrient Interrelationships

Antagonistic and synergistic interrelationships have been reported by several research workers, Smith (15). Certain reports suggest that such relationships may induce a deficiency or eliminate an excess or decrease the severity of a deficiency. The relationship between a given pair of elements has not always been the same for the different reports. Nearly all reports of research wherein the nutrient supply was changed there were changes in the plant content for one or more elements not altered. The results of this study show similar effects when the level of N or K in the growing media was varied.

An increase in N concentration resulted in an increase in N content of the leaves as would be expected. Increasing the N concentration, also, increased and decreased leaf Ca and Mg but decreased K, P, Cu, B, and Zn while Mn was not affected. Fe and Al were increased.

Table 49. A Comparison of the Composition of Chrysanthemum Leaves Number 3 to 8 with Values Proposed by Lunt *et al*., 1963, With 'Good News' Chrysanthemum

Element	Proposed by Lunt *et al* Adequate Range	Leaves 3 to 8*
%		
N	4.5 - 6.0	3.61 - 3.95
P	.26 (?) - 1.15	0.95 - 0.97
K	3.5 - 10.0	4.94 - 5.70
Ca	0.50 - 4.6	1.36 - 1.83
Mg	0.14 - 1.5	0.42 - 0.55
Mn ppm	195 - 260	81 - 104
Fe ppm	None given	224 - 273
Cu ppm	10 (?)	13.1 - 15.2
B ppm	25 - 200	49 - 65
Zn ppm	7 -26 (?)	17 - 27
Al ppm	None given	135 - 219

*For plants growing in nutrient solutions having 224 ppm N and 312 ppm K.

An increase in K concentration resulted in an increase in K content of leaves and also increased N, P, Mn, Fe, Cu, B, Zn, and Al while Ca and Mg decreased.

These main effects of N and K on absorption, as measured by leaf analysis, were not consistent but showed an effect of concentration. For example, increasing K concentration to 624 ppm caused an increase in leaf N when N concentration was 56, 112, or 224 ppm. However, when N was 448 or 896 ppm there was a decrease in leaf N.

At 312 ppm K, leaf K increased an N concentration was either above or below 112 ppm in the medium. At 624 ppm K, leaf K increased as the N level was either above or below 224 ppm in the medium. Thus, when the K concentration was increased, there was an increase in the N concentration at which the N-K interaction occurred.

Leaf P decreased as N concentration was increased with 312 and 624 ppm K. However, at the higher K concentration all leaf P values were higher, indicating that the level of K may not eliminate the influence of N concentration on leaf P but the higher level of K had a positive influence on leaf P regardless of the N level. Thus, a higher level of K could result in a leaf P level at a higher N level being equal to P level found at a lower N level.

Several of the other elements showed similar variations in the main effects of N and K concentrations on nutrient absorption. Perhaps, nutrient interactions lose their practical significance because of the multiple factor effect. Practical significance would be lost unless the interaction was of sufficient intensity to result in a change in absorption that would influence performance of the plant by possibly inducing a deficiency or an excess of an element. None of the nutrient interaction in this study showed such an effect.

Leaf Age

As the leaf became older, within the leaf positions studied, there was an increase in K, P, Ca, Mg, Mn, Fe, B, Zn, and Al but a decrease in N and Cu. This influence of leaf age was not in agreement with similar reports on other crops. The influence of leaf age on N and Ca appears to be consistent for all species of crops studied by others and for the Chrysanthemum.

Variations in the level of N and K, however, altered the leaf position at which there was a significant increase or decrease. For example, a N concentration of 896 ppm resulted in an increase in leaf N from the tip to the sixth leaf, while older leaves showed a decrease in leaf N. At lower levels of N, leaf N decreased from the tip downward. There were several other instances in which a similar effect was observed.

Some of the differences in leaf composition associated with leaf sampling positions may have been a result of the rate of growth. Those levels of N that resulted in maximum growth produced more leaves than used in collecting samples, while the lowest level of N produced only enough leaves to provide material for sampling. This would result in the true morphological age of each sample position being somewhat younger for those treatments making the most growth. Although such a variation must be recognized, it is believed that this was not the principal factor associated with changes found to be associated with sampling positions with levels of N and K.

Should it be desirable to check nutritional conditions by use of leaf analysis, the use of leaf positions 3-5 (leaves 3-8 below the tip of the plant) appears to be a reliable tissue for analysis as shown in Table 49. Leaves from this position reflected the least interaction of N and K with those elements held at a constant level of supply and at the same time reflected the induced variations of N and K concentrations.

<u>Selection of Leaf Samples</u>:

From Appendix Tables 2-12, leaf samples with the greatest variation in nutrient element content as N and K were selected.

For N, leaf samples 3 to 10 may be used.

For K, the last three leaf samples, 8, 9, 10, although leaf samples, 3, 4, 5, 6 and 7 tended to vary as N and K were altered.

For P, leaf samples 5 to 10 seem best.

For Ca, leaf samples 2 to 10.

For Mg, leaf samples 4 to 10.

For Mn, leaf samples 7, 8, 9, and 10.

For Fe, leaf samples 3 to 10.

For Cu, almost any leaf sample, variation was noticed when K was altered.

For B, leaf samples 3 to 10.

For Zn, leaf samples 5 to 10.

For Al, leaf samples 3 to 10.

For N, P, K, Ca and Mg leaf samples 5 to 10 will be most appropriate under the conditions the experiment was carried out.

For the minor elements Mn, Fe, Cu, B, Zn, and Al except for Mn, the same leaf samples would be acceptable.

SUMMARY

Growth as measured by height and weight was greatly influenced by N and K ratio. A 224 ppm N with 312 ppm K in the medium, produced the best growth. N concentration should be at the optimum level in order to produce the best growth. However, if the N level is too high an addition of K may reduce the effects of N excess.

Increased N concentration in the medium decidedly increased leaf N content, increased and decreased Ca and Mg, and decreased K, P, Cu, B, and Zn, while Fe and Al increased and Mn was not affected. At higher levels, N also disturbed the usual trend of N as the leaf tissue ages.

Increased K concentration in the medium increased leaf K content as expected, decreased Ca and Mg but increased N, P, Mn, Fe, Cu, B, Zn and Al.

Samples from leaf positions, 3, 4, and 5 (leaves 3-8 below the tips) are suggested for leaf tissue sampling.

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APPENDIX

Appendix Table 1. Nutrition Solution Used For Each Treatment

A molar concentration of each of the following chemical compounds was prepared to provide the necessary elements called for in the experiment including the trace elements and Fe. Deionized water was used.

Treatment Number	1	2	3	4	5	6	7	8	9	10
Nitrogen ppm	56	112	224	448	896	56	112	224	448	896
Potassium ppm	312	312	312	312	312	624	624	624	624	624
Chem. Cpds.	me of stock solution*/liter of water									
$NH_4H_2PO_4$	2	2	2	2	2	2	2	2	2	2
KNO_3	2	6	6	6	6	2	6	6	6	6
KCl	6	2	2	2	2	14	10	10	10	10
$Ca(NO_3)_2$	-	-	4	4	4	-	-	4	4	4
$CaCl_2$	4	4	-	-	-	4	4	-	-	-
NH_4NO_3	-	-	-	8	24	-	-	-	8	24
$MgSO_4$	2	2	2	2	2	2	2	2	2	2

*A molar concentration for each chemical. B, Mn, Zn, Cu, and Mo added according to Hoagland and Arnon (1950). For Fe 41g Sequestrene iron/liter deionized H_2O for Stock Sol. Use 25 cc/100 liters of nutrient solution.

Appendix Table 2. Nitrogen Content of Chrysanthemum Leaves as Influenced by Leaf Position and Solution Composition

Treatment N	K	Leaf Position 1	2	3	4	5	6	7	8	9	10
ppm		% dry weight									
56	312	4.24	3.94	3.43	3.00	2.84	2.87	3.02	3.04	2.90	2.53
112	312	4.00	3.52	3.39	3.29	2.95	2.77	2.58	2.56	2.58	2.65
224	312	4.47	3.39	3.95	3.89	3.61	3.73	3.60	3.54	3.51	3.52
448	312	5.11	5.13	5.45	5.49	5.27	5.13	4.88	4.67	4.60	4.38
896	312	5.39	5.94	6.26	6.54	6.36	6.34	6.33	6.10	5.71	5.48
56	624	4.38	4.00	3.75	3.42	3.33	3.12	3.04	2.90	2.84	2.17
112	624	4.83	4.58	4.24	3.93	3.65	3.52	3.37	3.21	3.21	3.16
224	624	4.70	4.31	4.23	4.19	3.88	3.86	3.87	3.70	3.73	3.67
448	624	5.55	5.30	5.17	5.00	4.71	4.60	4.48	4.44	4.29	4.22
896	624	6.40	6.37	6.16	5.98	5.95	5.60	5.55	5.33	5.34	4.06

Req. for Sign.: .05 - .34
.01 - .39

Appendix Table 3. Potassium Content of Chrysanthemum Leaves as Influenced by Leaf Position and Solution Composition

Treatment N	K	Leaf Position 1	2	3	4	5	6	7	8	9	10
ppm		% dry weight									
56	312	3.77	4.83	5.95	6.33	6.48	7.26	8.01	8.57	8.59	8.56
112	312	3.80	4.17	5.11	5.48	5.54	5.78	5.78	6.16	6.08	6.58
224	312	4.11	4.43	4.94	5.59	5.70	6.17	6.41	6.55	6.73	6.96
448	312	3.97	4.55	5.02	5.44	5.91	6.21	6.41	6.63	7.13	7.55
896	312	3.73	4.29	4.55	5.17	5.45	5.94	6.51	7.30	7.80	8.13
56	624	4.04	5.05	6.40	6.61	7.13	7.25	7.50	8.55	9.40	9.81
112	624	4.51	5.49	6.20	7.05	7.79	8.01	8.15	8.44	9.29	8.97
224	624	4.29	5.23	6.10	6.67	7.31	7.89	8.21	7.97	8.49	8.79
448	624	4.64	5.35	6.33	6.96	8.00	8.48	8.74	9.11	9.47	9.71
896	624	4.90	5.83	6.92	7.60	8.88	8.97	9.29	9.29	9.11	9.21

Req. for Sign.: .05 - .63
.01 - .72

Appendix Table 4. Phosphorus Content of Chrysanthemum Leaves as Influenced by Leaf Position and Solution Composition

Treatment N	K	Leaf Position 1	2	3	4	5	6	7	8	9	10
ppm		% dry weight									
56	312	0.909	1.013	1.069	1.164	1.341	1.600	1.847	2.097	2.044	2.291
112	312	0.938	0.932	0.986	1.034	1.025	1.192	1.254	1.304	1.361	1.507
224	312	0.998	0.992	0.950	0.974	0.968	1.049	1.117	1.171	1.311	1.361
448	312	0.974	1.001	1.049	1.034	1.040	1.096	1.180	1.266	1.326	1.344
896	312	0.828	0.837	0.864	0.950	1.055	1.135	1.278	1.358	1.469	1.612
56	624	1.028	1.144	1.388	1.487	1.522	1.966	2.288	2.550	2.750	3.039
112	624	1.180	1.230	1.300	1.307	1.355	1.463	1.656	1.728	1.918	2.073
224	624	1.135	1.344	1.329	1.300	1.454	1.513	1.567	1.805	1.895	2.026
448	624	1.248	1.400	1.454	1.546	1.561	1.653	1.787	1.895	1.948	2.163
896	624	0.992	1.209	1.299	1.367	1.537	1.677	1.841	1.930	2.079	2.133

Req. for Sign.: .05 - .25
.01 - .28

Appendix Table 5. Calcium Content of Chrysanthemum Leaves as Influenced by Leaf Position and Solution Composition

Treatment N	Treatment K	Leaf Position 1	2	3	4	5	6	7	8	9	10
ppm		% dry weight									
56	312	1.149	1.412	1.476	1.493	1.476	1.589	1.685	1.670	1.790	1.922
112	312	0.915	0.965	1.264	1.444	1.573	1.844	1.844	1.955	2.002	2.033
224	312	1.016	1.182	1.362	1.685	1.828	2.080	2.158	2.268	2.359	2.406
448	312	0.982	1.264	1.523	1.685	1.780	1.907	2.017	2.033	2.033	2.064
896	312	0.847	0.982	1.181	1.297	1.444	1.508	1.555	1.653	1.684	1.796
56	624	0.813	0.847	0.999	0.948	0.914	1.148	1.132	1.231	1.330	1.492
112	624	0.863	0.931	1.099	1.199	1.248	1.314	1.395	1.379	1.460	1.540
224	624	0.796	1.066	1.149	1.297	1.330	1.476	1.460	1.621	1.685	1.718
448	624	0.745	0.864	0.999	1.166	1.166	1.248	1.330	1.346	1.379	1.460
896	624	0.641	0.762	0.915	0.999	1.099	1.182	1.297	1.363	1.428	1.444

Req. for Sign.: .05 - .14
.01 - .16

Appendix Table 6. Magnesium Content of Chrysanthemum Leaves as Influenced by Leaf Position and Solution Composition

Treatment N	K	Leaf Position 1	2	3	4	5	6	7	8	9	10
ppm		% dry weight									
56	312	0.338	0.405	0.424	0.447	0.457	0.500	0.515	0.505	0.525	0.560
112	312	0.338	0.321	0.356	0.419	0.438	0.510	0.515	0.525	0.525	0.554
224	312	0.383	0.392	0.424	0.505	0.545	0.617	0.616	0.626	0.664	0.670
448	312	0.351	0.392	0.447	0.476	0.520	0.535	0.555	0.545	0.540	0.545
896	312	0.312	0.330	0.361	0.397	0.415	0.405	0.400	0.401	0.406	0.419
56	624	0.321	0.308	0.343	0.300	0.266	0.334	0.312	0.321	0.321	0.383
112	624	0.352	0.326	0.334	0.329	0.325	0.321	0.329	0.316	0.312	0.334
224	624	0.338	0.321	0.321	0.325	0.334	0.351	0.334	0.360	0.356	0.347
448	624	0.316	0.316	0.312	0.321	0.308	0.321	0.321	0.321	0.325	0.316
896	624	0.243	0.226	0.261	0.261	0.257	0.253	0.261	0.270	0.274	0.266

Req. for Sign.: .05 - .047
.01 - .054

Appendix Table 7. Manganese Content of Chrysanthemum Leaves as Influenced by Leaf Position and Solution Composition

Treatment N	K	Leaf Position 1	2	3	4	5	6	7	8	9	10
ppm		ppm dry weight									
56	312	94.36	99.91	101.8	96.22	94.36	112.9	129.5	153.4	208.9	212.9
112	312	75.70	77.56	92.49	86.91	99.93	120.3	123.9	129.5	144.2	166.1
224	312	75.69	66.26	81.23	94.30	103.6	118.4	125.8	127.6	156.9	164.2
448	312	99.83	94.35	98.07	105.5	107.4	122.1	125.8	149.5	162.4	167.9
896	312	66.33	77.58	81.32	81.32	96.29	112.9	129.4	146.0	146.1	186.1
56	624	71.94	68.21	71.96	77.56	73.79	118.4	111.1	133.2	157.1	189.7
112	624	96.22	90.64	101.8	105.5	105.5	116.6	144.2	151.5	173.4	195.1
224	624	85.01	109.2	112.9	120.3	136.9	129.5	123.9	149.7	158.8	158.8
448	624	94.36	98.05	99.94	103.6	125.9	133.2	147.9	144.2	158.8	175.2
896	624	90.64	101.8	107.4	122.2	127.7	125.8	140.5	144.2	169.7	162.5

Req. for Sign.: .05 - 24.0
.01 - 27.8

Appendix Table 8. Iron Content of Chrysanthemum Leaves as Influenced by Leaf Position and Solution Composition

Treatment N	K	Leaf Position 1	2	3	4	5	6	7	8	9	10
ppm		ppm dry weight									
56	312	174.9	163.1	131.7	135.6	137.6	165.1	174.9	184.8	206.4	253.6
112	312	190.7	210.3	218.2	196.6	220.1	263.4	253.6	235.8	249.6	262.3
224	312	188.7	192.6	224.1	259.5	273.2	273.2	279.1	227.1	343.9	355.8
448	312	222.1	241.8	273.2	265.4	283.0	302.7	300.7	306.7	314.5	300.7
896	312	178.9	202.5	229.9	245.7	263.4	279.1	286.9	286.9	304.7	247.9
56	624	196.6	204.4	198.5	216.2	216.2	351.8	308.6	400.9	457.9	528.7
112	624	212.3	228.0	243.7	290.9	271.2	286.9	296.8	292.9	277.1	298.8
224	624	163.1	229.1	229.9	279.1	296.8	269.3	249.6	298.8	306.6	281.1
448	624	214.2	253.6	237.8	283.0	273.2	273.2	302.7	330.2	240.0	442.3
896	624	255.5	288.9	263.4	316.5	288.0	279.1	330.2	312.5	308.6	365.6

Req. for Sign.: .05 - 66.7
.01 - 77.0

Appendix Table 9. Copper Content of Chrysanthemum Leaves as Influenced by Leaf Position and Solution Composition

Treatment N	K	Leaf Position 1	2	3	4	5	6	7	8	9	10
ppm		ppm dry weight									
56	312	28.5	18.4	14.5	15.0	10.6	11.6	11.0	12.1	10.2	15.0
112	312	19.4	17.0	17.4	11.6	11.6	14.0	16.0	11.0	13.6	11.6
224	312	21.8	12.6	13.1	15.0	15.5	16.9	15.5	14.5	14.0	15.0
448	312	12.6	11.0	8.7	9.7	10.2	13.1	11.6	12.1	13.6	15.5
896	312	15.5	14.5	11.6	8.7	8.7	10.2	11.0	12.6	10.6	17.4
56	624	35.8	27.1	23.7	20.0	20.3	26.0	20.0	16.9	20.3	20.8
112	624	37.7	31.9	26.0	23.0	20.8	19.8	22.7	19.4	18.4	37.8
224	624	22.5	19.8	18.9	17.0	19.8	13.6	39.2	11.6	16.0	12.6
448	624	27.6	25.6	20.0	19.8	18.9	17.0	17.0	17.9	15.5	14.0
896	624	31.9	24.7	26.0	16.0	15.0	16.5	14.0	12.1	12.1	10.6

Req. for Sign.: .05 - 10.6
.01 - 12.2

Appendix Table 10. Boron Content of Chrysanthemum Leaves as Influenced by Leaf Position and Solution Composition

Treatment N	K	Leaf Position 1	2	3	4	5	6	7	8	9	10
ppm		ppm dry weight									
56	312	28.1	43.7	55.7	67.5	73.1	83.9	88.3	85.8	79.0	79.3
112	312	27.6	36.2	48.5	56.9	61.5	79.3	80.9	83.1	86.1	91.3
224	312	32.2	38.0	49.3	59.4	65.1	72.7	73.9	73.9	83.5	84.3
448	312	31.3	41.5	48.0	50.6	53.6	57.8	61.1	62.7	66.8	67.6
896	312	32.2	38.0	42.4	46.8	51.0	54.0	56.9	58.6	61.5	67.6
56	624	30.3	43.7	57.4	64.3	64.5	81.2	78.7	79.0	70.3	83.0
112	624	34.9	45.9	56.9	63.5	63.6	67.7	73.5	83.9	86.1	91.5
224	624	30.8	50.1	57.4	61.9	68.4	70.8	71.5	78.9	83.5	88.7
448	624	31.7	43.3	49.3	57.3	59.8	64.3	72.3	75.5	81.3	91.4
896	624	34.4	42.0	49.8	53.2	58.1	62.3	69.8	71.1	75.5	78.2

Req. for Sign.: .05 - 7.5
.01 - 8.7

Appendix Table 11. Zinc Content of Chrysanthemum Leaves as Influenced by Leaf Position and Solution Composition

Treatment N	K	Leaf Position 1	2	3	4	5	6	7	8	9	10
ppm		ppm dry weight									
56	312	38.26	22.60	21.64	20.77	17.19	19.94	27.95	28.92	23.49	34.58
112	312	22.57	22.63	24.43	13.69	18.20	21.63	21.64	19.84	24.38	26.15
224	312	31.77	14.53	19.06	27.14	24.44	27.15	25.51	25.32	27.07	25.24
448	312	26.27	21.66	15.59	20.83	19.97	21.65	19.85	25.26	26.17	27.06
896	312	23.50	25.25	21.67	14.71	11.92	18.11	14.56	17.20	12.84	19.82
56	624	48.64	46.79	43.14	59.51	52.05	64.61	67.71	72.98	79.37	72.82
112	624	61.48	61.51	73.75	79.95	82.01	91.55	82.04	89.52	89.55	88.32
224	624	27.25	40.52	37.40	34.62	48.12	41.16	39.22	39.69	53.28	52.32
448	624	48.79	46.77	47.89	58.72	61.52	68.63	72.74	67.03	76.19	73.85
896	624	41.15	36.38	37.40	39.57	41.10	49.36	49.36	52.80	61.76	54.76

Req. for Sign.: .05 - 20.4
.01 - 23.5

Appendix Table 12. Aluminum Content of Chrysanthemum Leaves as Influenced by Leaf Position and Solution Composition

Treatment N	K	Leaf Position 1	2	3	4	5	6	7	8	9	10
ppm		ppm dry weight									
56	312	79.9	96.8	105.2	109.4	117.9	117.9	143.1	130.5	134.7	172.6
112	312	79.9	88.4	113.7	105.2	134.7	159.9	164.2	159.9	185.2	202.0
224	312	105.2	105.2	134.7	210.5	218.9	248.3	218.9	206.3	307.3	328.3
448	312	92.6	126.3	193.6	176.8	185.2	214.7	214.7	218.9	206.3	239.9
896	312	84.2	96.8	126.3	151.5	159.9	164.2	202.0	197.8	210.5	239.9
56	624	84.2	96.8	96.8	105.2	113.7	164.2	138.9	210.5	231.5	249.4
112	624	112.1	109.4	138.9	185.2	202.0	206.3	202.9	214.7	197.8	223.1
224	624	84.2	126.3	134.7	176.8	155.7	176.8	180.9	197.8	244.1	223.1
448	624	79.9	96.8	117.9	155.7	168.4	180.9	227.3	294.7	256.8	210.4
896	624	122.1	134.7	147.3	164.2	164.2	189.4	210.5	206.3	193.6	244.1

Req. for Sign.: .05 - 61.5
.01 - 71.0

Appendix Table 13. Sodium Content of Chrysanthemum Leaves as Influenced by Leaf Position and Solution Composition

Treatment N	K	Leaf Position 1	2	3	4	5	6	7	8	9	10
ppm		ppm dry weight									
56	312	108.4	93.7	88.1	102.3	88.8	93.0	88.5	90.6	89.2	101.9
112	312	86.7	92.3	89.9	87.1	89.5	99.0	99.4	96.2	96.9	96.2
224	312	98.7	93.0	91.9	102.6	95.5	105.7	108.6	100.1	101.5	120.5
448	312	101.2	94.8	93.7	93.7	101.5	96.9	95.9	99.4	88.8	102.6
896	312	92.7	83.5	85.9	85.3	89.5	88.5	91.3	101.2	96.6	105.4
56	624	103.3	96.9	107.1	92.3	103.3	123.4	102.6	100.1	104.3	115.6
112	624	106.8	99.7	99.0	97.9	107.1	107.1	103.9	102.2	103.3	101.2
224	624	92.3	99.7	93.7	94.1	90.2	94.5	93.4	91.6	105.0	99.4
448	624	97.3	96.6	90.6	105.7	97.3	103.3	114.2	121.2	110.3	103.6
896	624	102.9	100.1	104.7	102.6	101.9	111.0	108.6	110.7	106.8	104.7

Req. for Sign.: .05 - 14.2
.01 - 16.4