COLORADO FLOWER GROWERS ASSOCIATION, INC.

IN COOPERATION WITH COLORADO STATE UNIVERSITY
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Ion Balance in Carnation Nutrition II

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The first of a series of nutrition experiments dealing with ion balance and organic anion accumulation in carnation tissue was presented in C. F. G. A. Bulletin 248. The methods and materials given in that article apply equally to series 2 and 3 presented here.

Objectives for this series of experiments were (1) to study the effects of ammonium nutrition, and (2) to study the effect of Ca:Mg on plant uptake and yield.

The Ca:Mg replacement series, treatments 1-5 (Table 1), was formulated according to the method presented by Green (3). Each solution contained 27.0 meq/l total ionic concentration. Calcium and Mg were the only variables, with Mg replacing Ca in the solutions. Solution 3 served as the check treatment for the entire experiment. Solution 3 was selected as a standard, giving optimum yield as determined by Hartman and Holley (4).

The last series (15-19), the NH_4 series, had both a replacement series and a group of additions. The first solution of the replacement series (11, 15, 16, 17) had a total cation concentration of 19.5 meq/l. The sum of the cations K, Ca, and Mg was replaced by 2 meq increments of NH_4. Ratios among cations were constant. In the second part (3, 18, 19, 17), NH_4NO_3 content was increased by successive 2 meq/l increments.

Table 1. Treatment nutrient solution composition in milligram equivalents per liter.[a]

Treatment	K	Ca	Mg	Na	NH_4	NO_3	SO_4	H_2PO_4	Cl
	Milligram equivalents per liter								
Ca:Mg Replacement Series									
1	6.00	6.00	1.00	0.5	0	12	0.5	1	0
2	6.00	4.75	2.25	0.5	0	12	0.5	1	0
3	6.00	3.50	3.50	0.5	0	12	0.5	1	0
4	6.00	2.25	4.75	0.5	0	12	0.5	1	0
5	6.00	1.00	6.00	0.5	0	12	0.5	1	0
Ammonium Study									
K, Ca, and Mg:NH_4 Replacement Series									
11	8.77	5.12	5.12	0.5	0	18	0.5	1	0
15	7.85	4.58	4.58	0.5	2	18	0.5	1	0
16	6.90	4.05	4.05	0.5	4	18	0.5	1	0
17	6.00	3.50	3.50	0.5	6	18	0.5	1	0
Addition of NH_4NO_3									
3	6.00	3.50	3.50	0.5	0	12	0.5	1	0
18	6.00	3.50	3.50	0.5	2	14	0.5	1	0
19	6.00	3.50	3.50	0.5	4	16	0.5	1	0
17	6.00	3.50	3.50	0.5	6	18	0.5	1	0

[a]All solutions contained trace elements as follows: B, 1 ppm; Mn, .25 ppm; Fe, .56 ppm as sequestrene 330; Zn, .05 ppm; Cu, .02 ppm; and Mo, .01 ppm.

Ca:Mg replacement series

Calcium and Mg were about equally competitive for absorption by carnation (Fig. 1). The tissue concentrations indicated that with equal concentration in the applied solution the two ions were absorbed equally. Also, at the other solution concentrations Ca and Mg were absorbed according to their relative concentrations. Calcium concentrations varied between 280 and 950 meq/Kg dm, while Mg concentrations varied between 210 and 840 meq/Kg dm (Table 2). The sum of Ca plus Mg concentrations in the tissue was nearly constant, varying between 1,130 and 1,250 meq/Kg dm.

Potassium and Na concentrations in the tissue remained nearly constant regardless of the large fluctuation of Ca and Mg in the tissue and external solution. Total N and the anion concentrations were also unaffected by the changes in Ca and Mg (Table 2).

[1]This is a part of the research done by Larry Hartman while completing the requirements for the M.S. degree at Colorado State University.

Table 2. The effects of Mg replacement of Ca on carnation tissue composition and yield.[a]

Treat- ment	Milligram equivalance/kilogram dry matter												Mean[c] yield gms fr wt
	K	Ca	Mg	Na	C	NO_3	SO_4	H_2PO_4	Cl	A	Organic[b] Anion	Total N	
1	1052.4	954.4	213.7	27	2247.5	109.6	28	161.0	38	336.6	1910.1	2495.0	483.4
2	915.6	804.6	349.2	28	2097.9	92.3	26	146.4	40	304.7	1793.2	2427.2	425.5
3	1033.2	698.9	554.7	32	2318.8	104.9	31	144.3	42	322.2	1996.6	2445.0	440.4
4	1007.5	530.2	706.7	32	2276.4	111.2	32	160.0	47	350.2	1926.2	2541.4	425.4
5	1039.0	280.7	842.3	26	2188.0	108.0	30	148.9	38	324.9	1863.1	2377.2	449.5

[a]Tissue analyses values are means of two individual analyses. Yield is the mean of 16 plants.
[b]no significant F
[c]LSD = 71.84 at 5% level

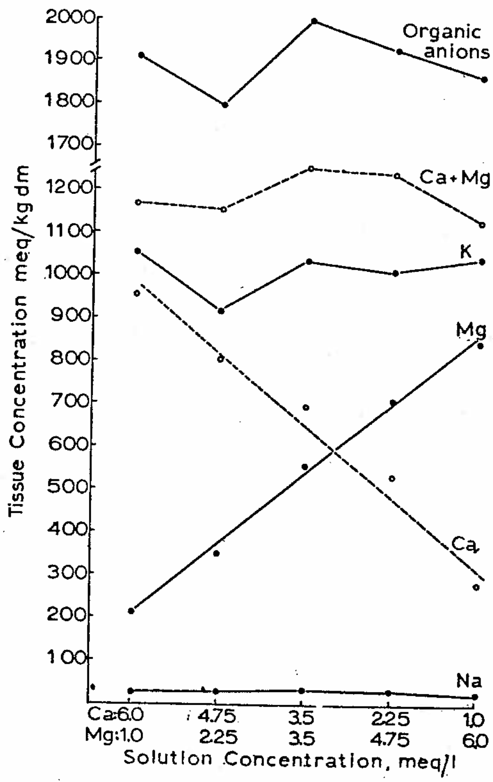

Fig. 1. Effects of Mg replacement of Ca on carnation tissue concentrations of K, Ca, Mg, Na, Ca+Mg, and organic anions.

There were no significant differences among yields of the five treatments (Table 2). The sum of Ca plus Mg, rather than either individual concentration, was more indicative of the divalent ion status in relation to yield and organic anion concentration.

The results of this experiment indicate that absolute concentrations of either ion in the nutrient solution or in the tissue were of little importance. However, absolute concentrations would have become important if either ion's concentration had been low enough to result in deficiencies. The sum of Ca + Mg in relation to K concentration was more important than the absolute concentrations.

In a nutrient solution Ca is provided as $Ca(No_3)_2$ and Mg as $MgSO_4$. Although Ca and Mg are interchangeable their accompanying anions are not. Sulfate is required in much lower concentrations than NO_3. These facts should be considered when deciding upon the Ca and Mg concentrations.

Ammonium study

The first part of the ammonium study was a replacement series with 2 meq NH_4 increments replacing K, Ca, and Mg, maintaining the same cation ratios as the check treatment (Table 1). Potassium concentration in the tissue decreased almost linearly with each added increment of NH_4 (Fig. 2). Calcium and Mg concentration decreased rapidly with the first NH_4 addition but with further addition tended to maintain low, fairly constant levels. Total cation concentration declined appreciably. The total anions increased due, primarily, to increased accumulation of NO_3 and H_2PO_4.

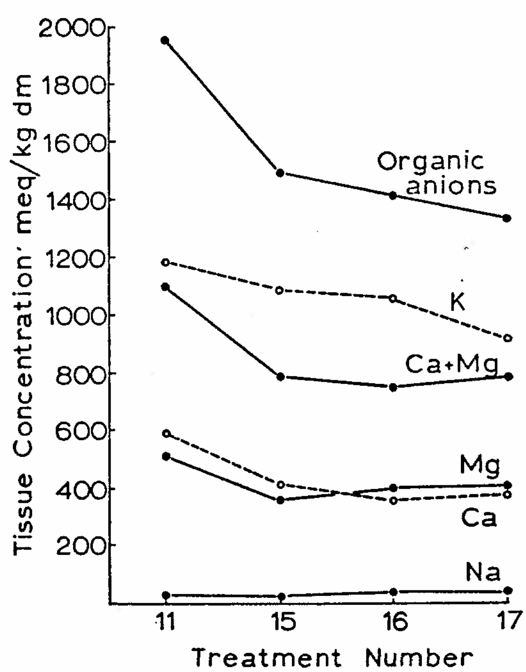

Fig. 2. Effects of NH_4 replacement of K, Ca, and Mg in 2 meq/l increments on carnation tissue concentration of K, Ca, Mg, Na, Ca+Mg, and organic anions.

The second part included the addition of NH_4NO_3 in 2 meq increments to the check treatment (Table 1). Even though K was constant in the solutions, K decreased

Table 3. The effects of nutrient solution treatment on carnation tissue composition and yield in the ammonium study.[a]

Treat-ment	Milligram equivalence/kilogram dry matter												Mean[c] yield gms fr wt
	K	Ca	Mg	Na	C	NO_3	SO_4	H_2PO_4	Cl	A	Organic[b] Anion	Total N	
K, Ca, and Mg — NH_4 Replacement Series													
11	1184.2	592.6	509.5	26	2312.3	135.3	33	148.9	35	352.2	1960.1	2416.5	403.5
15	1086.9	408.5	373.9	26	1895.3	144.7	41	175.7	38	399.4	1495.9	3019.7	544.2
16	1058.2	355.5	390.3	37	1841.0	168.8	41	179.4	39	427.2	1413.8	3269.5	501.1
17	915.6	374.5	406.8	42	1738.9	166.7	33	176.7	32	408.4	1330.0	3487.3	466.9
Addition of NH_4NO_3													
3	1033.2	698.9	554.7	32	2318.8	104.9	31	144.3	42	322.2	1996.6	2445.0	440.4
18	1029.4	449.0	402.7	30	1911.1	135.3	32	169.7	27	364.0	1547.1	3126.8	515.2
19	969.3	343.3	415.0	42	1769.6	144.7	33	159.5	31	368.2	1401.4	3216.0	497.0
17	915.6	374.5	406.8	42	1738.9	166.7	33	176.7	32	408.4	1330.0	3487.3	466.9

[a]Tissue analyses values are means of two individual analyses. Yield is the mean of 16 plants.
[b]no significant F
[c]LSD = 71.84 at 5% level

almost linearly with each added increment of NH_4 (Fig. 3). Calcium and Mg levels in the tissue decreased with the first addition of ammonium but increased concentrations of ammonium did not further depress their absorption. Total cation concentration decreased. Also, total anions increased slightly.

Inclusion of NH_4 in the nutrient solutions depressed accumulation of cations and, to a lesser degree, increased accumulation of inorganic anions (Table 3). The result was lowering of the organic anion content by 550 to 660 meq/Kg dm. The total N content increased by 680 to 1,000 meq/Kg dm due to the presence of NH_4.

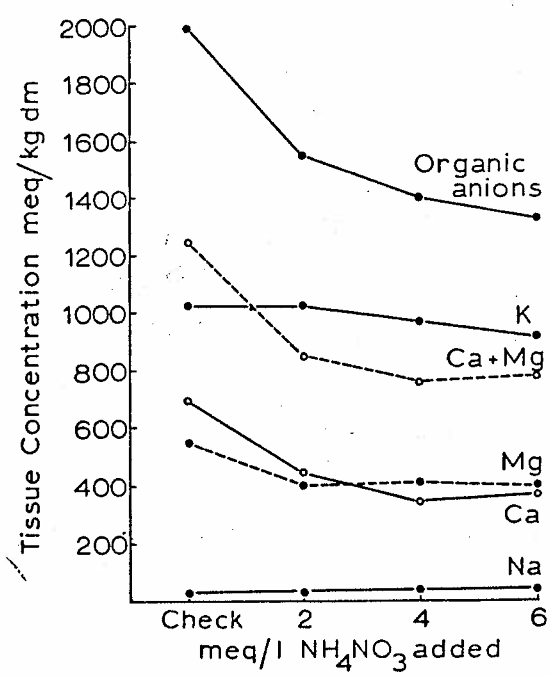

Fig. 3. Effects of addition of NH_4NO_3 in 2 meq/l increments to the check treatment on carnation tissue concentrations of K, Ca, Mg, Na, Ca+Mg, and organic anions.

Leachates were collected periodically and are listed in Table 4 for the NH_4 study. The pH of the applied solutions was 6.1 ± 0.2. In less than 24 hours the pH of the solution surrounding the roots had decreased to the levels listed. Also, the pH of the leachates continued to decrease with time.

Mean yield (Table 3) was significantly increased above the check treatment yield by the addition of 2 meq NH_4NO_3 and the replacement of K, Ca, and Mg by 2 meq NH_4 (Fig. 4). The first 2 meq addition of NH_4 greatly increased yield but additional increments reduced yield to a level approaching that of the check treatment. Figure 5 illustrates the differences in yields obtained by the addition of NO_3 to the check treatment in 2 meq increments with various cations. In this study, NH_4 was a more effective cation partner for NO_3 increasing yield.

Decreased cation accumulation and increased anion accumulation resulting in a decreased organic anion concentration due to added NH_4 is in agreement with the findings of several authors (3, 4, 8, 9). These authors postulated that a reduced organic anion concentration, resulting from NH_4 addition, led to reduced yields.

However, in this study inclusion of 2 meq/l NH_4 in the nutrient solutions significantly increased yield above the check yield. Further addition of NH_4 (4 and 6 meq/l NH_4) depressed yield in relation to the yield from 2 meq NH_4 to a point approaching the check yield. These results do not agree with the findings of Green (3) or Hartman and Holley (4) with carnation nor Wit et al. (9), Tuil (8), and Kirkby (5) with other crops. However, positive yield responses have been obtained using NH_4 as at least part of the N source for solution or gravel cultures (1, 2, 6, 7).

There are several possible reasons for the positive yield response from NH_4 addition observed in this study. Optimal environmental conditions, including the nutrient solution, were prerequisites to obtain a high organic anion concentration and maximum growth of carnation. The nutrient solutions in treatments containing NH_4 in previous carnation studies were inadequate; if NH_4 had been deleted, the solutions still would not have produced a "normal" organic anion concentration or optimal yield. In this study a low concentration of NH_4 apparently increased yield because the nutrient solution composition was optimal before NH_4 was added.

Inadequate K in the presence of NH_4 resulted in protein degradation (2). Hartman and Holley (4) found that NH_4 in the nutrient solution greatly reduced yield. One factor which may have caused yield reduction was low K. However, in the current study, K levels in the nutrient solution were high enough to provide adequate tissue K to prevent protein degradation.

Another possible response to the NH_4 may be due to an inadequate NO_3 reduction rate. Even though the tissue analyses from all treatments indicate no NO_3 accumulations, the rate of reduction may have been too slow to provide enough NH_3 for adequate protein synthesis. Nitrate reduction is controlled by several factors including genetic constitution of the plant, available NO_3, and light. This experiment was conducted during the lowest light period of the year and inadequate light may have prevented adequate reductase activity.

Table 4. The relation of applied NH_4 concentrations to the pH of the leachate from perlite substrate during a 4 month period.

Treatment*	Applied NH_4 Conc meq/l	Leachates Date 12/23	1/15	2/20	3/18
11	0	6.6	7.0	6.6	6.8
15	2	4.9	4.6	3.4	3.1
16	4	4.7	4.0	3.2	3.0
17	6	4.4	3.6	3.2	3.2
3	0	6.6	6.8	6.4	6.3
18	2	5.1	4.5	3.4	3.3
19	4	4.6	3.9	3.2	3.3
17	6	4.4	3.6	3.2	3.2

*Each applied nutrient solution had an initial pH of 6.1±0.2

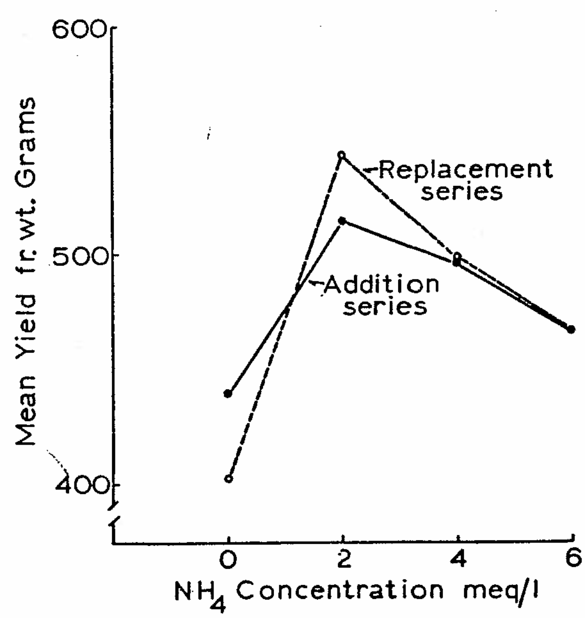

Fig. 4. The relation of applied NH_4 concentration to yield of carnation growing in perlite.

Conclusions from ammonium study

Inclusion of 2 meq/l NH_4 in the nutrient solution produced yields significantly greater than the check yield. The benefits from NH_4 were realized during a period of predominantly low light intensity and duration. It may be that during periods of low light NO_3 reduction does not proceed at a rate fast enough to satisfy the need for NH_3 in organic N synthesis. Under conditions of high light, adequate NH_3 may be produced from NO_3 reduction and the beneficial affect of NH_4 no longer realized.

Ammonium in the nutrient solution competes with K, Ca, and Mg for absorption. Each added increment of NH_4 depressed K accumulation in the tissue. The first increment of NH_4 added depressed Ca and Mg accumulation but additional NH_4 did not further depress Ca and Mg concentration in the tissue. Within the limits of this experiment, it appears that K competes with NH_4 more effectively for absorption than does Ca or Mg.

During periods of low light the rate of NO_3 reduction may limit yield if NO_3 is the sole source of N supplied to carnation in an inert medium. The yield decrease may be due to reduced NH_3 formation and subsequent reduction in organic N synthesis. Low concentrations, 2 meq/l or less, of NH_4 will increase organic N synthesis resulting in increased yield. However, precautions should be taken to avoid previously observed detrimental effects of NH_4.

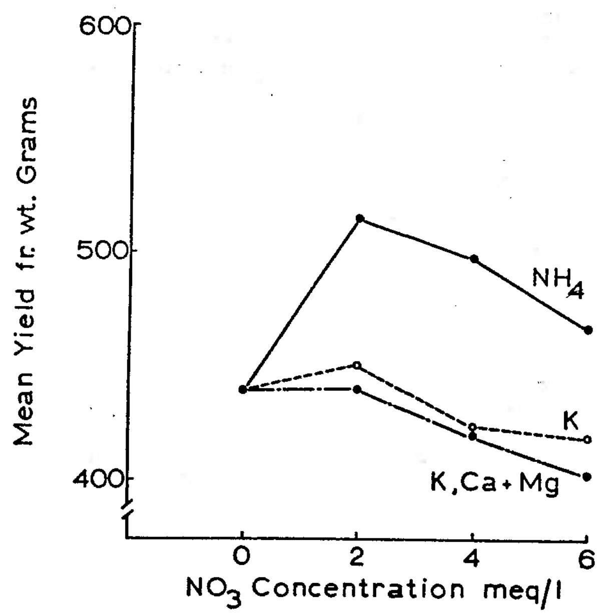

Fig. 5. The relation of NO_3 addition with different cations in 2 meq/l increments to yield of carnation.

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CARNATION STUDIES

A. C. Bunt

From Glasshouse Crops Research Institute Annual Report 1968. Rustington, Littlehampton, Sussex, England—Examination of data from the sequential planting of rooted carnation cuttings at 14-day intervals throughout the year has shown the importance of light intensity in carnation culture. Rates of growth and development were determined from plants grown under full natural light intensities and also from plants grown under a plastic netting which reduced the light intensity by 50 per cent.

Growth

Growth rates, defined as the increase in plant dry weight per day of paired cuttings grown for 27 days, showed a linear response with increasing solar radiation integrals. Under full light intensity the growth rates ranged from approximately 0.01 g per day with a mean solar radiation of 30 calories cm^{-2} day^{-1}, to approximately 0.11 g per day with a mean radiation of 300 calories cm^{-2} day^{-1}. Plants grown at half the normal light intensity showed a corresponding decrease in growth rates. (Note—Colorado winter light seldom averages less than 200 outside.)

From these data there is no evidence of the carnation reaching light saturation under glasshouse conditions within the range of 30 to 300 calories cm^{-2} day^{-1}. The maximum mean relative growth rate of the carnation, reported as 4.66 per cent per day (see Annual Report 1967), is low by comparison with that of pot-grown year-round chrysanthemums, where values of approximately 10 per cent per day for rooted cuttings over a 27-day growth period in summer have been obtained.

Development

Other carnation cuttings were "stopped" at six leaf-pairs 21 days after planting and were grown to anthesis under full or half light conditions. Plants grown under the reduced light intensity showed a delay in anthesis ranging from approximately seven days for plantings made in early March to a maximum of 80 days for a planting made in mid-July.

The stem strength of flowers cut throughout the year from all plants grown under normal and reduced light intensity was measured objectively and has been examined in relation to solar radiation. Stem strength was found to be an exponential function of the mean daily level of radiation intensity over the period from planting to anthesis, the function being of the form $Y = Ke^{-ax}$, where Y is a measure of stem strength, x the mean daily radiation integral, and K and a are constants.

This relationship of stem strength with radiation was also examined for several growth stages, and the correlation coefficient was found to increase as the period prior to anthesis was reduced (see Table 1).

Table 1. Correlation Coefficients of Stem Strength and Mean Daily Solar Radiation for Different Development Stages

Development Stage	Correlation coefficient (25 d.f.)
Planting to anthesis	0.046
Eight leaf pairs to anthesis	–0.415
Bud visible to anthesis	–0.683
Bud (1 cm) to anthesis	–0.717
Bud split to anthesis	–0.777

This suggests that stem strength was most influenced by solar radiation in the latter stages of flower development.

Row position

In another experiment the yield of flowers from plants in each longitudinal row in the bed was recorded over a two-year period for two plant densities, namely, 20 and 60 square inches per plant. During the two years after planting the total yield of each outside row, i.e., the row adjacent to the path, was approximately four times that of the center rows when the spacing was 5 in X 4 in and twice that of the center rows when the spacing was 10 in X 6 in. Although the differences in yield due to row position were evident six months after planting, the most significant effect occurred during the second year when the plant canopy was more developed. These differences in yield may be related to the different amounts of light being received by the various rows.

The work described in this section has shown the importance of light intensity in carnation culture, and it is concluded that if carnations can be adequately ventilated to maintain cool temperatures the application of shading to the glasshouse would be detrimental.

Your editor,

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