COLORADO FLOWER GROWERS ASSOCIATION, INC.

IN COOPERATION WITH COLORADO STATE UNIVERSITY
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NITROGEN SOURCES FOR CARNATIONS AND GENERAL LIMITS ON SALINE WATERS

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Growers have four nitrogen sources available: $Ca(NO_3)_2$, KNO_3, HNO_3, and NH_4NO_3. Calcium nitrate is a good supply where the irrigation supply may lack calcium, but it is expensive. Many water supplies have Ca^{++} concentrations which exceed recommended levels so no additional calcium is required. All irrigation waters lack sufficient K^+. Potassium nitrate can supply all potassium, but insufficient nitrate at the recommended levels (12 meq/1). Another possible nitrogen source for waters with bicarbonate ions is nitric acid. The HCO_3^- acts as a buffer against large pH changes. However, HNO_3 can be corrosive and dangerous. Its main use would be to improve solubility in concentrate tanks in amounts too low to add significantly to NO_3^- supply.

Ammonium nitrate is one of the most economical nitrogen sources available. However, in CFGA Bulletins 211, 212, and 221, Green, Hartman, and Holley found that NH_4^+ caused reduced growth. In Bulletin 249, Hartman reported that up to 2 meq/1 NH_4^+ resulted in more growth. The experiments reported here showed like results, and it appears that desirable ammonium nutrition varies with the time of year. The specific objectives of this study were to determine if:

1. Ammonium nitrate can be used as a nitrogen source in saline or alkaline waters.
2. Nitric acid can be used as a nitrogen source.

MATERIALS AND METHODS

Ammonium Study I.

White Sim carnation cuttings were rooted and grown in the same manner as reported in CFGA Bulletin 251. Nutrient solution concentrations are given in Table 1. Rooted cuttings were planted November 10, 1969 and harvested April 28, 1970. This study was divided into two parts. The first solution series (Solutions 1–4) was an NH_4NO_3-HNO_3 replacement. The second series (Solutions 5–8) was an evaluation of the effect of HCO_3^- or $CO_3^=$ buffers on carnation plants grown in the presence of NH_4^+ ions. It has been demonstrated that pH of the solution surrounding plant roots decreases as NH_4^+ ions are taken up. The presence of a buffer reduced injury from low pH levels. Bicarbonate ions are present in many irrigation waters and could be added to the growing medium in the form of limestone ($CaCO_3$). Total fresh and dry weight yields, including all flower weights cut before harvest, were recorded at the end of the study. Tissue analyses were determined by the CSU Soil Testing Laboratory.

Ammonium Study II.

CSU White Sim cuttings were planted October 19, 1970 and harvested on March 13, 1971. Procedures were as in previous experiments of this type. The objectives were to test further for ammonium requirements in saline water, particularly at high levels of calcium, potassium, chloride, and sulfate. The nutrient solution concentrations are given in Table 2. This experiment has not been terminated. The tops were removed for measurement on March 13th, and

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[1] This is part of the research done by Kurt Schekel while completing the requirements for the Ph.D. Degree at Colorado State University. A portion of the work reported here was started by Dr. Schekel just before leaving CSU, and the authors wish to express their appreciation to James L. Green for compiling the data.

the plants allowed to continue growth in the same nutrient solutions through the spring and summer period.

Table 1. Nutrient concentrations for solutions in ammonium study I.* Concentrations in milliequivalents per liter.

	Nutrient Concentration									
Solution	Ca	K	Mg	Na	NH_4	NO_3	SO_4	Cl	HCO_3	Total meq/l
1	8	8	3	6.0	2.5	10.5	9	2	6	55
2	8	8	3	6.0	2.0	11.0	9	2	6	55
3	8	8	3	6.0	1.0	12.0	9	2	6	55
4	8	8	3	6.0	0.0	13.0	9	2	6	55
5	7	8	3	0.0	4.0	11.0	3	2	6	44
6	7	8	3	0.0	4.0	11.0	6	2	3	44
7	7	8	3	0.0	4.0	11.0	9	2	0**	44
8	7	8	3	0.0	4.0	11.0	9	2	0**	44
9	6	6	1	0.5	0.0	12.0	1	0	0	27

*Four ppm FeEDDHA added to solutions 1 through 6 and 8; 4 ppm FeEDTA to solutions 7 and 9. One ppm H_3BO_4 and 0.1 ppm $ZnSO_4$ added to all solutions. Superphosphate (44% P) was applied at 2 lb/100 ft^2, except treatment 9 which had 0.5 meq/l of H_2PO_4 in solution.

**Fifty grams per pot $CaCO_3$ were thoroughly mixed in the growing medium before planting.

Table 2. Nutrient concentrations for solutions in ammonium study II. Concentrations in milliequivalents per liter.

	Nutrient Concentration									
Solution	Ca	K	Mg	Na	NH_4	NO_3	SO_4	Cl	H_2PO_4	Total meq/l
1	7	8	3	0.5	0	12	6	0	0.5	37
2	7	8	3	0.5	0	17	1	0	0.5	37
3	7	8	3	0.5	5	12	11	0	0.5	47
4	7	8	3	0.5	5	7	16	0	0.5	47
5	3	4	3	0.5	5	12	3	0	0.5	31
6	3	10	3	0.5	5	12	9	0	0.5	43
7	10	4	3	0.5	5	12	10	0	0.5	45
8	7	10	3	0.5	4	12	10	2	0.5	49
9	7	10	3	0.5	6	12	12	2	0.5	53
10	7	14	3	0.5	6	12	12	6	0.5	61

RESULTS AND DISCUSSION

The presence of NH_4^+ ions caused a significantly increased yield (Tables 3 and 4). Not only did total weight increase as ammonium increased, but the flower yield and number of vegetative breaks did also. Increasing the HNO_3 concentration and decreasing NH_4NO_3 resulted in decreased yields (Table 3). The treatment of 5 meq/l HNO_3 and no NH_4NO_3 (Solution 4, Study I) had significantly lower yields than the treatment of 2.5 meq/l NH_4NO_3 and no HNO_3 (Solution 1, Study I). Both solutions contained equal amounts of total nitrogen (13 meq/l). Nitric acid seemed to be an unfavorable nitrogen source. In Study II (Table 4), those treatments (Solutions 1 and 2) without NH_4^+ had significantly lower yields. Chloride, sulfate, nitrate, potassium, and calcium varied over relatively wide ranges without effects similar to lack of ammonium. There appeared to be a trend toward higher yields in those treatments lacking Cl^-, and simultaneously lower total solution concentration, provided ammonia was present. The general observation was made during Study II that, December through January, treatments with 6 meq/l Cl^- and 6 meq/l NH_4^+ appeared to be growing the fastest. But, toward the end of the experiment under increasing light, treatment 10 began to lose ground.

Those treatments containing buffers in Study I (Solutions 6 and 8) had significantly higher yields, but even the treatment of 4 meq/l NH_4NO_3 (no buffer, Solution 7) had significantly higher yields than treatments containing no ammonium. The presence of buffers did have a marked effect on pH changes of the leachate (Table 5). Leachates were collected about 14 to 15 hours after irrigation. The results show that pH changes can occur very rapidly when NH_4^+ is applied. The irrigation frequency could also have some moderating effect on low pH. Each pot was watered from two to four times daily. Frequent irrigations would have limited the time that roots were in contact with an excessively acid solution.

Hartman (CFGA Bul. 249) discussed the possible reasons for differences in effect of ammonium. Other than the possibility of inadequate nutrition in previous experiments, the fact that they were carried out during high light periods as contrasted to present studies appears to be more reasonable. The continuation of Ammonium Study II through the summer period should be a good test.

Hartman suggested at least 2 meq/l NH_4NO_3 as an adequate addition for maximum carnation growth. We suggest that, in water supplies where ions such as calcium may be in high concentrations, NH_4NO_3 may be increased to 4 meq/l during the dark winter months. Nitric acid is not a good NO_3^- supply, and should only be used to reduce precipitation in concentrate tanks. It is probable that NH_4^+ concentration should be varied in accordance with the season and the quality of water supply. Chloride additions in good water may be beneficial during the winter.

On the basis of this and previous work on moderately saline waters, we can assign some general limits:

1. The best possible water should always be used. Where alternatives between good domestic water and a shallow well with moderate hardness are available, the use of the domestic supply will afford maximum versatility in nutrient programming and opportunities for maximum yields. Good water is the cheapest raw material in greenhouse production.
2. When forced to use a saline or alkaline supply, the water should be analyzed at regular intervals in order that the fertilizer program may be adjusted. Total ion concentration should always be as low as possible. As irrigation frequency increases, total concentration can be reduced.
3. The levels of various ions that are present in irrigation water may vary within limits without marked effect if the nutrient program is adjusted in accordance with water analyses:
   a. Sulfates can go as high as 10 meq/l (480 ppm). One-half to one meq/l is adequate. As with other

Table 3. The influence of NH_4^+ ions or HNO_3 and carbonate or bicarbonate buffers on flower, vegetative break, and total fresh weight yield of carnations. Ammonium study I.

Solution	NH_4 solution concentration (ppm)	HNO_3 solution concentration (me/1)	Buffer concentration (me/1)	Flower yield per plant	Vegetative breaks per plant	Total fresh yield (g)
8	72	0	1N $CaCO_3$[1]	2.6 d[2]	21.5 d[2]	623
6	72	0	3 HCO_3	2.2 d	21.8 d	598
7	72	0	none	1.9 cd	19.0 c	534
5	72	0	6 HCO_3	1.9 cd	20.2 cd	514
1	45	0	6 HCO_3	1.6 bcd	18.6 c	476
3	18	3	6 HCO_3	0.8 abc	16.0 ab	444
2	36	1	6 HCO_3	1.1 abc	17.0 b	434
9 (check)	0	0	none	0.6 abc	16.6 b	409
4	0	5	6 HCO_3	0.4 a	14.8 a	390

[1]Fifty grams/pot of $CaCO_3$ were thoroughly mixed in the growing medium before planting.

[2]Numbers followed by the same letter are not significantly different.

Numbers followed by the same line are not significantly different.

Table 4. Effect of ammonium nutrition on fresh weight of carnations. Ammonium study II.

Solution	NH_4 concentration (ppm)	Cl concentration (ppm)	Fresh weight* (grams)
5	90	0	299**
7	90	0	287
6	90	0	284
9	108	70	276
4	90	0	273
8	72	70	266
10	108	210	259
3	90	0	258
2	0	0	182
1	0	0	159

*Note that weight values in this table are per plant, whereas weight in Table 3 is for total of two plants, including flowers.

**Numbers followed by the same line are not significantly different.

ions in excess, however, high sulfates will increase total concentration and limit the potential for maximum yield.

b. **Sodium** can go as high as 8 meq/1 (184 ppm) as long as potassium is maintained equal in concentration. Beyond 8 meq/1, serious problems result in maintaining adequate soil structure, and potassium cannot be increased without limit.

c. **Calcium** concentrations of more than 10 meq/1 (200 ppm) are too high and may cause serious precipitation problems in concentrate tanks.

d. **Chloride** should not exceed 2 meq/1 (70 ppm) in the summer when NH_4^+ is used. It may be beneficial in the winter at concentrations up to 4 meq/1 (140 ppm) with ammonium.

e. **Ammonium** as a cheap nitrogen source will always be used; pending further study, it may vary from 2 meq/1 (36 ppm) in the summer to 4 meq/1 (72 ppm) in the winter. If the water is high quality, Hartman's recommendation of 2 meq/1 is probably sufficient.

f. **Potassium** may be increased slightly in the summer (with additional nitrate). In general, fairly close 1:1 ratio with sodium should be kept. Six to seven meq/1 (234 to 273 ppm) is adequate.

g. **Bicarbonate** does not appear to be a serious problem below 6 meq/1 (366 ppm). When present, ammonium may be increased. Bicarbonate may cause precipitation in concentrate tanks and reduce availability of calcium on the bench. Ammonium helps to counteract this. Precipitation in concentrate tanks may be reduced by adding 0.5 to 1.0 lbs. of HNO_3 per 50 gallons.

h. **Nitrate** recommendations of 12 meq/1 (744 ppm) have not changed from those given by Hartman and Holley (CFGA Bul. 221), although this probably can vary between 10 to 15 meq/1 without marked effect.

4. Total concentration of the nutrient solution may vary from 30 to 60 total meq/1. Milliequivalents are not a strictly correct means of expressing solution concentration, but are a rough approximation. The 61 meq/1 of Solution 10, Table 2, results in a theoretical, calculated osmotic potential of 1.2 bars (ca 17.6 psi), whereas Solution 9, Table 1, had a calculated potential of 0.55 bars (ca 8.1 psi). This roughly corresponds to an electrical conductivity between 1.5 and 4.0 millimhos per cm., or 800 to 2500 ppm. A potential of 1.5 bars (ca 5 mmhos), after fertilizer injection, is probably the upper limit. Beyond this total concentration, quite visible effects might be seen on carnation growth.

regardless of solution composition. If the water supply already contains sufficient materials to give a conductivity of 1.0 mmhos, serious difficulty will be experienced in keeping the total concentration below the upper limits.

We emphasize that the general limits given here do not represent ideal conditions for maximum yields, nor that the solution can be varied indiscriminately within these ranges. With proper management, they represent the situation which we can usually tolerate.

Table 5. The effect of NH_4^+ and HCO_3^- or $CO_3^{=}$ buffers on the leachate pH taken 14-15 hours after application to carnation plants. Study I.

Solution	NH_4^+ solution concentration (me/1)	HNO_3 solution concentration (me/1)	Buffer concentration (me/1)	Initial solution pH	Leachate pH
1	2.5	0.1	6 HCO_3	7.6	6.4
2	2.0	1.0	6 HCO_3	7.2	6.5
3	1.0	3.0	6 HCO_3	6.7	6.8
4	0.0	5.0	6 HCO_3	6.5	7.3
5	4.0	0.0	6 HCO_3	7.6	5.2
6	4.0	0.0	3 HCO_3	7.4	4.8
7	4.0	0.0	none	6.5	3.3
8	4.0	0.0	1 N $CaCO_3$*	6.6	6.2

*Fifty grams/pot of $CaCO_3$ were thoroughly mixed in the growing medium before planting.

Your editor,

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