J. AMER. SOC. HORT. SCI. 117(2):234-238. 1992.

Plant Growth and Cutting Production of Container-grown *Pelargonium* Stock Plants as Affected by N Concentration and N Form

Ruth Ganmore-Neumann and A. Hagiladi[1]

Department of Soil Chemistry and Plant Nutrition, Soil and Water Institute, Agricultural Research Organization, The Volcani Center, P. O. B. 6, Bet Dagan 50250, Israel

Additional index words Pelargonium zonale, NO_3^-: NH_4^+: ratios, N recovery, leachate

Abstract. **Stock plants of *Pelargonium zonale* 'Empress' were grown for 130 days on coarse tuff medium in a greenhouse. Four N concentrations (50, 100,200, and 400 mg N/liter) and three NO_3^-: NH_4^+: ratios (70:30, 60:40, and 40:60) were applied. The development of mother plants, production of cuttings, and the recovery of applied N were measured. Number of cuttings was not affected by any treatments except for the low N concentration. The proportion of absorbed N was higher than that of water in the plants treated with 50 or 100 mg N/liter, while those fertilized with 200 or 400 mg N/liter absorbed more water relative to N uptake. Nitrogen recovery efficiency decreased from 70% to 10% for the 50- to 400-mg N/liter treatments, respectively. Percentage of applied N lost by leaching (30% to 70%), and N that could not be accounted for (0.5% to 20%), increased with increasing N concentration and NH_4^+ percentage in the solution. The minimum concentration to be used in fertilization of *Pelargonium* mother plants is 100 mg N/liter. Optimal N supplied ranged between 100 and 200 mg N/liter.**

The quality of *Pelargonium* stock plants affects the size or number of cuttings and their root regeneration. Nutrition is one of the factors that has been reported to affect stock plant development and the production of cuttings (Read, 1987).

Nitrogen concentrations affect plant growth and cutting yield (Lemaire, 1983; Lemaire and Dartigues, 1984; Reuther and Rober, 1980). The proportion of NO_3^- or NH_4^+ absorbed by the plant depends on the plant species in question. Some plants exhibit a growth response as the NO_3^- proportion is increased (Dirr, 1975), others thrive on NH_4^+ as the N source (Colgrove and Roberts, 1956). Plants sensitive to NH_4^+ responded positively when the pH of the medium was controlled (Wander and Sites, 1956). The preference of N form by plant species depends on environmental conditions and stage of development (Ganmore-Neumann and Kafkafi, 1983, 1985).

Nitrogen concentration and sources have been compared for their effect on growth and quality of ornamental plants (Boodley, 1970; Dirr, 1975; Tew Schrock and Goldsberry, 1982). However, the fate of N from different N sources due to plant absorption, medium retention or loss from the container has not been examined in ornamental plants, except for some data on a single N fertilizer applied to potted plants (Stewart et al., 1981).

Addition of soluble N in the irrigation water at high volume has led to the question of N efficiency usage. Nitrate could be lost by leaching, plant uptake, gaseous loss, and denitrification. Ammonium is reduced through vitrification, volatilization, and adsorption to the growth medium. Water leaching through the pots may remove NO_3^- or, to a lesser extent, NH_4^+.

The objectives of this study were to determine a) the effect of N concentration and NO_3^-: NH_4^+ ratio in the nutrient solution on the growth of *Pelargonium* stock plants and the production of cuttings, and b) the fate of applied N.

Received for publication 29 Oct. 1990. Accepted for publication 16 Aug. 1991. Contribution from the Agricultural Research Organization, The Volcani Center, Bet Dagan, Israel. No. 3061-E, 1990 Series. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]Dept. of Ornamental Horticulture, Field Crop Institute, Agricultural Research Organization, The Volcani Center, POB 6 Bet Dagan 50250, Israel.

Materials and Methods

Plants of *Pelargonium zonale* 'Empress' (7 weeks old) were grown in 3-liter containers (each inserted into a 2-liter pot that served to collect the leachate) on tuff [particle sizes of 0.1 to 8 mm (Hershey and Paul, 1982)] in an unheated glass greenhouse irradiated by natural sunlight (1400 to 1600 $\mu mol \cdot m^{-2} \cdot s^{-1}$ photosynthetic photon flux) at a temperature range of 10 to 30C for 130 days (25 Nov. 1986 until 5 Apr. 1987). The plants were irrigated for 70 days with 200 ml of nutrient solution every other day, after which the irrigation regime was changed to daily application of 300 ml to compensate for the evaporation loss. Seven fertilization treatments were applied: four total N concentrations (50, 100, 200, and 400 $mg \cdot liter^{-1}$) with a constant ratio of 70 NO_3^-:30 NH_4^+; and three NO_3^-: NH_4^+: ratios (70:30, 60:40, and 40:60) with a constant N concentration (200 $mg \cdot liter^{-1}$). The four N concentrations treatments consisted of NO_3^- and NH_4^+ in the following concentrations ($mg \cdot liter^{-1}$): 35 NO_3^- + 15 NH_4^+, 70 NO_3^- + 30 NH_4^+, 140 NO_3^- + 60 NH_4^+, and 280 NO_3^- + 120 NH_4^+. The three NO_3^-: NH_4^+ ratio treatments consisted of NO_3^- and NH_4^+ in the following concentrations ($mg \cdot liter^{-1}$): 140 NO_3^- + 60 NH_4^+, 120 NO_3^- + 80 NH_4^+, and 80 NO_3^- + 120 NH_4^+ (the last ratio was tested only for the last 3 months). The concentrations of K, P, and Fe were 200, 31, and 0.5 $mg \cdot liter^{-1}$, respectively. Micronutrients were ($mg \cdot liter^{-1}$): Mn, 0.12; Cu, 0.076; Zn, 0.3; Mo, 0.05; and B, 0.5. The electrical conductivity (EC) and the pH were ≈ 2.0 $dS \cdot m^{-1}$ and 6.7, respectively. The solutions were prepared with tap water with an EC of ≈ 0.8 $dS \cdot m^{-1}$. Each treatment consisted of eight single-plant container replicates that were arrayed on the greenhouse benches in a completely randomized design. Control containers without plants (four replicates) were fertilized identically to the experimental treatments. Leachate was collected weekly from the 2-liter pots 120 min following irrigation. The leachate was analyzed for NO_3^-, NH_4^+, K^+, EC, and pH, and its volume was determined.

The cumulative applied N during the experiment was 750, 1500, 3000, and 6000 mg/plant for the 50-, 100-, 200-, and 400-$mg \cdot liter^{-1}$ treatments, respectively. Nitrogen balance was calculated (N unaccounted = applied N – N uptake – N leached).

At the end of the experiment, mother plants were divided into root, shoot, and leaves. The plant organs were weighed for fresh and dry weight (after drying at 60C). Total N was determined after wet ashing with H_2SO_4 and H_2O_2. Nitrogen, NO_3^-, and NH_4^+ were analyzed with a Technicon autoanalyzer (London, England) and K with a Corning 400 flame photometer (Corning, Rochester, N.Y.). Statistical analysis were preformed using SAS stepwise regression to test the effect of N concentration or NO_3^-: NH_4^+ ratio on various dependent variables.

Results and Discussion

Development of mother plants. Increasing the N concentration and the NO_3^-: NH_4^+ ratio applied to stock plants did not affect cutting production (Table 1), except that the lowest N concentration led to the lowest production, suggesting that 50 mg·liter^{-1} is below the optimal concentration for producing the optimum number of cuttings. Reuther and Rober (1980) reported that 20 to 30 mg N/liter was the optimum concentration for growth in the same variety; this discrepancy may be explained by the low light conditions in their experiment. Nitrogen form did not affect the production of cuttings. These data contradict those regarding the depressive effect of a high NH_4^+ percentage in the nutrient solution on yield after 140 days (Lemaire, 1983; Lemaire and Dartigues, 1984), possibly because of the differences in cultivar used or in the length of the experiment. The weight of a cutting, which was ≈2.6 to 2.7 g was not affected by the treatments. Root fresh weight and root : shoot ratio were negatively correlated with increasing N concentration and with the NO_3^- percentage in the nutrient solution. A similar trend was obtained for leaves and cuttings, but the regression was not significant. Nitrogen form did not affect the development of the above-ground plant organs, as observed for 'Sprinter Scarlet' grown in soil (Tew Schrock and Goldsberry, 1982). The potential production of cuttings was not affected by the weight of the root system. The percentage of dry matter was not significantly affected by the treatments, being 10% and 21% for the root and above--ground organ, respectively (detailed data not shown).

Nitrogen absorption by the mother plants. Total mineral N absorbed (Table 2) increased in all plant parts, except in the roots, with increasing N concentration in the nutrient solutions up to 200 mg N/liter. A further increase in N concentration resulted in a reduction of total N absorbed. Increasing the NH_4^+ proportion in the solution from 30% to 40% or 60% reduced total N absorption and N absorption by stems. Nitrogen absorption by roots showed a reversed trend, but the N content tended to decrease in the above-ground organs.

Nitrogen recovery. The efficiency of N recovery is defined as the percentage of N absorbed by the plant from the total N applied. Plant N recovery (Fig. 1A) was highest for 50 mg N/liter, with ≈ 70% of the N potentially available. Increasing N concentration in the solution to 100, 200, and 400 mg N/liter decreased plant N recovery to 50%, 25%, and 10%, respectively. These results are in accordance with those estimated for pot chrysanthemum (Barron, 1977; Holcomb, 1979). Increasing N concentration from 50 to 400 mg N/liter increased leaching losses from 30% to 70% and potentially available N that could not be accounted for from 0.5% to 20%, respectively. The percentage of N recovered by the plant organs (data calculated from Table 2) was found to be similar between 50 to 400 mg N/liter. In root, shoot (stem and leaves), and cuttings, the recovered N percentages were 6.5% to 7.5%, 52% to 57%, and 34% to 38%, respectively.

Nitrogen form in the solution (Fig. lB) did not affect recovery of N by the plant. Leaching losses and N that could not be accounted for were similar (70% and 6%, respectively) for the two high NO_3^- ratios (70:30, 60:40). With the 1ow-NO_3^- ratio, the leaching losses and unaccounted N were 49% and 25%, respectively. The fraction of the potentially available N that could not be accounted for (in the 40:60 ratio treatment) was of the same magnitude as that reported by Cox (1985) and Stewart et al. (1981), who suggested that volatilization or denitrification might be the cause for this portion. In the above experiment, although the vitrification could not be ruled out, only 6% of N could not be accounted for in the high-NO_3^- ratio treatment. Nitrogen losses calculated for the control and planted containers were similar; therefore, we assume that they might be due to NO_3^- adsorption by the tuff. The unaccounted N losses were ≈1 mM(+), 3% to 5% of the cation exchange capacity (CEC) of the tuff, which is 20 to 30 mM(+). 100 g^{-1} (Silber, 1984).

Chemical composition of the leachate. Nitrogen concentration in the leachate of control containers remained constant for all

Table 1. Effect of N concentration (70 NO_3^- : 30 NH_4^+ ratio) and NO_3^- : NH_4^+ ratio (total N concentration, 200 mg·liter^{-1}) on growth of *Pelargonium* stock plants (mean of eight replicates).

Variable	Cuttings[z] (no.)	Root	Stem	Leaves	Cuttings	Total	Root : shoot ratio
		g/plant, fresh wt					
N concn (mg·liter^{-1})							
50	15.0	41.9	42.3	54.3	41.1	180	0.43
100	17.3	39.0	37.6	58.8	46.7	182	0.40
200	16.5	32.3	36.8	49.0	44.7	163	0.37
400	16.3	24.6	33.5	46.4	42.5	148	0.30
Significance							
Linear	*	**	NS	NS	NS	***	***
Quadratic	**	NS	NS	NS	NS	*	*
NO_3^- : NH_4^+							
70:30	16.5	32.3	36.8	49.0	44.7	164	0.37
60:40	16.5	36.4	33.1	55.9	46.7	172	0.40
40:60	15.8	43.9	32.5	47.5	43.9	168	0.56
Significance							
Linear	NS	NS	NS	NS	NS	NS	*
Quadratic	NS	**	NS	NS	NS	NS	***

[z]Average cutting weight ranged between 2.6 and 2.7 g.
*,**,***,NS Significant at $P = 0.05, 0.01$, or 0.001, or nonsignificant, respectively.

Table 2. Effect of N concentration (70 NO_3^- : 30 NH_4^+ ratio) and NO_3^- : NH_4^+ ratio (total N concentration, 200 mg·liter^{-1}) on total N absorption in *Pelargonium* stock plants (mean of eight replicates).

Variable	Root	Stem	Leaves	Cuttings	Total
	mg N/plant				
N concn (mg·liter^{-1})					
50	39.0	61.9	239	173	512
100	48.7	82.7	341	281	753
200	59.1	103.0	321	277	760
400	42.6	120.6	204	281	648
Significance					
Linear	NS	**	NS	NS	NS
Quadratic	NS	***	**	*	NS
NO_3^- : NH_4^+					
70:30	42.8	103.0	321	277	744
60:40	54.6	86.1	246	299	686
40:60	56.2	71.5	314	255	696
Significance					
Linear	NS	***	NS	NS	NS
Quadratic	*	*	NS	***	***

*,**,***,NS Significant at P = 0.05, 0.01, or 0.001, or nonsignificant, respectively.

Table 3. Effect of N concentration (70 NO_3^- : 30 NH_4^+ ratio) and NO_3^- : NH_4^+ ratio (total N concentration, 200 mg·liter^{-1}) on total N concentration in the leachate from control and *Pelargonium* planted containers. Leachates were collected between irrigation.

Time (weeks)	Control containers[z]				Planted containers[y]			
	N concn (mg·liter^{-1}) in the applied solution							
	50	100	200	400	50	100	200	400
3	124	62	160	254	40	68	216	204
5	62	135	233	377	32	61	319	284
8	56	125	311	417	42	90	470	538
12	46	120	312	462	32	87	605	621
16	56	130	310	444	35	147	650	680

Time (weeks)	Control containers[z]			Planted containers[y]		
	NO_3^- : NH_4^+ ratio in the applied solution					
	70:30	60:40	40:60	70:30	60:40	40:60
3	168	160	137	194	169	121
5	231	300	165	234	222	269
7	290	300	171	340	280	227
9	300	312	200	593	423	260
11	311	312	213	618	515	292

[z]Mean of four replicates.
[y]Mean of eight replicates.

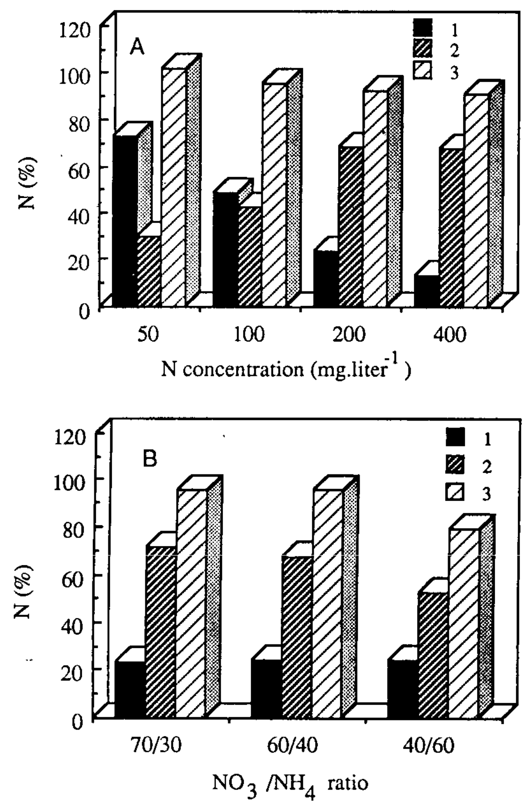

Fig. 1. Nitrogen balance in *Pelargonium* as affected by N concentration (**A**) and NO_3^- : NH_4^+ ratio (**B**) in the nutrient solution (1) Percent N in plant, (2) percent N in leachate of planted container, (3) percent N in leachate of control container.

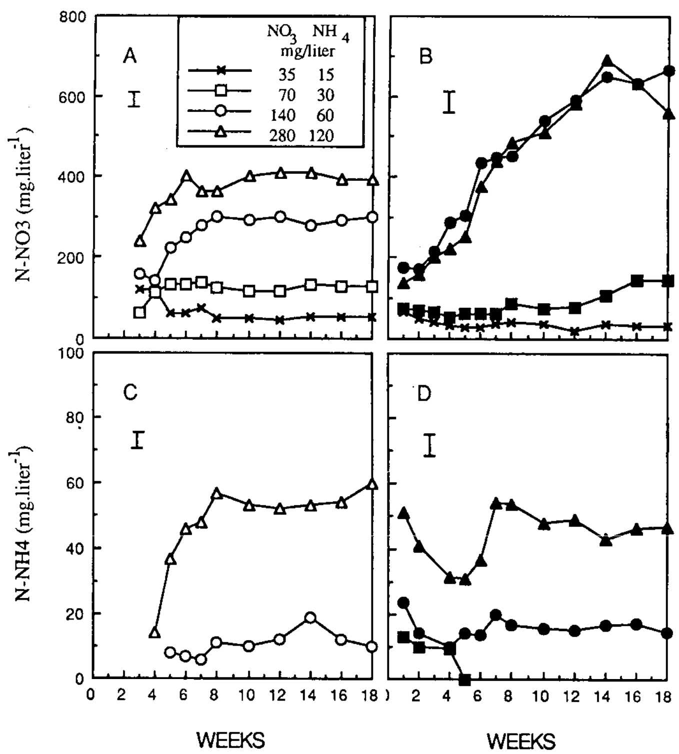

Fig. 2. Effect of N-NO_3^- and N-NH_4^+ concentration in the applied solution (inset) on N-NO_3^- and N-NH_4^+ concentration (mg N/liter) in the leachate of control (**A, C**) and planted (**B, D**) containers in y axis. Missing lines indicate that no NH_4^+ was detected in leachate. Vertical bars represent maximum ±SE.

treatments from the 5th week on (Table 3). In the presence of plants, the N concentration in the leachate was lower for 50 and 100 mg N/liter and higher for 200 and 400 mg N/liter when compared with the applied solution. Whether the N concentration in the leachate is higher or lower than that of the applied solution is determined principally by the relative uptake of water and N by the plant and evaporation losses. In the 50 and 100 mg N/liter treatments, the proportion of N taken up by the plants exceeded that of water absorbed, while in 200 and 400 mg N/liter, N concentration of the leachate was above that in the applied solution, suggesting that the proportion of water absorbed was higher than that of N. Nitrogen concentration increased with time in all treatments except the lowest N concentration. Increasing the NH_4^+ proportion decreased total N

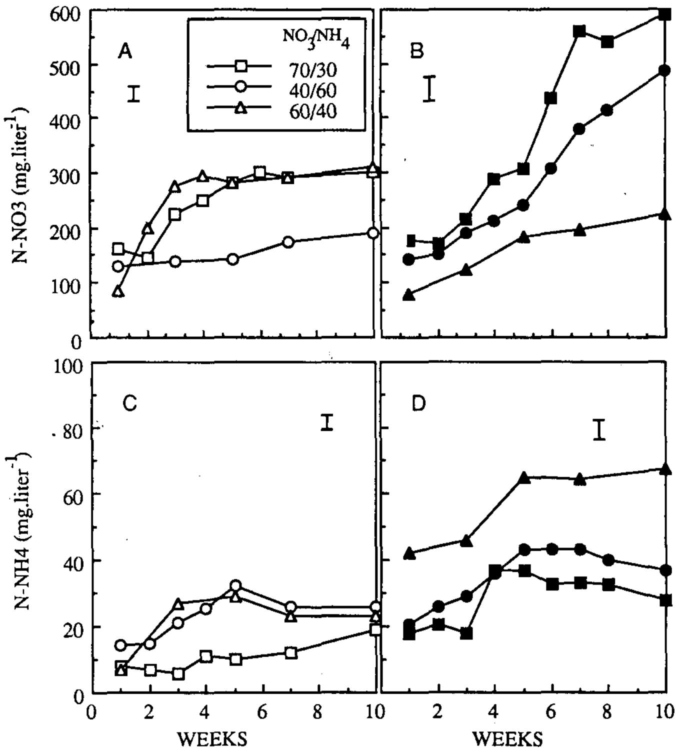

Fig. 3. Effect of NO_3 : NH_4 ratio (inset) on N-NO_3^- and N-NH_4^+ concentration in the leachate of control (**A, C**) and planted (**B, D**) containers. Vertical bar represent maximum ± SE.

concentration in the leachate, suggesting adsorption of NH_4^+ to the tuff.

The NO_3^- concentration in the leachate of the control and planted containers was higher than in the applied solution (Fig. 2 A and B), while NH_4^+ concentration was lower than the applied NH_4^+ for 200 and 400 mg N/liter (Fig. 2 C and D). No NH_4^+ was detected in 50 and 100 mg N/liter. In the leachate of the control containers, low NO_3^- and NH_4^+ contents were obtained at 40 NO_3^-:60 NH_4^+ and 70 NO_3^-:30 NH_4^+, respectively (Fig. 3 A and C). In the presence of plants, NO_3^- concentration increased with time above that of the applied solution (Fig. 3B). Ammonium concentration was ≈ 50% of that of the applied and remained constant from the 5th week onward (Fig. 3D). The percentages of NO_3^- in the leachates of the three NO_3^-: NH_4^+ ratios were calculated at the end of the experiment and were 95, 93, and 85 in the control and 98, 94, and 74 in planted containers for NO_3^- : NH_4^+ ratios of 70:30, 60:40, and 40:60, respectively.

An increase in N concentration and NO_3^-: NH_4^+ ratio of the applied solution affected the K, pH, and EC of the leachate (Table 4). Increasing N concentration increased K in the leachate of the control containers. The NH_4^+ concentration in the solution presumably increased with increasing total N, competing with K for adsorption sites of the tuff, thus resulting in the increase of K concentration in the leachate of the control container. An inverse effect of the concentration was observed in the presence of plants when K concentration was lower than that in the applied solution. A high NH_4^+ ratio of the solution resulted in a reduction in K concentration.

The pH of the leachate was strongly affected by the ionic strength, but not by the NO_3^-: NH_4^+ ratio of the applied solution. In the control container, the pH decreased with an increase in N concentrations; the presence of a plant moderated this effect (Table 4). Changes in pH affect nutrient uptake (Riley and Barber, 1982). EC of the leachate of control and planted containers mostly was higher than the applied solution whether the N concentration or the ratio was changed.

A positive linear correlation, unaffected by time, was obtained between NO_3^-, NH_4^+, K, and total N concentrations in leachate of the control containers (Fig. 4A-C). The presence of

Table 4. Effect of N concentration (70 NO_3^- : 30 NH_4^+ ratio) and NO_3^- : NH_4^+ ratio (total N concentration, 200 mg·liter^{-1}) on K concentration, pH, and electrical conductivity (EC) in the leachate from control and planted *Pelargonium* containers.[z]

	Control containers[y]			Planted containers[x]		
Variable	K (mg·liter^{-1})	pH	EC (dS·m^{-3})	K (mg·liter^{-1})	pH	EC (dS·m^{-3})
N concn (mg·liter^{-1})						
50	85	7.5	1.7	164	7.5	3.7
100	95	6.7	2.0	123	6.4	5.5
200	150	5.2	4.4	113	5.9	5.9
400	188	4.1	4.0	109	5.9	6.0
Significance						
Linear	*	*	NS	*	NS	NS
Quadratic	***	***	***	**	***	**
NO_3^- : NH_4^+						
70:30	150	5.2	4.2	113	5.9	5.9
60:40	140	5.0	4.3	113	5.9	5.9
40:60	120	5.3	3.8	85	6.0	5.9
Significance						
Linear	NS	NS	**	NS	NS	NS
Quadratic	*	NS	*	***	NS	NS

[z]Initial values were K = 200 mg·liter^{-1}, pH = 6.7, EC ≈ 2.0 dS·m^{-3}.
[y]Mean of four replicates.
[x]Mean of eight replicates.
*,**,***,NS Significant at P = 0.05, 0.01, or 0.001, or nonsignificant, respectively.

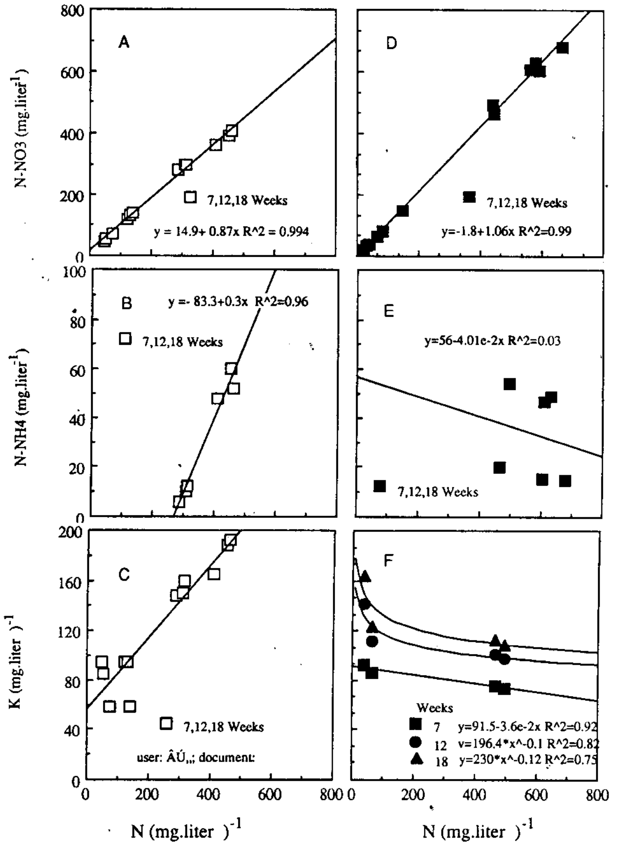

Fig. 4. The correlation between total N and N-NO_3^-, N-NH_4^+, and K concentration in the leachate of control **(A-C)** and planted **(D-F)** containers. Data from 7, 12, and 18 weeks after starting treatments.

plants resulted in a similar correlation for NO_3^- (Fig. 4D), no significant correlation for NH_4^+ (Fig. 4E), and an exponential decrease in K concentration with total N and an increase with time (Fig. 4F).

It seems that fertilization with 50 mg N/liter at the irrigation frequencies applied in our experiment might be inadequate for *Pelargonium* mother plants to produce optimal number of cuttings, as also reported for chrysanthemum (Rober and Reuther, 1982), and that 100 mg N/liter is the minimal concentration that should be used to fertilize *Pelargonium* stock plants. The optimal level of N supplied lies between 100 and 200 mg N/liter, since 50 mg N/liter resulted in a decrease of cutting production and low residual amounts of available N in the solution. High N concentration (400 mg N/liter) failed to enhance cutting yield and was followed by signs of salinity damage that started to appear in the end of the experiment. Nitrogen source did not affect cutting yield production. Increasing N concentration in the solution resulted in a high proportion of leached N. Increasing NH_4^+ ratio in the solution resulted in a higher amount of unaccounted N, which was probably adsorbed to the tuff. The concentration and NO_3^-: NH_4^+ ratio in the fertilizer applied to the stock plant can have a significant effect on N absorption by the plant and losses from the medium.

Literature Cited

Barron, H.M. 1977. Control release fertilizer and its use in hot climates. S. Fla. Nurseryman 89:16-17, 35–38.

Boodley, J.W. 1970. Nitrogen fertilizers and their influence on the growth of poinsettias. Florists Rev. 148(1):26-39.

Colgrove, M.S. and A.N. Roberts. 1956. Growth of azalea as influenced by ammonium and nitrate nitrogen. J. Amer. Soc. Hort. Sci. 68:522-536.

Cox, D.A. 1985. Nitrogen recovery by seed geranium as influenced by nitrogen source. HortScience 20:923-925.

Dirr, M.A. 1975. Effect of nitrogen form and pH on growth, NO_3-N, NH_4-N and total N content of container-grown double-file *Viburnum.* J. Amer. Soc. Hort. Sci. 100:216-218.

Ganmore-Neumann, R. and U. Kafkafi. 1983. The effect of root temperature and NO_3/NH_4 ratio on strawberry plants. I. Growth, flowering, and mot development. Agron. J. 75:941-947.

Ganmore-Neumann, R. and U. Kafkafi. 1985. The effect of root temperature and NO_3/NH_4 ratio on strawberry plants. II. Nitrogen uptake, mineral ions and carboxylate concentration. Agron. J. 77:835-840.

Hershey, D. and J.L. Paul. 1982. Leaching-losses of nitrogen from pot chrysanthemums with controlled-release or liquid fertilization. Scientia Hort. 17:145-152.

Holcomb, E.J. 1979. Cost and efficiency of slow-release fertilizer. Pa. Flower Growers Bul. 316:9-10.

Lemaire, F. 1983. Influence of $CaCO_3$, added to the substrate on the nitrogen nutrition of *Pelargonium hortorum* mother plants. Acta Hort. 150:203-217.

Lemaire, F. and A. Dartigues. 1984. Importance of NO_3-N/NH_4-N ratio in the nutrient solution for the production of cuttings by pelargonium mother plants. ISOSC Proc. 4:301-315.

Read, P.E. 1987. Introduction to the symposium: Effect of the stock paint on propagation success. HortScience 22:736-737.

Reuther, G. and R. Rober. 1980. Influence of various N-supply on photosynthesis and yield of *Pelargonium* stock plant. Gartenbauwissenschaft 45:21-29.

Riley, D. and S.A. Barber. 1971. Effect of ammonium and nitrate fertilization on phosphorus uptake as related to root-induced pH changes at the root–soil interface. Soil Sci. Soc. Amer. Proc. 35:301-306.

Rober, R. and G. Reuther. 1982. The influence of different N-forms and concentrations on the yield and quality of chrysanthemum cuttings. Gartenbauwissenschaft 47: 182–188.

Silber, A. 1984. Reaction of phosphorus with tuff from the Golan Heights (in Hebrew). MS Thesis, Hebrew Univ., Jerusalem, Israel.

Stewart, J. A., L.J. Lund, and R.L. Branson. 1981. Nitrogen balance for container grown private. J. Amer. Soc. Hort. Sci. 106:565-569.

Tew Schrock, P.A. and K.L. Goldsberry. 1982. Growth responses of seed geranium and petunia to N source and growth media. J. Amer. Soc. Hort. Sci. 107:348-352.

Wander, I.W. and J.W. Sites. 1956. The effect of ammonium and nitrogen with and without pH control on growth of Rough Lemon seedlings. Proc. Amer. Soc. Hort. Sci. 68:21 1–226.