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Effects of Nitrogen Form and Potassium Concentration on Growth, Flowering, and Nitrogen Utilization of Greenhouse Roses[1]

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Abstract. **'Forever Yours' roses (*Rosa* Hybrid Tea) were grown in recirculating nutrient solutions at 1.0 and 10.0 meq/liter K in combination with 10.0 meq/liter NO_3-N or NH_4-N. Low K limited the growth and flower production, regardless of N form. Ammonium-N fertilized plants showed NH_4-N toxicity symptoms as interveinal chlorosis of the lower leaflets. An increased K supply reduced NH_4-N toxicity symptoms. Concentrations of Ca and Mg were lower, while P was higher, in the tissue of NH_4-N fertilized plants, as compared to NO_3-N fertilized plants. Total N, alcohol insoluble N, soluble organic N, and NH_4-N were higher in the tissue of plants which received NH_4-N, as compared to NO_3-N, regardless of K level. An increased K supply from 1.0 to 10.0 meq/liter resulted in higher NO_3-N in NO_3-N fertilized plants and lower NH_4-N in NH_4-N fertilized plants.**

The effect of NH_4-N, as compared to NO_3-N, on plant growth has been studied extensively (8, 9, 10, 14, 15, 17). High levels of NH_4-N fertilization have resulted in reduced growth, lower tissue concentrations of cations and higher P concentration (10, 14, 15, 17). In addition, NH_4-N fertilized plants generally contain higher levels of total N, free amines and amides, and free NH_4-N, as compared to plants receiving NO_3-N (8, 9, 17).

Barker et al. (3) found NH_4-N toxicity symptoms of tomato were magnified under conditions of K deficiency. Subsequently, Maynard et al., (12) observed when K was supplied in adequate amounts, NH_4-N toxicity symptoms were prevented and NH_4-N did not accumulate in the tissue. Similar results have been obtained with a number of plant species (1, 11, 16).

The purpose of the present work was to determine the influence of K concentration on the growth, flowering, ion composition, and N utilization of roses grown in a recirculating nutrient solution containing NO_3-N or NH_4-N.

Materials and Methods

Rooted cuttings of 'Forever Yours' roses were established in a recirculating nutrient solution system consisting of 12 troughs, each of which contained 10 roses spaced 30 cm apart. The system was supported on 2 raised greenhoues benches. Treatment solutions were contained in 4, 110 liter reservoirs, each of which supplied 3 troughs. The outside troughs on each bench, and the end plants in each trough were guard plants and were not used in statistical analysis of data. The remaining troughs were randomized and each treatment consisted of 16 single plants. Prior to starting treatments all plants received, expressed as meq/liter: 2.5 $Ca(NO_3)_2$, 1.5 KNO_3, 0.5 KH_2PO_4, and 0.5 $MgSO_4$ for 4 weeks. In addition, throughout the experiment plants received micronutrients in the following concentrations, expressed as ppm: Fe, 3 as Sequestrene 330; Mn, 0.5 as $MnCl_2$; Zn, 0.1 as $ZnSO_4$; Cu, 0.02 as $CuSO_4$; B, 0.5 as H_3BO_3; and Mo, 0.01 as $(NH_4)_6Mo_7O_{24}$. Treatment variables consisted of 2 levels of K at 1.0 and 10.0 meq/liter in combination with 10.0 meq/liter N as NO_3^- or NH_4^+. Solutions were formulated to supply Ca^{2+}, Mg^{2+}, and $H_2PO_4^-$ at 5, 1, and 1 meq/liter, respectively. The only ions varying in concentration besides K were Na^+, Cl^-, and SO_4^{2-}.

Solutions were depleted of nutrients over a 7 day period and then completely renewed. The pH of the NO_3-N solutions increased with time and was adjusted daily to 6.0 with 1 N HCl. The pH of the NH_4-N solutions decreased with time and was maintained above 4.0 by daily adjustments to a pH of 6.0 with 1 N NaOH. Water lost by transpiration was replaced daily.

The experiment was conducted in a Department of Floriculture and Ornamental Horticulture greenhouse at Ithaca, N.Y. during the fall months. Temperature was maintained at 24°C during the day and at 18° during the night. In addition to natural sunlight, supplemental lighting was provided by high pressure sodium lamps for 18 hr each day from 6:00 AM until 12 midnight with an irradiance of 200–250 $\mu Em^{-2}sec^{-1}$ between 400 to 700 nm. Plants were given one soft pinch about 2 weeks after their establishment in the recirculating solution system and then allowed to flower. Flowers were cut daily just above the lowest 5-leaflet leaf. Yield was recorded as length (cm) and fresh weight (g) of flowering stems. Plants were grown for 10 weeks in treatment solutions and harvested. Fresh weight of the tops was determined at harvest and combined with the weight of any flowers removed to give total fresh weight of the tops.

The first, second and third 5-leaflet leaves below the flower bud and roots were collected at harvest for foliar or tissue analysis. Tissue collected from 16 plants was combined in 4 samples per treatment. Tissue was oven-dried at 75°C for 48 hr and ground in a small Wiley mill to pass through a 20-mesh screen. K, Ca, Mg, and P were determined by a photoelectric emission spectrograph on HCl extracts after ashing at 500°. Total N was determined by a modified Kjeldahl procedure in which selenium is used as an oxidation catalyst. The alcohol-soluble N was ex-

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Table 1. Influence of K concentration and N form on the top growth characteristics of 'Forever Yours' roses.

K concn (meq/liter)	N form	Fresh wt of tops (g)	No. of flowering stems	Length of stems (cm)	Fresh wt of stems (g)
1.0	NO_3^-	19.11[z]	0.00	0.00	0.00
10.0	NO_3^-	149.39	2.56	45.70	30.92
1.0	NH_4^+	75.61	1.88	33.32	18.81
10.0	NH_4^+	124.77	2.81	37.40	22.96
K concn		.01[y]	.01	.01	.01
N form		NS	.01	.01	.01
Concn x form		.01	.05	.01	.01

[z]Means represent 16 measurements.
[y]Level of significance as determined by F-test.

tracted with 70% ethanol (v/v) according to MacLeod and Carson (11). Insoluble N was determined on the residue of ethanol extracted tissue after Kjeldahl digestion with an Orion NH_3 electrode, model 95-10 (Orion Research, Inc., Cambridge, Mass., 02139). The ethanol extracts, which contained soluble organic N compounds (free amines and amides), were evaporated to dryness and redissolved in concentrated H_2SO_4. Soluble organic N was determined with the Orion NH_3 electrode after Kjeldahl digestion. Free NO_3-N and NH_4-N in the tissue were determined in water extracts with the Orion NO_3^- and NH_3 electrodes, models 93-07 and 95-10, respectively (13).

N uptake was determined by solution depletion. Solution samples were analyzed for NH_4-N and NO_3-N potentiometrically (13). By analyses of the 100% NH_4-N treatment solutions for NO_3-N it was determined that no conversion to NO_3-N had occurred and therefore, that the plants absorbed their N in the form supplied.

Results

Growth and flower production. Low K concentration (1.0 meq/liter) reduced the growth and flower production of 'Forever Yours' roses regardless of N form (Table 1). Plants which received 1.0 meq/liter K in combination with 10.0 meq/liter NO_3-N produced no flowers over the 10 week treatment period and were stunted and chlorotic in appearance. In contrast, those plants which received 1.0 meq/liter K in combination with 10.0 meq/liter NH_4-N, produced flowers and showed symptoms of NH_4-N toxicity as interveinal chlorosis of the lower leaflets. Growth, as indicated by fresh weight of the tops, was significantly affected by the K level × N form interaction. At 10.0 meq/liter K, NH_4-N fertilized plants had lower top weights than those plants which received NO_3-N. Ammonium toxicity symptoms were reduced in those NH_4-N fertilized plants as K concentration was increased from 1.0 to 10.0 meq/liter.

Nitrogen uptake. Nitrogen uptake from solutions containing 10.0 meq/liter N was influenced by K concentration and N form (Fig. 1). As K concentration was increased in solution from 1.0 to 10.0 meq/liter, N uptake increased in both NO_3-N and NH_4-N fertilized plants, but to a larger extent in NO_3-N fertilized plants. Plants which received 10.0 meq/liter K, in combination with 10.0 meq/liter NH_4-N, absorbed more N from solution over the 10 week treatment period than those that received 10.0 meq/liter K, in combination with 10.0 meq/liter NO_3-N.

Inorganic ion composition. An increased concentration of K resulted in higher concentrations of K in the tissue, regardless of N form (Table 2). The Ca and Mg concentrations of the leaves increased in NO_3-N fertilized plants, and decreased in NH_4-N fertilized plants, as K supply was increased. Plants fertilized with NH_4-N accumulated lower concentrations of Ca and Mg in the tissue, as compared to NO_3-N fertilized plants.

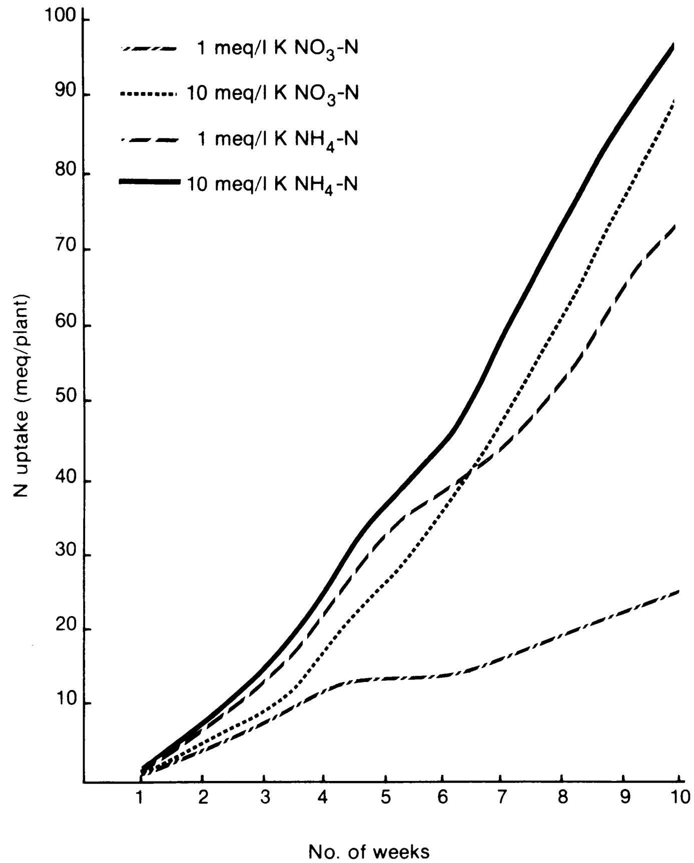

Fig. 1. Influence of K level and N form on the N uptake of 'Forever Yours' roses.

Phosphate concentration increased in the leaves and decreased in the roots of NO_3-N fertilized plants as K concentration in solution increased (Table 2). When averaged over K levels, Phos-

Table 2. Influence of K concentration and N form on the concentration of inorganic ions in the tissue of 'Forever Yours' roses.

K concn (meq/liter)	N form	Ion concn (meq/kg dry wt) K	Ca	Mg	H_2PO_4
		Leaves			
1.0	NO_3^-	291[z]	488	62	49
10.0	NO_3^-	498	798	233	241
1.0	NH_4^+	356	373	181	248
10.0	NH_4^+	630	255	144	241
K concn		.01[y]	.01	.01	.01
N form		.01	.01	.05	.01
Concn x form		.05	.01	.01	.01
		Roots			
1.0	NO_3^-	364	309	336	346
10.0	NO_3^-	568	370	265	218
1.0	NH_4^+	231	131	75	153
10.0	NH_4^+	431	84	56	144
K concn		.01	NS	.01	.01
N form		.01	.01	.01	.01
Concn x form		NS	.01	.01	.01

[z]Means represent 4 measurements.
[y]Level of significance as determined by F-test.

phate concentration was higher in the leaves and lower in the roots of NH_4-N fertilized plants, as compared to NO_3-N fertilized plants.

Nitrogen composition. The concentration of total N increased significantly in both leaves and roots as K supply was increased, regardless of N form (Table 3). Leaves of plants which received NH_4-N contained higher concentrations of total N, as compared with plants which received NO_3-N. Insoluble N increased in the leaves and roots as K supply increased in NO_3-N fertilized plants (Table 3). Insoluble N was higher in those plants fertilized with NH_4-N, as compared with those supplied NO_3-N. Soluble organic (amines and amides) N was higher in the leaves of NH_4-N fertilized plants as compared to NO_3-N fertilized plants (Table 3). K concentration did not affect the concentration of soluble organic N in the leaves of either NH_4-N or NO_3-N fertilized plants. However, an increased level of K resulted in higher concentrations of soluble organic N in the roots of both NH_4-N and NO_3-N supplied plants.

NH_4-N concentration in the tissue was higher in NH_4-N fertilized plants, as compared to NO_3-N fertilized plants (Table 3). As K concentration was increased from 1.0 to 10.0 meq/liter, the concentration of free NH_4-N in the leaves of NH_4-N fertilized plants was reduced.

Plants which received NH_4-N did not contain measurable concentrations of NO_3-N (Table 3). Nitrate-N increased in the leaves and roots of NO_3-N fertilized plants as K supply was increased.

Table 3. Influence of K concentration and N form on the N fractions in the tissue of 'Forever Yours' roses.

K concn (meq/liter)	N form	N fraction (meq/kg dry wt) Total	Insol.	Sol. Org.	NO_3	NH_4
Leaves						
1.0	NO_3^-	2,219[z]	1,582	624	4.6	8.6
10.0	NO_3^-	3,031	2,375	631	13.0	12.0
1.0	NH_4^+	4,193	2,677	1,490	0.0	25.9
10.0	NH_4^+	4,286	2,711	1,556	0.0	19.1
K concn		.01[y]	.01	NS	.01	NS
N form		.01	.01	.01	.01	.01
Concn x form		.01	.01	NS	.01	.01
Roots						
1.0	NO_3^-	2,815	1,785	470	537	23.7
10.0	NO_3^-	4,466	2,102	1,655	669	40.4
1.0	NH_4^+	3,364	2,352	873	0.0	138.8
10.0	NH_4^+	3,539	2,203	1,197	0.0	138.7
K concn		.01	NS	.01	.05	.01
N form		.05	.01	NS	.01	.01
Concn x form		.01	.01	.01	.05	.01

[z]Means represent 4 measurements.
[y]Level of significance as determined by F-test.

Discussion

Growth and flower production of 'Forever Yours' roses were found to be limited by inadequate K supply, regardless of N form. Although flower production was not reduced by NH_4-N as compared to NO_3-N when adequate K (10.0 meq/liter) was supplied, flower quality was reduced as indicated by lower fresh weight and length of flowering stems.

A reduction in the accumulation of cations with NH_4-N has been reported by several researchers (2, 14, 15, 17). In our investigation Ca and Mg concentrations were reduced in the tissue of NH_4-N fertilized plants, as compared to NO_3-N fertilized plants. When NH_4-N, a cation, is used to fulfill the plant's inherent requirement for large amounts of N, competition for uptake and accumulation between cations would be expected to reduce the concentrations of cations.

The concentrations of cations increased in the leaves of roses supplied with NO_3-N, as K supply was increased. An increased supply of K resulted in an increased uptake (Fig. 1) and accumulation (Table 3) of NO_3-N. Ben Zioni et al. (5, 6) found that the reduction of NO_3-N resulted in a stoichiometric synthesis of organic acid anions. The increase in cation accumulation might be the result of increased synthesis of organic acids in response to the increase in NO_3-N reduction, which would be expected to increase the capacity for cation accumulation by providing a source of indiffusible organic anions (7).

Inorganic P increased in the leaves and decreased in the roots of NO_3-N supplied plants as K supply was increased. This may be the result of K serving as a counterion for the translocation of P from the roots to the shoot. Furthermore, in NH_4-N supplied plants P was higher in the leaves and lower in the roots, as compared to NO_3-N supplied plants when averaged over K level. This would suggest that either NH_4-N or basic amino acids synthesized in the roots, in response to NH_4-N, served as counterions for the translocation of P to the shoots.

Those plants which received NH_4-N contained higher concentrations of total N, insoluble N, and soluble organic N, as compared to those which received NO_3-N. Others have attributed this increase in N compounds in NH_4-N fertilized plants to the concentrating effect of reduced growth (8, 9, 17). In our investigation plants which received NH_4-N absorbed more N from solution than those that were supplied with NO_3-N. This result suggests that the increase in the concentrations of N fractions in the tissue resulted, at least partially, from increased absorption of N when supplied as NH_4-N, as compared to NO_3-N.

NH_4-N toxicity has been attributed to the accumulation of free NH_4-N in the leaves of plants (4). NH_4-N is generally assimilated in the roots of plants and translocated to the shoots as organic N compounds, largely amides, where further assimilation occurs (4). When the assimilation of NH_4-N in the roots is limited, usually by the lack of available carbon skeletons, free NH_4-N would be expected to accumulate in the leaves where toxicity would result. In our investigation, accompanying the increased supply of K was a concomitant decrease in the concentration of free NH_4-N in the leaves. This could not be explained by a reduction in NH_4-N uptake by competition with K for absorption, as suggested by others (1, 12, 16), since NH_4-N uptake increased when K supply was increased (Fig. 1). Therefore, our results suggest that increased K supply results in improved utilization of NH_4-N. Furthermore, consistent with this conclusion was the finding that soluble organic N was significantly increased in the roots as K supply was increased. This result indicates the assimilation of NH_4-N into organic forms of N in the roots was improved by increased K supply.

Although the mitigating effect of K on NH_4-N toxicity is probably the result of improved NH_4-N utilization, the nature of this response is not fully understood. Possibly the improvement in NH_4-N assimilation with increased K supply results from increased synthesis and availability of carbon skeletons, which would facilitate the incorporation of NH_4-N into amino acids.

Literature Cited

1. Ajayi, O., D. N. Maynard, and A. V. Barker. 1970. The effects of potassium on ammonium nutrition of tomato (*Lycopersicon esculentum* mill.). Agron. J. 62:818–821.

2. Barker, A. V. and D. N. Maynard. 1972. Cation and nitrate accumulation in pea and cucumber plants as influenced by nitrogen nutrition. J. Amer. Soc. Hort. Sci. 97:27–30.
3. Barker, A. V., D. N. Maynard, and W. H. Lachman. 1967. Induction of tomato stem and leaf lesions, and potassium deficiency by excessive ammonium nutrition. Soil Sci. 103:319–327.
4. Barker, A. V. and H. A. Mills. 1980. Ammonium and nitrate nutrition of horticultural crops. Hort. Rev. 2:395–423.
5. Ben Zioni, A., Y. Vaadia, and S. H. Lips. 1970. Correlations between nitrate reduction, protein synthesis and malate accumulation. Physiol. Plant. 23:1039–1047.
6. Ben Zioni, A., Y. Vaadia, and S. H. Lips. 1971. Nitrate uptake by roots as regulated by nitrate reduction products of the shoot. Physiol. Plant. 24:288–290.
7. Blevins, D. G., N. M. Barnett, and W. B. Frost. 1978. Role of potassium and malate in nitrate uptake and translocation by wheat seedlings. Plant Physiol. 62:784–788.
8. Hoff, J. E., G. E. Wilcox, and C. M. Jones. 1974. The effect of nitrate and ammonium nitrogen on the free amino acid composition of tomato plants and tomato fruit. J. Amer. Soc. Hort. Sci. 99:27–30.
9. Kirkby, E. A. 1968. Influence of ammonium and nitrate nutrition on the cation-anion balance and nitrogen and carbohydrate metabolism of white mustard plants grown in dilute nutrient solutions. Soil Sci. 105:133–141.
10. Kirkby, E. A. and K. Mengel. 1967. Ionic balance in different tissues of the tomato plant in relation to nitrate, urea or ammonium nutrition. Plant Physiol. 42:6–14.
11. MacLeod, L. B. and R. B. Carson. 1966. Influence of K on the yield and chemical composition of grasses grown in hydroponic culture with 12, 50, and 75% of the N supplied as NH_4^+. Agron. J. 58:52–57.
12. Maynard, D. N., A. V. Barker, and W. H. Lachman. 1968. Influence of potassium on the utilization of ammonium by tomato plants. Proc. Amer. Soc. Hort. Sci. 92:537–542.
13. Mills, H. A. 1980. Nitrogen specific ion electrodes for soil, plant, and water analysis. J. Assoc. Off. Anal. Chem. 63:797–801.
14. Pill, W. G. and V. N. Lambeth. 1977. Effects of NH_4 and NO_3 nutrition with and without pH adjustment on tomato growth, ion composition, and water relations. J. Amer. Soc. Hort. Sci. 102:78–81.
15. Pill, W. G., V. N. Lambeth, and T. M. Hinckley. 1978. Effects of nitrogen form and level on ion concentrations, water stress, and blossom-end rot incidence on tomato. J. Amer. Soc. Hort. Sci. 103:265–268.
16. Suski, M. and L. B. MacLeod. 1970. Effect of N source and rate of N, P, and K on the ammonium, amino, and amide nitrogen levels in vegetative tissue of barley grown in hydroponic culture. Can. J. Plant Sci. 50:445–450.
17. Wilcox, G. E., C. A. Mitchell, and J. E. Hoff. 1977. Influence of nitrogen form on exudation rate, and ammonium, amide and cation composition of xylem exudate in tomato. J. Amer. Soc. Hort. Sci. 102:192–196.

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Inheritance of Virus Tolerance in Strawberry[1]

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Abstract. **Seedlings of strawberry (*Fragaria* x *ananassa* Duch.) from 29 crosses were evaluated in a field trial over a 2½-year period for tolerance to a complex of viruses. The seedlings and plants of the parent clones were subjectively rated for tolerance on the basis of vigor, runnering, and appearance of virus symptoms. 'Totem' and 'Aiko' produced the highest percentage of tolerant-appearing seedlings, while 'Olympus', 'Belrubi', and 'Hood' produced the highest percentage of susceptible seedlings. At the end of the trial, when the symptoms were most severe, heritability for tolerance was 0.73. Specific combining ability variance was much smaller than general combining ability variance, indicating that a high proportion of genetic variance was additive. Therefore, rapid progress in breeding for tolerance can be expected from selecting parent clones on the basis of phenotypic performance.**

Many strains of a number of viruses commonly infect strawberries (9). Several of the viruses (mottle, mild yellow-edge, crinkle and vein banding) are transmitted by the aphids *Chaetosiphon fragaefolii* (Cockerell) and *C. thomasi* (Hille Ris Lambers) (9). The viruses often occur together as a complex in infected plants (14). Utilization of virus-tolerant cultivars is an important method of limiting yield losses caused by viruses in the Pacific Northwest (3, 7). Thus, selecting for tolerance is a major objective in breeding programs in the region (5, 16, 17). Although differences in tolerances have been reported from these and from other programs (4, 7, 17) there is no information on its inheritance. This study was undertaken to determine the nature of inheritance of tolerance in seedling populations obtained from parent cultivars and selections (both subsequently referred to as clones) representing varying levels of tolerance. Tolerance was evaluated as a single entity. It is recognized that the situation is probably more complex considering the number of viruses possible and the number of strains within each. The term "virus tolerance rating" was used to describe the overall appearance of the plant with respect to vigor and to characteristic virus-like symptoms which are probably, but

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