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

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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 NO₃-N or NH₄-N. Low K limited the growth and flower production, regardless of N form. Ammonium-N fertilized plants showed NH₄-N toxicity symptoms as interveinal chlorosis of the lower leaflets. An increased K supply reduced NH₄-N toxicity symptoms. Concentrations of Ca and Mg were lower, while P was higher, in the tissue of NH₄-N fertilized plants, as compared to NO₃-N fertilized plants. Total N, alcohol insoluble N, soluble organic N, and NH₄-N were higher in the tissue of plants which received NH₄-N, as compared to NO₃-N, regardless of K level. An increased K supply from 1.0 to 10.0 meq/liter resulted in higher NO₃-N in NO₃-N fertilized plants and lower NH₄-N in NH₄-N fertilized plants.

The effect of NH₄-N, as compared to NO₃-N, on plant growth has been studied extensively (8, 9, 10, 14, 15, 17). High levels of NH₄-N fertilization have resulted in reduced growth, lower tissue concentrations of cations and higher P concentration (10, 14, 15, 17). In addition, NH₄-N fertilized plants generally contain higher levels of total N, free amines and amides, and free NH₄-N, as compared to plants receiving NO₃-N (8, 9, 17).

Barker et al. (3) found NH₄-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, NH₄-N toxicity symptoms were prevented and NH₄-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 NO₃-N or NH₄-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 greenhouses 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(NO₃)₂, 1.5 KNO₃, 0.5 KH₂PO₄, and 0.5 MgSO₄ 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 MnCl₂; Zn, 0.1 as ZnSO₄; Cu, 0.02 as CuSO₄; B, 0.5 as H₃BO₃; and Mo, 0.01 as (NH₄)₆Mo₇O₂₄. 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 NO₃-N or NH₄-N. Solutions were formulated to supply Ca²⁺, Mg²⁺, and H₂PO₄⁻ at 5, 1, and 1 meq/liter, respectively. The only ions varying in concentration besides K were Na⁺, Cl⁻, and SO₄²⁻.

Solutions were depleted of nutrients over a 7 day period and then completely renewed. The pH of the NO₃-N solutions increased with time and was adjusted daily to 6.0 with 1 N HCl. The pH of the NH₄-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°C 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 μEm⁻²sec⁻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 spectrophotograph on HCl extracts after ashing at 500°C. Total N was determined by a modified Kjeldahl procedure in which selenium is used as an oxidation catalyst. The alcohol-soluble N was ex-
Table 1. Influence of K concentration and N form on the top growth characteristics of 'Forever Yours' roses.

<table>
<thead>
<tr>
<th>K concn (meq/liter)</th>
<th>N form</th>
<th>Fresh wt of tops (g)</th>
<th>No. of flowering stems</th>
<th>Length of stems (cm)</th>
<th>Fresh wt of stems (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 NO₃⁻</td>
<td></td>
<td>19.11</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>10.0 NO₃⁻</td>
<td></td>
<td>149.39</td>
<td>2.56</td>
<td>45.70</td>
<td>30.92</td>
</tr>
<tr>
<td>1.0 NH₄⁺</td>
<td></td>
<td>75.61</td>
<td>1.88</td>
<td>33.32</td>
<td>18.81</td>
</tr>
<tr>
<td>10.0 NH₄⁺</td>
<td></td>
<td>124.77</td>
<td>2.81</td>
<td>37.40</td>
<td>22.96</td>
</tr>
</tbody>
</table>

\(^2\)Means represent 16 measurements.
\(^\gamma\)Level of significance as determined by F-test.

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

<table>
<thead>
<tr>
<th>K concn (meq/liter)</th>
<th>N form</th>
<th>Ion concn (meq/kg dry wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>K</td>
</tr>
<tr>
<td>Leaves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0 NO₃⁻</td>
<td></td>
<td>291</td>
</tr>
<tr>
<td>10.0 NO₃⁻</td>
<td></td>
<td>498</td>
</tr>
<tr>
<td>1.0 NH₄⁺</td>
<td></td>
<td>356</td>
</tr>
<tr>
<td>10.0 NH₄⁺</td>
<td></td>
<td>630</td>
</tr>
</tbody>
</table>

\(^2\)Means represent 4 measurements.
\(^\gamma\)Level of significance as determined by F-test.

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 NO₃⁻ 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 NH₄⁺ produced flowers and showed symptoms of NH₄⁺ toxicity as interveinal chlorosis of the lower leaflets. Growth, as indicated by fresh weight of the tops, was significantly affected by the K level \(\times\) N form interaction. At 10.0 meq/liter K, NH₄⁺ fertilized plants had lower top weights than those plants which received NO₃⁻. Ammonium toxicity symptoms were reduced in those NH₄⁺ 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 from 1.0 to 10.0 meq/liter, N uptake increased in both NO₃⁻ and NH₄⁺ fertilized plants, but to a larger extent in NO₃⁻ fertilized plants. Plants which received 10.0 meq/liter K, in combination with 10.0 meq/liter NH₄⁺, 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 NO₃⁻. Ammonium toxicity symptoms were reduced in those NH₄⁺ fertilized plants as K concentration was increased from 1.0 to 10.0 meq/liter.
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 NH₄-N contained higher concentrations of total N, as compared with plants which received NO₃-N. Insoluble N increased in the leaves and roots as K supply increased in NO₃-N fertilized plants (Table 3). Insoluble N was higher in those plants fertilized with NH₄-N, as compared with those supplied NO₃-N. Soluble organic (amines and amides) N was higher in the leaves of NH₄-N fertilized plants as compared to NO₃-N fertilized plants (Table 3). K concentration did not affect the concentration of soluble organic N in the leaves of either NH₄-N or NO₃-N fertilized plants. However, an increased level of K resulted in higher concentrations of soluble organic N in the roots of both NH₄-N and NO₃-N supplied plants.

NH₄-N concentration in the tissue was higher in NH₄-N fertilized plants, as compared to NO₃-N fertilized plants (Table 3). As K concentration was increased from 1.0 to 10.0 meq/liter, the concentration of free NH₄-N in the leaves of NH₄-N fertilized plants was reduced.

Plants which received NH₄-N did not contain measurable concentrations of NO₃-N (Table 3). Nitrate-N increased in the leaves and roots of NO₃-N fertilized plants as K supply was increased.

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 NH₄-N as compared to NO₃-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 NH₄-N has been reported by several researchers (2, 14, 15, 17). In our investigation Ca and Mg concentrations were reduced in the tissue of NH₄-N fertilized plants, as compared to NO₃-N fertilized plants. When NH₄-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 NO₃-N, as K supply was increased. An increased supply of K resulted in an increased uptake (Fig. 1) and accumulation (Table 3) of NO₃-N. Ben Zioni et al. (5, 6) found that the reduction of NO₃-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 NO₃-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 NO₃-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 NH₄-N supplied plants P was higher in the leaves and lower in the roots, as compared to NO₃-N supplied plants when averaged over K level. This would suggest that either NH₄-N or basic amino acids synthesized in the roots, in response to NH₄-N, served as counterions for the translocation of P to the shoots.

Those plants which received NH₄-N contained higher concentrations of total N, insoluble N, and soluble organic N, as compared to those which received NO₃-N. Others have attributed this increase in N compounds in NH₄-N fertilized plants to the concentrating effect of reduced growth (8, 9, 17). In our investigation plants which received NH₄-N absorbed more N from solution than those that were supplied with NO₃-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 NH₄-N, as compared to NO₃-N.

NH₄-N toxicity has been attributed to the accumulation of free NH₄-N in the leaves of plants (4). NH₄-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 NH₄-N in the roots is limited, usually by the lack of available carbon skeletons, free NH₄-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 NH₄-N in the leaves. This could not be explained by a reduction in NH₄-N uptake by competition with K for absorption, as suggested by others (1, 12, 16), since NH₄-N uptake increased when K supply was increased (Fig. 1). Therefore, our results suggest that increased K supply results in improved utilization of NH₄-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 NH₄-N into organic forms of N in the roots was improved by increased K supply.

Although the mitigating effect of K on NH₄-N toxicity is probably the result of improved NH₄-N utilization, the nature of this response is not fully understood. Possibly the improvement in NH₄-N assimilation with increased K supply results from increased synthesis and availability of carbon skeletons, which would facilitate the incorporation of NH₄-N into amino acids.

Literature Cited


Inheritance of Virus Tolerance in Strawberry

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Abstract. Seedlings of strawberry (Fragaria x ananassa Duch.) from 29 crosses were evaluated in a field trial over a 21/2-year period for tolerance to a complex of viruses. The seedlings and plants of the parent clones were subjected to rating 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 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 of the tomato plant in relation to nitrate, urea or ammonium nutrition. Plant Physiol. 42:6–14.


