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Effects of Urea and Nitric Acid on Water and Medium Quality and on Response of Anthurium

Yuncong Li and Min Zhang

ADDITIONAL INDEX WORDS. bicarbonate, acidified water, nitrogen, plant nutrition, pH

SUMMARY. Excessive bicarbonate concentrations and high irrigation water pH affect the growth and appearance of nursery plants in southern Florida. A greenhouse experiment consisting of five nitrogen (N) rates of urea or nitric acid was conducted to evaluate the influence of N sources and rates in irrigation water on bicarbonate concentrations, medium pH, and growth and appearance of anthurium (*Anthurium andraeanum* Lind.) plants. Pot medium pH, dry weight, plant appearance and N uptake by plants were significantly affected by N rates in irrigation water amended with either liquid urea or nitric acid, but the differences between the two N sources were not significant. The optimum growth and the best appearance of anthurium were achieved when N was added to irrigation well water as either urea or nitric acid at a rate of 20 mg·L⁻¹ (ppm) and an electrical conductivity in a range of 0.36 to 0.42 dS·m⁻¹. Nitrogen rates at 80 and 120 mg·L⁻¹ induced adverse plant growth because of the greater salinity of the solutions and the lower pH of the medium.

Southern Florida is underlain by a shallow limestone aquifer. The groundwater contains a high concentration of calcium bicarbonate, commonly more than 100 mg·L⁻¹ with water pH as high as 8.0 (Herr and Shaw, 1989). This source of

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Table 1. The pH values, electrical conductivities (EC) and bicarbonate (HCO_3^-) concentrations of the irrigation water amended with liquid urea and nitric acid at various nitrogen (N) rates.

Parameter	Urea [$\text{mg}\cdot\text{L}^{-1}$ (ppm) N]						Nitric acid [$\text{mg}\cdot\text{L}^{-1}$ (ppm) N]					
	0	10	20	40	80	120	0	10	20	40	80	120
pH	7.78	7.79	7.88	7.90	7.91	7.91	7.78	6.82	6.27	3.55	3.28	3.08
EC ($\text{dS}\cdot\text{m}^{-1}$)	0.34	0.36	0.42	0.49	0.69	0.83	0.34	0.34	0.36	0.65	0.90	1.20
HCO_3^- [$\text{mg}\cdot\text{L}^{-1}$ (ppm)]	151.9	146.7	146.7	149.3	149.3	149.3	151.9	103.0	61.8	0	0	0

water used in irrigation often induces chlorosis by lowering the solubility of magnesium, iron, zinc, and manganese in potting medium or soil (Kidder and Hanlon, 1998). Although calcium is an essential plant nutrient, high concentrations in the irrigation water and soil reduce P availability (Kidder and Hanlon, 1998; Zhou and Li, 2001). With overhead sprinklers commonly used in nurseries in south Florida, calcium residues on leaves cause cosmetic damage to plants. Acidification of this type of irrigation water removes bicarbonate, reduces medium pH, and avoids calcium deposits.

Research information on anthurium nutrition and fertilization is limited. Sakai and Hanohano (1994) recommended a liquid fertilizer (12N-16P-30K + micronutrients) at a rate of $75 \text{ mg}\cdot\text{L}^{-1}$ N with an electrical conductivity (EC) of $0.74 \text{ dS}\cdot\text{m}^{-1}$ for large plants, and $25 \text{ mg}\cdot\text{L}^{-1}$ N with an of $0.5 \text{ dS}\cdot\text{m}^{-1}$ for small plants. In an experiment with two cultivars and annual N rates of 1.39, 1.85, 2.46, and 3.07 g (0.05, 0.06, 0.09, and 0.11 oz) per 15-cm (6-inch) pot [660, 990, 1320 and $1650 \text{ kg}\cdot\text{ha}^{-1}$ (600, 900, 1200, 1500 lb/acre) per year], Conover and Henny (1995) found that plant grade, total number of flowers, and growth for both cultivars decreased as N increased. They concluded that lowered N rates improved anthurium growth and flowering. Similar research with high bicarbonate irrigation water is lacking.

The objective of this study was to evaluate the effects of five rates of N supplied as urea or nitric acid on amelioration of a high bicarbonate well water, potting medium pH, and on growth response of potted anthurium.

Materials and methods

Tissue-cultured anthurium plants (Fancy Flora, Miami, Fla.) were planted into 15-cm pots [2120 mL (0.56 gal)] filled with a mixture of [by volume] 1 peat : 1 perlite : 1 bark and grown under 60% shade at the Tropical Research and Education Center, Homestead, Fla. The

experimental design was a factorial split plot with two water treatments as the main plots and five N rates as the subplots replicated four times. The two irrigation water treatments were 1) nitric acid (Fisher Scientific, Pittsburgh, Pa.) as the N source and acidifier for irrigation well water and 2) liquid urea (Unocal Plus, Unocal Corp., Brea, Calif.) as N source in irrigation well water. Nitrogen rates were 0, 10, 20, 40, 80, $120 \text{ mg}\cdot\text{L}^{-1}$ N in irrigation water either as nitric acid or urea. Each pot was irrigated using a sprayer three times a week with 100 mL (3.38 fl oz) treated well water. The total N application during the growing season (3 months) were equivalent to 0, 82, 164, 328, 656, and $984 \text{ kg}\cdot\text{ha}^{-1}$ (0, 73, 146, 293, 586,

and 879 lb/acre) N [0, 0.168, 0.336, 0.672, 1.344, and 2.016 g (0, 0.006, 0.012, 0.024, 0.048, and 0.071 oz) per pot]. The pH, EC and bicarbonate concentration of the amended irrigation water are shown in Table 1. Bicarbonate concentrations in water samples were measured with an acid titration method (Hanlon et al., 1994). Micronutrients (iron, zinc, copper, manganese, and boron) and phosphorous, potassium, and magnesium fertilizers as Hoagland's nutrient solution without N were applied using a sprayer at the rate of 100 mL per pot weekly to all pots.

Fig. 1. Relationships and regression equations between various nitrogen (N) rates in irrigation water amended with liquid urea and nitric acid and medium pH at day 14, 55, and 92. Each data point represents a mean of three replications.

Table 2. The dry weights of leaf, root and total biomass of the plants and plant grades as influenced by different nitrogen (N) rates in irrigation well water amended with liquid urea or nitric acid.

N rate in irrigation water ^z [mg·L ⁻¹ (ppm)]	Dry wt (g/pot)			Plant grade ^y
	Leaf	Root	Total	
0	2.17 a ^x	2.03 a	3.45 b	2.375 b
10	2.38 a	2.27 a	4.64 ab	4.000 a
20	2.43 a	2.31 a	4.74 ab	4.250 a
40	2.78 a	2.17 a	4.95 a	4.000 a
80	1.96 a	1.36 b	3.32 b	2.500 b
120	2.22 a	1.26 b	3.48 b	2.135 b

^zEach pot was irrigated three times a week with 100 mL (3.38 fl oz) well water amended with either liquid urea or nitric acid.

^xMean separation within each column by Duncan's multiple range test, $P \leq 0.05$.

^yPlants were visually evaluated 92 d after planting based on a scale of 0 to 5 (0 = very poor quality and 5 = excellent quality).

Medium samples were collected from the pot three times 14, 55, and 92 d after the initiation of the experiment. The samples were air-dried, ground and passed through a 2-mm (0.08-inch) sieve. Medium pH and EC were measured.

At harvest (3 months after planting), anthurium plants were visually rated based on a scale of 0 to 5 [0 = very poor quality (small and yellow leaves), and 5 = excellent quality (large, dark green leaves)]. Thereupon the plants were removed from the pots and the roots were washed with water to remove potting medium. The leaves and roots were separated and washed with dilute acid and rinsed with deionized water. Tissue samples were oven-dried at 70 °C (158 °F) for 72 h and weighted. Plant leaf and root samples were analyzed for concentration of N with the Kjeldahl method. All data were analyzed with SAS (SAS Institute, 1996). The analysis of variance (ANOVA) was conducted to check for differences for potting medium pH,

plant biomass, tissue N and plant grade. Means were separated with Duncan's multiple range tests. Linear regression analyses were also performed to determine the effect of urea or nitric acid on medium pH.

Results and discussion

EFFECTS ON IRRIGATION WATER.

The untreated well water used in this study had a high pH (7.8), high concentration of bicarbonate (152 mg·L⁻¹), and an EC of 0.34 dS·m⁻¹ (Table 1). Addition of urea to water did not significantly change water pH or the concentration of bicarbonate, but increased EC values from 0.335 to 0.828 dS·m⁻¹. Nitric acid effectively reduced water pH and the concentration of bicarbonate. The bicarbonate in the irrigation water was completely neutralized with nitric acid greater than 20 mg·L⁻¹ N. Also water pH dramatically decreased from 6.3 to 3.6 as nitric acid increase from 20 to 40 mg·L⁻¹ N.

EFFECTS ON POTTING MEDIUM.

Potting medium pH values measured 14, 55, and 92 d after planting were highly correlated to N rates of urea ($r^2 = 0.79$ to 0.84) and of nitric acid ($r^2 = 0.77$ to 0.78) (Fig. 1). In comparison with control, medium pH irrigated with well water treated by 10 or 20 mg·L⁻¹ N decreased slightly. This decrease was greater as N rates increased from 40 to 120 mg·L⁻¹ N. Medium pH dropped by 0.9 to 1.23 units for the 80 and 120 mg·L⁻¹ N treatments, respectively, as compared to the control 92 d after planting. The lowest medium pH value was found for the treatment of 120 mg·L⁻¹ N with urea in irrigation water. For the irrigation water treated with urea, ammonium (NH₄⁺) was the readily available form of N in the medium as a result of hydrolysis of urea. Soil acidification caused by N fertilizer applied in the NH₄⁺ form has been reported (He et al., 1998; Wallace, 1994). For the irrigation water treated with nitric acid, hydrogen ions (H⁺) were introduced directly to reduce the pH of the potting medium, while, nitrate (NO₃⁻) was the available N form for the plant. The roots would be expected to release hydroxide ions (OH⁻) to compensate for the directly added H⁺. These changes would be expected to keep the medium pH at an acceptable level, provided that the irrigation water pH is not lower than 5.0 at 10 to 40 mg·L⁻¹ N range (Table 1).

The regression equation between N rate and potting medium pH indicated that the medium pH would be kept at 5.5 to 6.5 if the N rates were in the range of 10 to 40 mg·L⁻¹ N in the irrigation water for either nitric acid or urea. However, if the N rate was greater than 80 mg·L⁻¹ N, the medium pH would decrease considerably and the plant may be damaged by the low pH

Table 3. Nitrogen (N) concentrations and N uptake by anthurium plants as influenced by various N rates in irrigation water amended with liquid urea or nitric acid at day 92.

N rate in irrigation water ^z [mg·L ⁻¹ (ppm)]	N concn (g·kg ⁻¹) ^y		N uptake (mg/plant) ^x		
	Leaf	Root	Leaf	Root	Total
0	16.23 d ^w	13.53 e	34.83 b	27.33 b	62.15 b
10	20.40 cb	22.61 d	48.08 ab	49.72 a	97.81 a
20	18.99 c	28.56 c	46.57 ab	66.67 a	113.2 a
40	19.40 c	32.31 c	53.42 ab	68.40 a	121.8 a
80	22.90 b	47.80 b	45.09 ab	63.54 a	108.6 a
120	25.83 a	54.23 a	57.25 a	65.99 a	123.2 a

^zEach pot was irrigated three times a week with 100 mL (3.38 fl oz) well water amended with either liquid urea or nitric acid.

^y1.00 g·kg⁻¹ = 0.100%.

^x1.00 mg = 0.0035 oz.

^wMean separation within each column by Duncan's multiple range test, $P \leq 0.05$.

and by the high osmotic pressure caused by greater EC.

EFFECTS ON THE PLANT DRY WEIGHT AND GRADE. Although N rates had no effect on leaf dry weight, the dry weights of the roots for the 80 and 120 mg·L⁻¹ N treatments were significantly lower than those of the other N rate treatments (Table 2). The weight of total plant biomass with 10 to 40 mg·L⁻¹ N were the highest among the N rate treatments, and were significantly greater than those of the 0, 80, and 120 mg·L⁻¹ N treatments.

Plant appearance was also significantly influenced by the N rates 92 d after planting (Table 2). The highest grade (4.25) was found from the treatment of 20 mg·L⁻¹ N. On the other hand, the grades were significantly lower for 80 and 120 mg·L⁻¹ N and no N treatment. The negative effect of high N level is probably attributed to the high EC of medium (Table 1). The EC values for the medium treated with 80 and 120 mg·L⁻¹ N were much greater than those of medium treated with 10, 20, or 40 mg·L⁻¹ N and the higher values of EC correlated closely with lower plant grades (Table 2). The results clearly suggest that anthurium is very salt sensitive. Indeed, the lower N rates ranging from 10 to 40 mg·L⁻¹ N in the irrigation well water accompanied with lower medium EC values produced better plants than higher N rates. These findings agree with the results reported by Conover and Henny (1995) and Higaki and Poole (1978) that plant grade, total number of flowers, and growth for the anthurium plants decreased as N increased.

EFFECTS OF N RATES ON PLANT N UPTAKE. Concentration of N in the roots and leaves increased significantly with increasing N rates in irrigation water (Table 3). The highest N concentrations in leaves and roots were 25.83 and 54.23 g·kg⁻¹ (2.583 and 5.423%), respectively, with irrigation water treated by 120 mg·L⁻¹ N, while the lowest were those plants irrigated with well water only. N concentrations in roots were higher than in leaf tissues, except in control plants.

The total N uptake by anthurium plants was calculated based on dry weight and N concentration in leaves and roots (Table 3). The amounts of N taken up by the plant were similar among the different N rates, except in the control treatment. Plants in control treatment had lower root dry

weights than in the 80 and 120 mg·L⁻¹ N treatments. These results suggest an increased root N concentration with increased N rates, but reduced root growth rate at the high N level.

In conclusion, this study demonstrates that bicarbonate in irrigation water can be neutralized effectively with nitric acid, and that medium pH decreases with the application of either urea or nitric acid. An optimal N rate in irrigation water was essential for the growth and plant appearance of anthurium. On the other hand, excessive levels of N combined with low medium pH reduce anthurium growth and quality of appearance. The results also suggest that anthurium appear to be salt sensitive when treated with irrigation water containing high level of fertilizers. This study demonstrated that for both best plant appearance and maintaining optimal medium pH, the N rate of 20 mg·L⁻¹ N with electrical conductivity of 0.3 to 0.42 dS·m⁻¹ in irrigation water is needed.

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Growth of 'Cunningham's White' Rhododendron in Plastic and Fiber Pots Treated With Copper Hydroxide

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ADDITIONAL INDEX WORDS. container production, SpinOut, root growth regulation, soil temperature, transplanting

SUMMARY. Shoot and root growth responses of 'Cunningham's White' rhododendron (*Rhododendron x*) was studied when grown in black plastic or molded fiber pots treated with copper hydroxide, or not treated. Containers of two sizes were studied, and the influence of pot type on substrate temperature was recorded. Rhododendron shoot height and dry weight was not influenced by pot volume, pot type, or copper treatment at 49, 131, or 362 d after potting. Rhododendron shoots were larger when grown in 3.8-L (trade 2-gal) pots compared to 2.8-L (trade 1-gal) pots, or when grown in 3.8-L fiber pots compared to 3.8-L plastic pots, both 131 and 362 d after potting. Copper treatment did not influence shoot size. Copper treatment reduced the amount of circling or matted roots at the container-substrate interface for both plastic and fiber pots, but there was better control of root growth in 3.8-L pots compared to 2.8-L pots. Substrate average minimum temperatures were warmer, and average maximum temperatures were cooler when pots were located near the center of the growing block compared to the southwest corner of

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