Effects of Ammonium to Nitrate Ratios on Substrate pH Shifts during Growth of *Calibrachoa* with Alkaline Water©

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INTRODUCTION

Calibrachoa is considered an iron inefficient plant that commonly has problems with iron deficiency (Wik et al., 2006) (Fig. 1). Iron becomes less available to the plant as substrate pH increases. Deficiency is most commonly the result of high substrate pH, rather than undersupply of the nutrient. Monitoring and controlling substrate pH will prevent the majority of nutritional problems during crop production. Avoiding these problems will increase crop quality. The composition of fertilizer can cause substrate pH to decrease or increase and the direction of the shift is controlled primarily by the form of nitrogen. Nitrogen is the most important pH controlling ion because it is the only element required by plants that can be supplied as both a positive cation (ammonium: NH_4^+) or a negative anion (nitrate: NO_3^-) and accounts for more than half of the nutrient ions taken up by plant roots. Fertilizers high in NH_4^+ have an acidifying effect and cause substrate pH to decrease and the opposite is true for fertilizers high in NO_3^-. When NH_4^+ (or other positive cations) is taken up by the plant a positive charge enters the root. Plants must remain electrochemically neutral and thus the root secretes a positively charged H^+, which reduces the pH (Fig. 2). When NO_3^- (or other negative anions) is absorbed, the root balance the negative charge by absorbing H^+. As more NO_3^- is absorbed, more H^+ is removed from the soil solution and the substrate pH increases (Fig. 3). The purpose of this experiment was to determine the ammonium to nitrate ratio that would hold substrate pH constant for *Calibrachoa* grown with deionized water and tap water containing excessive alkalinity.

Fig. 1. Iron deficiency on *Calibrachoa* expressed as interveinal and complete chlorosis of the youngest leaves (Photo courtesy of Dr. Brian Whipker, North Carolina State University).

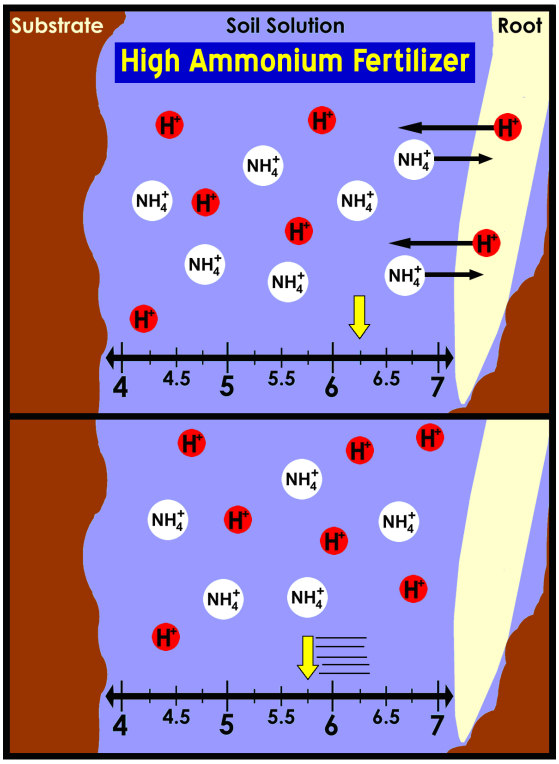

Fig. 2. Uptake of ammonium fertilizer causes substrate pH to decrease.

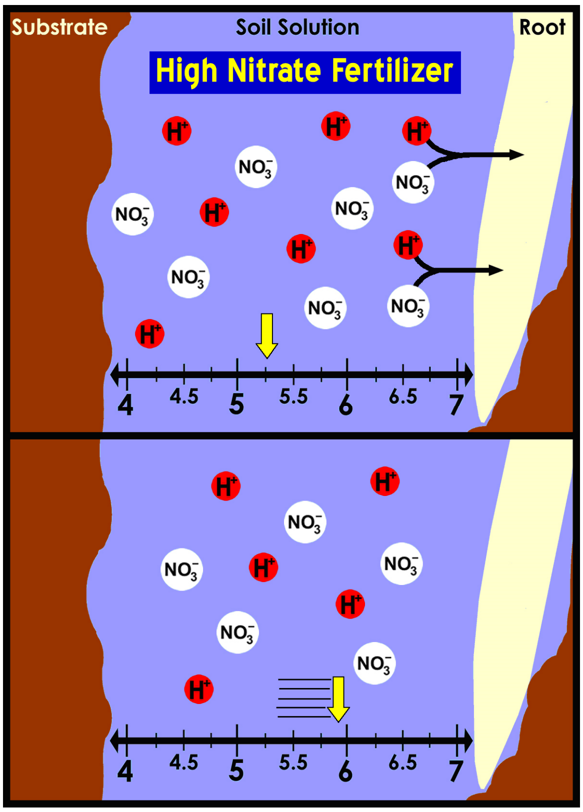

Fig. 3. Uptake of nitrate fertilizer causes substrate pH to increase.

MATERIALS AND METHODS

Calibrachoa hybrid 'Superbells Royal Blue' plants were grown in 3-L pots, with 3 plants per pot for 10 weeks starting 3 March 2008. Plants were grown in a glass covered greenhouse at Weihestephan University in Freising, Germany. The substrate was peat moss amended with dolomitic limestone to a pH of 5.4 and plants were sub-irrigated as needed. There were two irrigation treatments (deionized and tap with 0 and 300 ppm calcium carbonate equivalent, respectively) and 5 fertilizer treatments with ammonium to nitrate ratios of 90:10, 70:30, 50:50, 30:70, and 10:90 with four replications. Starting 2 weeks after planting, plants were fertilized at each irrigation with a complete fertilizer that contained 100 ppm N, 28 ppm P_2O_5, 76 ppm K_2O, and micronutrients. Starting 6 weeks after planting, plants were fertilized 2 times per week at 3 times the above rate. The greenhouse was heated when the day/night temperature fell to 16/15°C and ventilated when the temperature reached 20°C. Substrate pH was determined every 2 weeks by calcium chloride substrate extraction.

RESULTS AND DISCUSSION

When plants were grown with deionized water, substrate pH decreased over time regardless of fertilizer treatment (Fig. 4). The two fertilizer treatments with the highest amounts of ammonium had the lowest end-of-crop substrate pH and as the amount of ammonium in the fertilizer decreased, end-of-crop substrate pH increased. Plant roots and associated microorganisms are continually releasing carbon dioxide (CO_2) as a byproduct of respiration. CO_2 combines with water in the soil solution to form carbonic acid, which lowers substrate pH. If there is not an alkaline force, such as bicarbonate in the water, pH will decline. As discussed above, high nitrate fertilizers should cause pH to increase, but when irrigating with deionized water in this experiment, high nitrate merely reduced the rate of acidification.

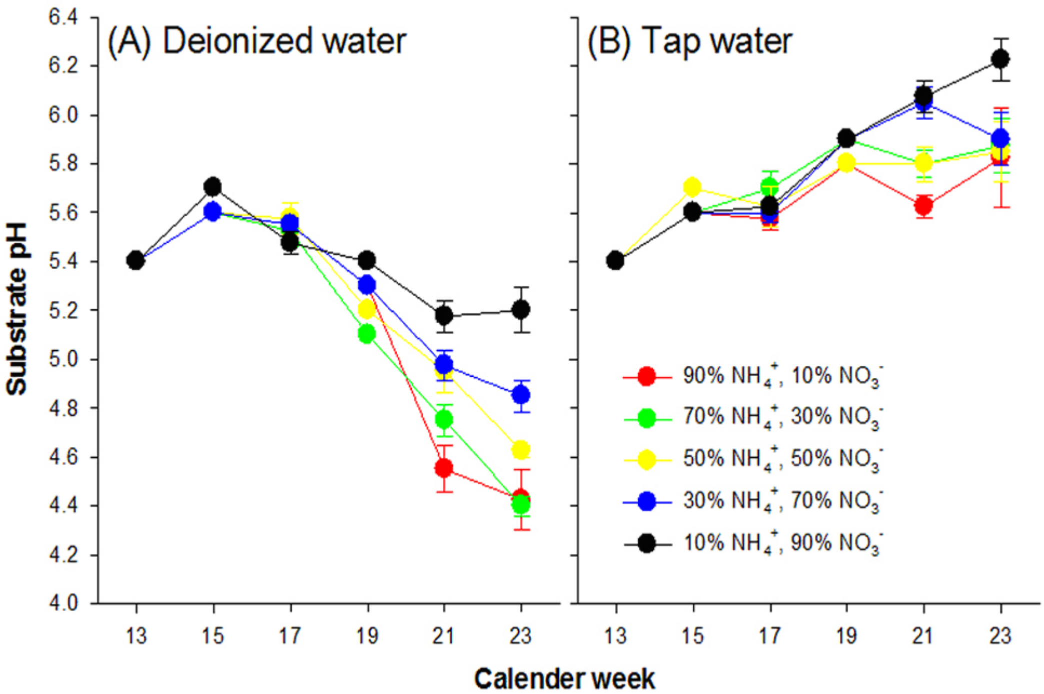

Fig. 4. The effect of various ammonium to nitrate ratios in fertilizer on substrate pH of *Calibrachoa* grown for 10 weeks with deionized water (A) and tap water with 300 ppm calcium carbonate equivalent (B). Error bars represent standard error.

When plants were grown with highly alkaline tap water, the opposite occurred and substrate pH increased over time, regardless of fertilizer treatment (Fig. 3). Fertilizer treatment did not have as strong of an effect on end-of-crop substrate pH as with deionized water. Only when plants were fertilized with 90% nitrate was the end-of-crop substrate pH significantly different. These results indicated that the bicarbonate in the water is the primary factor controlling the change in substrate pH. One bicarbonate ion (HCO_3^-) added to the soil solution with irrigation water will neutralize one H^+ ion (Reaction 1). Reaction 2 shows that the carbonic acid is then converted to H_2O and CO_2.

This is the opposite of what was discussed above where CO_2 and H_2O react to form carbonic acid. With high amounts of bicarbonate in the system the reactions will be pushed to the right and acid will be neutralized. This is a similar process whereby limestone neutralizes H^+. Thus, addition of bicarbonate is equivalent to the addition of limestone.

Reaction 1: $H^+ + HCO_3^-$ (bicarbonate) $\rightarrow H_2CO_3$ (carbonic acid) [H^+ neutralized]
Reaction 2: $H_2CO_3 \rightarrow H_2O$ (water) + CO_2 (carbon dioxide)

There was no significant effect of irrigation or fertilizer treatment on plant mass or crop quality. The recommended substrate pH for *Calibrachoa* is 5.0-5.5. Although pH levels in this experiment were above this range, iron deficiency was not observed. It may be possible that the regular application of iron in the fertilizer prevented this from occurring.

The results of this experiment indicate when water is completely devoid of alkalinity, substrate pH may decline regardless of the fertilizer composition. With the 90% nitrate treatment, pH only fell 0.2 units. This indicates it may be possible to hold calibrachoa substrate pH stable if the nitrate percent is greater than 90% and the water has zero alkalinity. With water alkalinity at 300 ppm calcium carbonate equivalent, substrate pH increased over time regardless of fertilizer composition. Water with this level of alkalinity is not recommended for crop production and should be blended with rain water or another source to reduce the hardness. If this is not possible, high ammonium fertilizers may not be able to counter act the increase in substrate pH. In addition, fertilizers with excessively high ammonium can reduced growth and increase the incidence of ammonium toxicity (Nelson and Hsieh, 1971).

Many factors influence substrate pH. When attempting to maintain substrate pH within an acceptable range one must consider the type of substrate used, rate of plant growth, species of plant, limestone, water alkalinity, fertilizer, and environmental conditions. The results of this study do not indicate a particular ammonium to nitrate ratio for holding *Calibrachoa* substrate pH stable. Growers should continually monitor substrate pH in order to make pH corrections when needed. This will prevent tedious large pH adjustments, improve crop quality, and increase profits.

ACKNOWLEDGEMENT
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Literature Cited

Nelson, P. and Hsieh, K. 1971. Ammonium toxicity in chrysanthemum: critical level and symptoms. Com. In Soil Sci. and Plant Analysis 2:439-448.

Wik, R., Fisher, P.R., Kopsell, D.A. and Argo, W.R. 2006. Iron form and concentration affect nutrition of container-grown *Pelargonium* and *Calibrachoa*. HortScience 41:244-251.