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Research note

Response of hydroponically grown tomato and solution acidity to ammonium as a nutrient solution

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Abstract

Impaired growth and yield restrictions have been reported as a result of using ammonium as sole or dominating N source of nitrogen. To study the effects of different ammonium supply on growth of tomato plants and changes in pH of the soilless solution, a greenhouse experiment was conducted in a Randomized Complete Block Design with seven ammonium concentrations (0, 6, 12, 25, 50, 75, 100%) replicated three times in 2011. Fresh weights of roots and shoots as well as pH of the solutions were measured in this study. The results of the experiment indicated that increasing the ammonium concentration in the soilless solution was detrimental to the tomato plants. The highest shoot and root fresh weights were obtained from the 0 and 6% ammonium concentration followed by normal pH changes in their concentrations showing that there was no destructive damage to tomato plants, unlike high amount of ammonium. These results were supported by the visual observations recorded during the experiment. Results of this study suggests that to maintain a normal pH at the root zone and to prevent detrimental damages to the tomato plants, ammonium concentrations should be kept in a low level.

Key words: Ammonium, Hydroponic, Nitrogen, Solution acidity, Tomato yield.

Introduction

Plant growth and yield in either soil-based or soilless grown crops can be influenced by the form of supplied nitrogen. (Forde and Clarkson, 1999; Savvas et al., 2003). Impaired growth and yield restrictions have been reported as a result of using ammonium as sole or dominating N source of nitrogen (Findenegg, 1987; Guo et al., 2002; Sonneveld, 2002). Under such conditions, N is mainly taken up as NH_4^+ rather than NO_3^- (Forde and Clarkson, 1999; Fageria, 2005). However, the intensive uptake of NH_4^+ may increase the intracellular concentration of ammonia, which is highly toxic the plant cells (Givan, 1979; Taiz and Zeiger, 1991; Marschner, 1995). It is very important to maintain the ion charge balance of the solution due to the consequences of pH regulation and carbohydrate turnover. It is reported that maintenance is easier in soilless solutions due to higher control and reduce the transplanting shock (McDonald, 2005; Navindra et al., 2011). To detoxify excess NH_4^+, higher demand of carbon skeletons may also exert an adverse effect on plant growth when NH_4^+ is rapidly taken up (Beevers and Hageman, 1983; Mengel and Kirkby, 1987; Savvas et al., 2003). When external NH_4^+ is not kept at a low, suboptimal level, predominant N uptake in a cationic form, suppresses the total anion uptake and this action is balanced by excessive H^+ release from the root cells (Kirkby and Knight, 1977; Magalhaes and Wilcox, 1983; Lea-Cox et al., 1996). The pH in the root environment, as a result, may drop to levels that are detrimental for most plant species (Stensvand and Gislerød, 1992; Lang and Kaiser, 1994). In soil, the presence of ammonium in the root environment may further depress pH due to release of H^+ originating from the nitrification process, particularly the oxidation of NH_4^+ to NO_2^-, which is carried on by *Nitrosomonas* sp. and several other genera of nitrifying bacteria (Delwiche, 1983; Bolan et al., 1991). Besides, the nitrification reaction requires O_2 (Lin et al., 2009). Therefore, high concentration of ammonium stimulates intensive nitrification leading to suppression of root growth as a lack of O_2 presence which restricts root respiration. Nevertheless, it has been observed that low ammonium concentration stimulates growth and enhances crop yield (Bloom et al., 1993; Sonneveld, 2002). A main tool to balance the total cation to anion uptake ratio, thus maintaining pH within the desired range in the root zone is to allocate the total N supply into the anionic and cationic nitrogen forms. The supply of a minor part of N in form of NH_4^+ has become a standard practice in soilless culture enabling regulation of pH in the root zone of the plants (Lea-Cox et al., 1999; Bar-Tal et al., 2001; Sonneveld, 2002). To prevent crops from being damaged by pH alteration as a result of using nitrogen sources in a soilless culture, specific knowledge arising from experimental work is required for each particular crop concerning its response to the regulation of pH in the root zone via ammonium supply and pH of the delivered nutrient solution. In this study, the effects of different ammonium supply on growth of tomato plants and changes in pH were investigated.

Results and Discussion

There was a significant difference among shoots of tomato plants influenced by varying %N as NH_4^+ (Figure 1). The highest shoot biomass was observed in 0% N as ammonium whereas the lowest one was obtained from the 100% N as

Table 1. Formulation of nutrient solutions with varying amounts of ammonium-N in a full-strength solution supplying 210 mg N/liter.

Salt	Percent of N supplied as ammonium-N						
	0	6	12	25	50	75	100
	ml of 0.5 M stock solutions (rounded to 0.1)						
$Ca(NO_3)_2$	10	9.1	8.1	6.2	2.5	0	0
KNO_3	10	10	10	10	10	7.5	0
$(NH_4)2SO_4$	0	0.9	1.9	3.8	7.5	11.3	15
KH_2PO_4	2	2	2	2	2	2	2
$MgSO_4$	4	4	4	4	4	4	4
KCL	0	0	0	0	0	2.5	10
$CaCl_2$	0	0.9	1.9	3.8	7.5	10	10
Minor	1	1	1	1	1	1	1
Iron	1	1	1	1	1	1	1

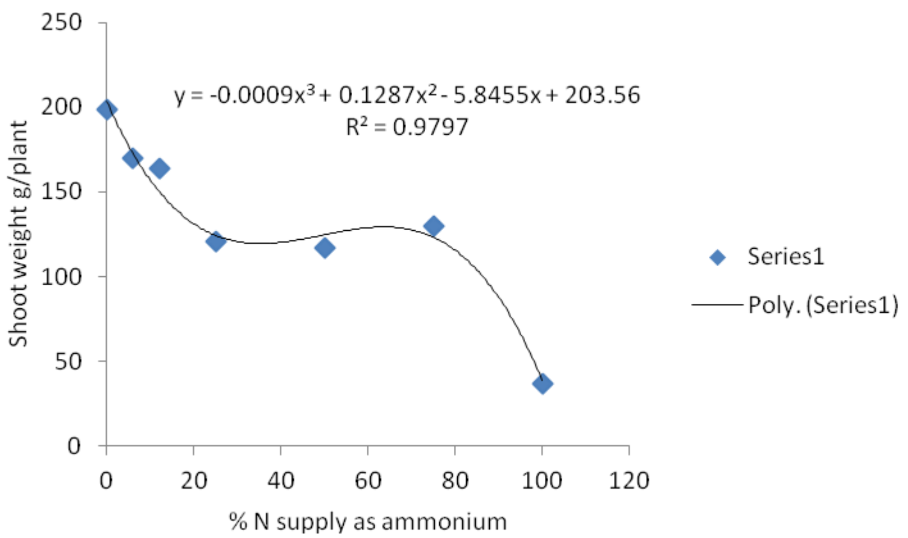

Fig 1. Shoot biomass of tomato plants in nutrient solutions with varying proportions of ammonium nitrogen.

NH_4^+ showing 81% reduction in the aboveground biomass. As the percent of nitrogen in a form of NH_4^+ increased, the shoots decreased linearly. The exception was ammonium at 75% which was higher than 50 and 25. Root biomass of tomato plants was significantly different as affected by various proportion of ammonium (Figure 2). The similar trend was observed among roots biomass as was for shoots biomass. Root biomass decreased linearly as %N increased, and the highest root biomass was recorded from %6 N as NH_4^+ which had no significant difference with %0 N. Shoot/root ratio, unlike shoot and root biomass, did not decrease linearly but quartically (Figure 3) which was due to decrease of shoot/root ratio at 100% ammonium. Overall at 100 % ammonium both shoot and root growth suppression were drastic. It is reported that N is mainly taken up as NH_4^+ rather than NO_3^- (Forde and Clarkson, 1999). The intensive uptake of NH_4^+ may increase the intracellular concentration of ammonia, which is highly toxic the plant cells (Givan, 1979; Taiz and Zeiger, 1991; Marschner, 1995). Visual observation supported the results of this experiment. Tomato plants looked normal at 0 and 6% ammonium whereas, at 100% ammonium, they looked dark, wilted and with advanced maturity senescence of the lower leaves and then of the whole plant was observed. Differences among 12, 25, 50 and 75% ammonium were not quite obvious and tomato plants almost looked the same at these concentrations. Acidity of the nutrient solution increased linearly with the increase of ammonium percentage in the solution in the first two weeks (Table 1). However; there was a cubic relationship between percent ammonium and nutrient solution pH. Increase in the acidity of nutrient solution due to increase in percent ammonium, could be the cause of shoot and root biomass reduction (Figures 4 and 5). High acidic solution as a result of high (100%) ammonium concentration reduced the shoot and root biomass 81 and 63%, respectively. Positive effects of ammonium on plant growth have been observed at low ammonium concentrations (Bloom et al., 1993; Lang and Kaiser, 1994). However, when the ammonium concentration exceeds 1 mM, ammonium may impair growth (Haynes and Goh, 1978). This action; however, is species dependent and each species will respond differently. The results of this study confirmed that tomato plants are prone to high ammonium concentration in the solution which acidified the soilless culture leading to above and below-ground biomass reduction.

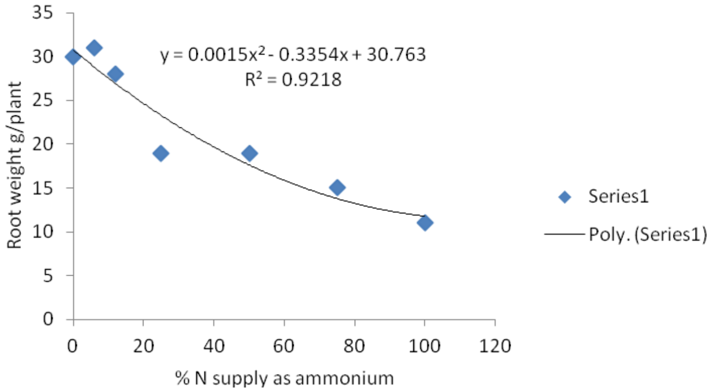

Fig 2. Root biomass of tomato plants in nutrient solutions with varying proportions of ammonium nitrogen.

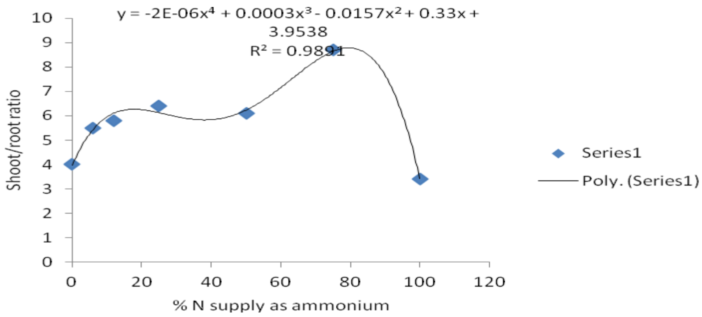

Fig 3. Shoot/root ratio of tomato plants in nutrient solutions with varying proportions of ammonium nitrogen.

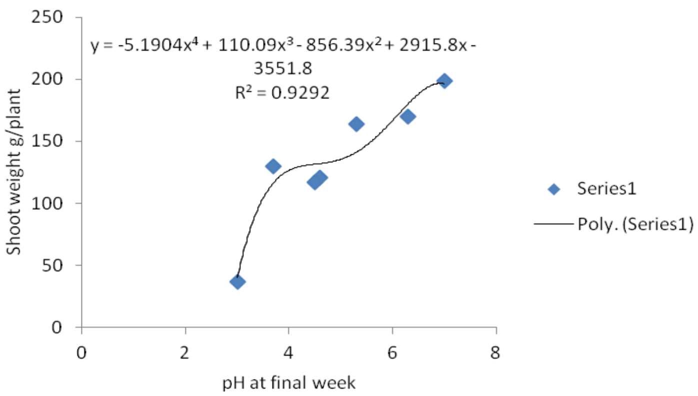

Fig 4. Effect of solution acidity on shoot biomass of tomato plants.

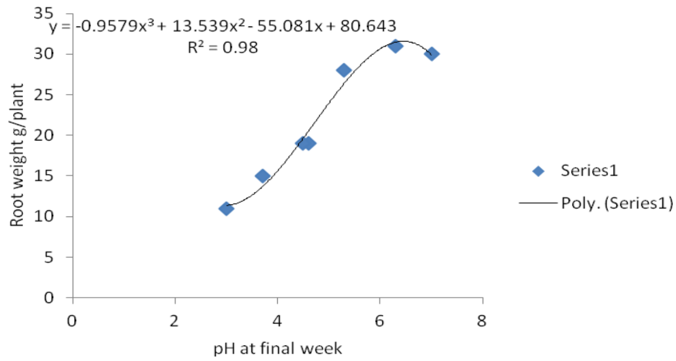

Fig 5. Effect of solution acidity on root biomass of tomato plants.

Material and methods

Tomato seedlings were transferred to hydroponics vessels, and were grown for 1 week on Hoagland's solution (100% NO_3^-). Seven ammonium nitrogen treatments (0, 6, 12, 25, 50, 75, and 100% of the total N supply) were arranged in a Randomized Complete Block Design with three replications in October 3rd 2011. After one week, 10 to 20 liters of each nutrient solution were formulated as shown in table 1. Hoagland's solution in each vessel was replaced with the new solutions so that plants received each of the solutions with varying amounts of NO_3^- and NH_4^+. Initial pH of the solutions was measured and weekly pH measurements were continued up to the third week (October 24th). Nutrient solutions were added to the vessels as the water was absorbed by the plants. Plants were harvested when the ones in 100% NH_4^+ solutions were near death or in severe decline in health on October 24th and fresh weights of shoot and root were weighed and recorded. During the experiment, plants were observed to record possible symptoms of deficiency.

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