The Effects of Sodium Chloride (NaCl) Solution on the Growth of Tomato Plants (*Lycopersicon esculentum*)

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Abstract

The objective of our experiment was to determine how different concentrations of a solution of sodium chloride affect primary growth in tomato plants *(Lycopersicon esculentum).* Three experimental tomato plant groups were watered once a week with 23.00%, 11.50%, and 5.75% concentrations of sodium chloride solutions and one control group received water only. The plants were watered enough to keep them moist. The height of each plant was measured from its base to the apical meristem every seven days. The pH of the soil for each group of plants was determined at the beginning and conclusion of the experiment to determine if the sodium chloride affected the soil.

The results indicated that sodium chloride solution inhibits the primary growth of tomato plants. The results that supported our conclusion were a greater amount of growth in the control group, and the more primary growth occurred on the experimental groups that received lower concentrations of sodium chloride solution. The experimental group that had the greatest amount of primary growth was the group watered with the 5.75% concentration of solution. The other two experimental groups died after the first sodium chloride treatment. Future recommended experiments include decreasing salt solutions to levels that plants can still remain viable and using grafted plants to enhance salt tolerance such as those used in Fernandez-Garcia (2004) experiment on fruit quality grown under saline conditions.

Introduction

Soil salinity can often be increased by the use of sodium chloride for winter management control of icy roads particularly in the spring when snow and ice melt. Once the ice melts the sodium chloride becomes part of the run off and affects vegetation in the surrounding areas. The interaction between salinity, nutrition, and crop yield is a major concern in improving crop production (Flores, et al. 2001). Another study analyzing the effects of roadside salinity showed one-fifth of irrigated agriculture is adversely affected by soil salinity (Chinnusamy, et al, 2005).

A study of woody vegetation along Minnesota Roads showed adverse effects of salt solution runoff (Sucoff, 1975). Sodium chloride is used in parts of the United States such as Minnesota, Wisconsin, and Michigan to de-ice roads (National Research Council (USA), 1991). The solution is the preferred product by departments of transportation because sodium chloride is readily available and inexpensive (National Research Council (USA), 1991). A brine solution with a ratio of 23% salt to 77% water per volume is the industry standard, which creates a lower freezing temperature on the roads than surrounding ice and snow (National Research Council (USA), 1991). Brine solutions with less than 23% salt content can refreeze (National Research Council (USA), 1991). Our question was how different concentrations of sodium chloride affect growth of tomato plants.

We predict that high concentrations of sodium chloride will inhibit the growth of tomato plants. Since Flores, et al. (2001) found that salt stress inhibits the uptake and transport of potassium, calcium, and phosphorus, we predict that sodium chloride will inhibit growth in our tomato plants. A study conducted by Chinnusamy, et al. (2005) on improving salt tolerance in plants found salt stress can also cause oxidative damage to membrane lipids, proteins, and nucleic acids. Although an experiment by Verdez, and Menendez, (2001) showed that tomato plants can tolerate high levels of salt, excessive concentrations were shown to have detrimental effects on the plants. To test our predictions, tomato plants will be grown in a greenhouse and watered with different concentrations of salt and water solutions to observe the effects on plant growth. In support of our hypothesis we expect to observe plants watered with a salt solution mixture to measure smaller than a control group of tomato plants receiving only water. If the measured height of the plants receiving salt solution is higher than the control group, then our hypothesis will be negated.

Materials and Methods

To test the effects of salt on tomato plant (*Lycopersicon esculentum)* growth, sixteen tomato plants of similar height in 5.08 cm pots were divided into four groups. The acidity of the soil in each pot was measured using a Hellige-Truog Soil Reaction (pH) testing kit. Following the manufacturer's instructions, two drops of Reagent No 697-27 were added to testing dish and soil from each pot was placed on top of the reagent. One drop of Triplex Indicator No 697-24 was added to the test plate and then soil color was compared to color pH scale provided by the test kit.

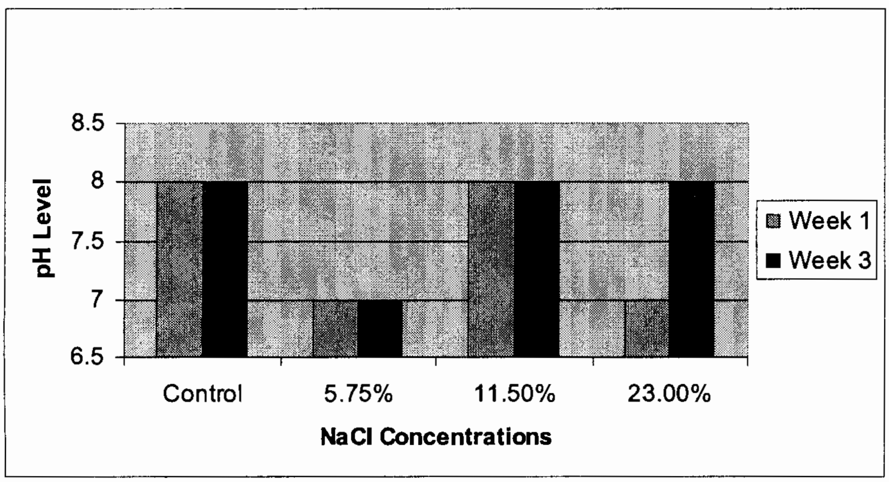
The control group containing four plants received only water. Of the experimental groups, the first group was watered only with the 23% salt solution. To simulate dilution caused by snow, ice, and rain as described by the National Research Council (1991), the next group received 11.5% of the salt solution treatment once a week. The last group received 5.75% of the salt solution. For three weeks the plants were watered to keep moist and every seven days were measured from base of stem to apical meristem.

A stock 23% solution of sodium chloride was prepared. From this stock solution, an 11.5% solution was made by mixing water and the stock solution in a 1:1 proportion of water to solution. The 5.75% solution was prepared by the same method using a 3:1 proportion.

Results

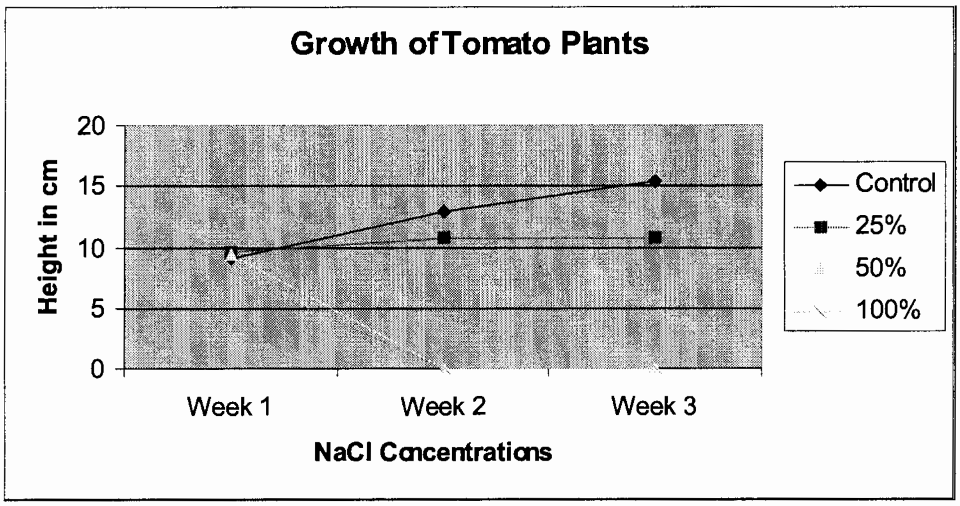
The soils of the control group and the 11.5% concentration group started with a pH level of 8, which is alkaline and ended with a pH level of 8 (see Figure 1). The soil of the plants receiving 5.75% concentration began with a pH level of 7, which is neutral and ended at a pH level of 7 (see Figure 1). The soil of the plants receiving 23% concentration began with a pH level of 7 and at the end of the experiment was at a pH level of 8 (see Figure 1).

Figure 1. Measured pH of Soil of Tomato Plants for Week 1 and Week 3



The control group showed increasing growth each week as shown in Figure 2. The 5.75% NaCl concentration group showed substantially less growth compared to the control group after the first week (see Figure 2). The second and third week showed no substantial growth. For the higher concentrations of 11.5% and 23% the plants died after the first NaCl watering.

Figure 2 Salt Solution Effects on Growth of Tomato Plants



Discussion

As predicted in our hypothesis, overall growth of plants receiving salt solution was less than the control group. Figure 2 shows the overall growth of the control group of tomato plants with an increase of 6 cm, while plants receiving 5.75% of the solution showed only an overall increase in height 3 cm. Two of the experimental groups receiving over 5.75% solution, were flaccid at day two, and were unable to recover to a turgid state with subsequent watering. Chinnusamy, et al. (2005) suggest the turgor loss of these plants is caused by osmotic stress that is a result of a decrease in water potential due to soil salinity. Death of group's 11.5% and 23% maybe attributed to a salt affected soil, creating the high concentrations of ions, particularly Na+, resulting in cytoplasmic toxicity (Ashraf, 2004). In another study Flores et al. (2001) found salinity exposure affects the transport process in the plant which can alter the nutritional status and tissue ion balance that lower plant growth. The complete loss of tugor pressure in our experimental groups supports our hypothesis that high concentrations of salt solutions adversely affect the growth of tomato plants. Limited growth achieved in the 5.75% group compared to the control group supports our hypothesis. From this we can also conclude that tomato plants can tolerate salinity at certain concentrations.

Soil pH values were measured to evaluate if salt concentration had an effect on the soil. Cation exchange and chemical form of minerals are affected by pH levels (Campbell and Reece, 2002). Changing hydrogen ion concentrations makes some minerals more available to the plant while hindering other minerals (Campbell and Reece, 2002). Under excessive saline conditions plants take up high amounts of Na+ while uptake of K+ and Ca^{2+} is significantly reduced (Ashraf, et al. 2004). Calcium plays a crucial role in maintaining the structural and functional integrity of plant membranes and has significant roles in cell wall stabilization, regulation of ion transport and selectivity and activation of cell wall enzymes (Asharf, et al. 2004). As Figure 1 shows, pH levels of the control and two experimental groups did not change. The 23% concentration group of plants became more alkaline. This switch in pH values may be attributed to human observation as two different people observed the pH chart rating according to color.

Further experiments could be conducted using salt solutions between 5.75-11.5% concentrations to evaluate at what average concentration reduces tomato plants to an unrecoverable flaccid state. Other experiments could test different solutions to relieve salt stress on plants. In a greenhouse experiment, misting tomato plants improved the yield three to four times higher than control group plants (Romero-Aranda, et al. 2002).

Grafting tomato plants could also increase tomato plant tolerance to salt stress. In a study of effects of salinity on growth, mineral composition, and water relations of grafted tomato plants, plants that were grafted had an increased resistance to drought and an enhanced nutrient uptake (Fernandez-Garcia, et al. 2004). Salt tolerance in plants is usually associated with the ability to restrict the uptake and transport of saline ions from roots to shoots (Fernandez-Garcia, et al. 2004).

Results of this experiment indicate support that different salt concentrations can hinder the growth of tomato plants. Since salt solutions are an industry standard, specific tomato crops can be selected according to location and salinity content of soil.

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