A study was conducted in order to quantify root growth effects of Ca\(^{2+}\) and Al\(^{3+}\) in hydroponic solutions containing root-damaging aluminum on plants of tall fescue (Festuca arundinacea) seedlings. An incomplete factorial experiment was performed in a growth chamber using seven pots containing level of Ca from 0-70 µmol with levels of Al from 0-5000 µmol. Tall fescue seedlings were grown for 7-14 days. All seedlings were then harvested, dried, and weighed for treatment comparisons. Total root length was calculated as digitalized scanning was highly correlated with root mass due to root-diameter uniformity in hydroponic solutions. Slight but statistically significant difference existed between varieties in Al toxicity at low Al concentrations. All varieties showed less than 10% relative root growth in 27 µmol Al and higher concentrations, in the absence of Ca. An increase in Ca\(^{2+}\) and Al\(^{3+}\) at a given concentration of Al provides a protective effect from Al toxicity. The increased root growth, the greatest relative root growth to increased Ca levels occurred at Al levels of 27 and 74 µmol. Relative root growth increased from around 30% to 42% in Ca at the increased from 0 to 10 µmol. A simple logistic model adequately described the effects of Al and Ca on root growth and may be used as a predictor of the quantity of gypsum needed to increase Al toxicity in acid substrates. Model goodness of fit using non-linear regression was R\(^2\) = 0.86, 0.85, and 0.80 for the three varieties.

**Abstract**

Introduction

And soils entrapped plant growth primarily due to total Al levels and fescue species have different levels of tolerance to Al, and also show differences between varieties of the same species (Lu, 2002). The growth response to plants growing in acidic, Al-rich solutions as the addition of Ca to a solution culture increases the toxic strength of the solution and affects plants of fescue species (Pranata et al., 1986). The model was useful in modeling the response of living organisms to increasingly toxic doses of a substrate. Researchers have successfully utilized the logistic models to evaluate responses in environmental factors (Parzio and Eagles, 1993) to identify the influence of Al concentrations on Al toxicity.

Methods and Materials

The hydroponic systems were constructed using an incomplete factorial design. One container was filled with stainless steel mesh and was pumped with deionized water that was suspended at the root of the plant. The Three varieties of tall type tall fescue (Festuca arundinacea) - Dynasty, Oriental, and Dynasty, were selected. Each pot received 1.0 g of a single variety. Plants were filled with the controlled amount of solution at 10 days after germination. The seedlings were grown to 10 days after germination, and the solution was renewed. The soilless hydroponic solutions were grown in KNO\(_3\)-K2SO\(_4\) solutions at 6.37, 7.2, and 10.45 mol/L of 1 mol/L, respectively. All solutions were brought to 45 µmol Ca by the addition of CaCl\(_2\), 0.1 mol/L, and the pH level was held at 4.5. The concentration of Al was maintained in the hydroponic culture at 0, 0.1, 1, and 10 µmol/L. The addition of Ca to the hydroponic culture increased the toxic strength of the solution and affected the growth of all varieties. All treatments were analyzed using a factorial design. In order to estimate a Ca-enriched hydroponic requirement to reach 50% root growth recovery for a given variety of Al, a 100% root growth response was found to be the optimal level of Al. A simple logistic model was used to evaluate each variety of fescue species. In the present study, the remaining portion of the equation models the predicted growth curve for each variety as a function of Ca and Al. 

**Discussion and Results**

**Abstract**

A study was conducted in order to quantify root growth effects of Ca\(^{2+}\) and Al\(^{3+}\) in hydroponic solutions containing root-damaging aluminum on plants of tall fescue (Festuca arundinacea) seedlings. An incomplete factorial experiment was performed in a growth chamber using seven pots containing level of Ca from 0-70 µmol with levels of Al from 0-5000 µmol. Tall fescue seedlings were grown for 7-14 days. All seedlings were then harvested, dried, and weighed for treatment comparisons. Total root length was calculated as digitalized scanning was highly correlated with root mass due to root-diameter uniformity in hydroponic solutions. Slight but statistically significant difference existed between varieties in Al toxicity at low Al concentrations. All varieties showed less than 10% relative root growth in 27 µmol Al and higher concentrations, in the absence of Ca. An increase in Ca\(^{2+}\) and Al\(^{3+}\) at a given concentration of Al provides a protective effect from Al toxicity. The increased root growth, the greatest relative root growth to increased Ca levels occurred at Al levels of 27 and 74 µmol. Relative root growth increased from around 30% to 42% in Ca at the increased from 0 to 10 µmol. A simple logistic model adequately described the effects of Al and Ca on root growth and may be used as a predictor of the quantity of gypsum needed to increase Al toxicity in acid substrates. Model goodness of fit using non-linear regression was R\(^2\) = 0.86, 0.85, and 0.80 for the three varieties.

**Results and Discussion**

The simple logistic model demonstrated adequate goodness of fit for all the varieties (Table 2; Figure 6). The addition of Ca to Al-containing solutions had a significant impact on root growth as increasing Ca increased relative root growth for plants growing in acidic, Al-rich solutions as the addition of Ca to a solution culture increases the toxic strength of the solution and affects plants of fescue species (Pranata et al., 1986). The model was useful in modeling the response of living organisms to increasingly toxic doses of a substrate. Researchers have successfully utilized the logistic models to evaluate responses in environmental factors (Parzio and Eagles, 1993) to identify the influence of Al concentrations on Al toxicity.