EFFECTS OF SILICATE SUPPLEMENTATION ON GROWTH AND SILICON ACCUMULATION IN TALL FESCUE (*Festuca arundinacea*) AND BENTGRASS (*Agrostis stolonifera*)

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ABSTRACT

We assessed the effect of silicon supplementation on biomass production and Si accumulation of tall fescue (*Festuca arundinacea*) and bentgrass (*Agrostis stolonifera*). Plants were grown in buffered Hoagland's media (pH 6) with four Na_2SiO_4 treatments (0, 0.5, 1, 2, 4 mM). The two species responded very differently to Si supplementation in terms of biomass. In bentgrass, biomass was enhanced by Si supplementation, but only significantly ($p < 0.05$) at the highest concentration (4 mM Si). Lower Si concentrations (0.5, 1 and 2 mM) significantly increased biomass in tall fescue, but there was no increase in biomass from 0.5 mM to 2 mM. We also analyzed tissue for Si concentrations after six weeks of growth using inductively coupled plasma optical emission spectrometry (ICP-OES). There was a positive linear relationship between Si concentration in media and Si concentrations in tissue. At 4mM Si, the Si concentrations in aboveground tissue of tall fescue and bentgrass averaged 24 and 30.5 g/kg dry mass, respectively. Epifluorescence microscopy of combusted leaf tissue showed that elevated silicon concentrations in growth media promoted formation of silica bodies. The highest Si rates (4 mM Si) resulted in the highest silica body areal coverage in leaves of both grasses. We observed two silica body morphologies (which we termed long and barbed). No silica bodies were observed in the 0 mM Si treatment for either species. These findings clearly indicate that in addition to being essential for Si body formation, supplying dissolved Si promotes growth of tall fescue and bentgrass. Typical natural background dissolved Si concentrations rarely exceed 0.6 mM. Our findings indicate that tall fescue is likely to benefit from Si supplementation when soil pore water dissolved Si is below 0.5 mM, but increases above this concentration are unlikely to increase biomass. In contrast, benefits in bentgrass may only be realized if dissolved Si in pore water is increased to 4 mM.

INTRODUCTION

Silicon (Si) is considered as a non-essential nutrient in agronomy, while plants take up significant amount of Si from soil every year (Guntzer, Keller, and Meunier, 2012). Soil contains 5-40% silicon by weight, primarily as silicon dioxide (Teixeira, Tokuda, and Yoko, 2009) and aluminosilicate minerals. However, Silicon is one of the most abundant elements in the Earth's crust (Fauteux et al., 2005). Soil solution only contains 0.1- 0.6 mmol/L of silicic acid, which is the dissolution product resulting from silicate mineral weathering (Orlov, 1985).

Plants take up Si in the form as silicic acid through rejective, passive, or active pathways depending on species (Mitani and Ma, 2005). Older tissues contain more Si than younger tissues (Blackman, 1968; Jones and Handreck, 1967; Sangster, 1970). Silicon can transport to different plant parts then plant silicification happens. Silicification occurs in cell walls, cell lumens, and intercellular spaces (Kumar, Soukup, and Elbaum, 2017). The Si deposits are called silica bodies (Sangster, 1970). Silica bodies appear as different sizes and shapes depending on plant species, and some of them perform green autofluorescence under fluorescence microscopy (Dabney et al., 2016).

The application of silicon fertilizers has a long history in agriculture, especially for rice cultivation. It has been reported that Si prevents rice lodging by increasing the thickness of the culm wall and the size of the vascular bundle (Shimoyama, 1958). It also decreases transpiration in rice leaves (Agarie et al., 1998). Potassium silicate (K_2SiO_3) was reported to increase grass biomass in an experiment on rhodes grass (*Chloris gayana*), timothy grass (*Phleum pratense*), sudan grass (*Sorghum sudanense*) and tall fescue (Eneji et al., 2008). Our objective for this study is to observe the differences in growth, development, and Si tissue distribution at different sodium silicate amendment rates in cool-season grasses (bentgrass and tall fescue).

MATERIALS AND METHODS

The experiment was conducted at University of Kentucky, Lexington, KY. Seeds of tall fescue [*Festuca arundinacea*, Hogan tall fescue blend (endophyte free)] and bentgrass (*Agrostis stolonifera*, Barracuda) were germinated in petri dishes on phytagel and then transplant in Hoagland solution in a growth chamber. The temperature was kept at 20°C with 16 h photoperiod. Plants were grown in buffered Hoagland's media (pH 6) with four Na_2SiO_4 treatments (0, 0.5, 1, 2, 4 mM). After four weeks of Si treatment, the grasses were harvested. Plant height, dry biomass and Si content of tissue were analyzed, and silica bodies in leaf ash were observed using epifluorescence microscope. Rstudio was used for data analysis.

RESULTS AND DISCUSSION

Our data showed tall fescue (at 0.5, 1 and 2 mM Si) and bentgrass (at 4 mM Si) both advantaged from Si supplementation in biomass compared to controls. Silicon concentrations in aboveground tissue had a positive linear relationship with Si concentrations in media for both grasses. The highest Si concentration in aboveground tissues was 24 (tall fescue) and 30.5 (bentgrass) g/kg dry biomass at 4mM Si (Fig.1). There were two silica body morphologies observed in leaf ash, and we called them long and barbed (Fig. 2). We only observed autofluorescence silica bodies in leaf tissue when Si was added in media. Taking together, Si supplementations can contribute to increasing aboveground biomass of tall fescue and bentgrass. Silicon supplementation could provide benefits when soil pore water dissolved Si below 0.5 and 4 mM for tall fescue and bentgrass, respectively.

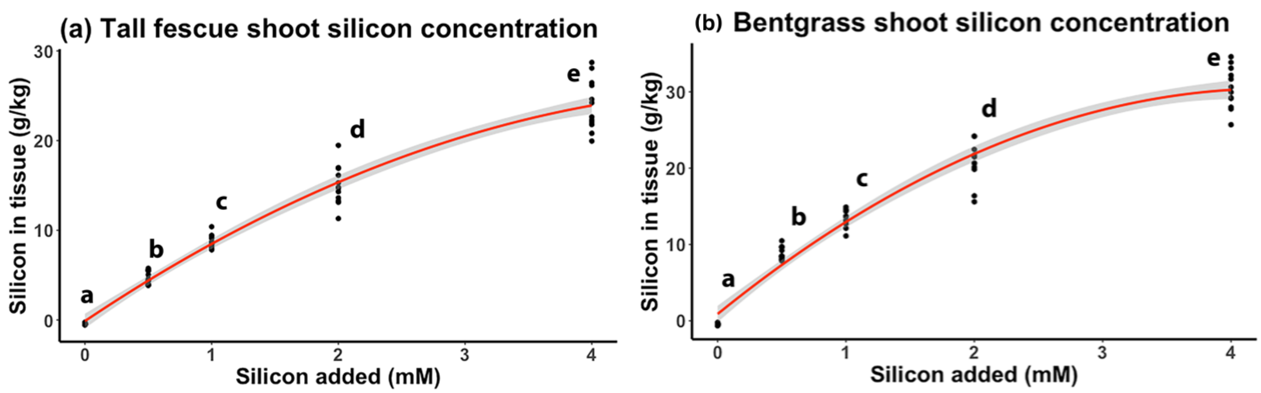

Figure 1. Effect of Si fertilization on tall fescue shoot (a), and bentgrass shoot (b) silicon concentrations (g kg^{-1} dry mass) at harvest. The solid lines represent linear regression through all data points. Shaded area indicates the 90% confidence interval for the regression line. Different lower-case letters indicate significant differences (p < 0.05) between different Si treatments in hydroponic culture, as determined by Tukey tests. The sample size n= 12 for each treatment.

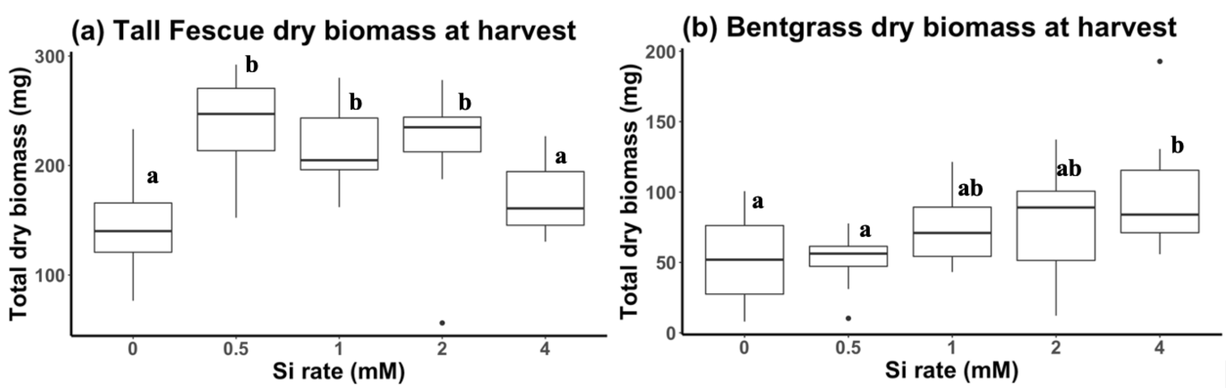

Figure 2. Boxplots representing whole plant dry biomass (mg) at harvest under the effect of silicon fertilization on (a) tall fescue and (b) bentgrass. The bold horizontal segments in the boxes represent the medians dry biomass of the treatment. The whiskers represent the 99% range, and the black dots represent the outliers. Different lower-case letters above boxes indicate significant differences ($p < 0.05$) between different silicon treatments in hydroponic culture, as determined by Tukey tests. The sample size n= 12 for each treatment..

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