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Exploring the efficacy of silicon products to enhance herbivory protection

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Introduction

Restoration in arid systems typically involves the addition of plants through seeding or planting of native species to enhance plant biodiversity and reduce soil erosion (Epanchin-Niell et al. 2009). Despite the increasing interest and investment in arid land restoration, we are still incredibly inefficient at achieving management goals. On average, only about 7% of restoration projects in western grassland systems can be considered successful based on plant cover (Copeland et al. 2018).

In many cases, particularly when plants are installed as transplants into the field, restoration species are the only healthy, green forage available for wildlife. It is not uncommon for 100% of plant species to be decimated by both vertebrate and invertebrate herbivores almost immediately following transplantation (Ruhren & Handel 2003). This is clearly untenable for managers. Unfortunately, current management approaches to exclude herbivores and reduce herbivory are expensive, typically ineffective and are unfeasible to deploy across large scales. These can include the installation of tree shelters and enclosures, strategic deployment of green manure and installation of predatory bird perches (Reis et al. 2019).

One novel technology to reduce herbivore effects on transplants is the use of silicon as a growth amendment for plant materials. Silicon accumulation, in addition to alleviating environmental stress in many plants, can confer physical resistance against herbivores (Johnson et al. 2021). Silicon is typically taken up as silicic acid by plant roots both passively and actively whereupon it is transported and deposited as silica within and between cells and at the leaf epidermis (Kumar et al. 2017). Silicon accumulation can confer resistance to herbivory by wearing down mouthparts, lacerating herbivore organs and inhibiting nutrient absorptions once ingested (Massey et al., 2006). This interaction leads to lower preference of high silicon plants.

Nurseries have been aware of the value of nutrient loading in the greenhouse prior to field transplantation to reduce herbivory for a very long time. However, nutrient loading tends to focus on the use of nitrogen or phosphorous (e.g. Watkinson et al. 2021), which can have negative unintended effects in arid systems, such as enhancing non-native species proliferation (Williams et al. 2022). Although the natural accumulation of silicon in plant species is known to deter herbivory (Hamilton et al. 2015), there is still a dearth of knowledge related to which commercial product is most effective at boosting silicon loading in plants. This work describes how effective commonly available and inexpensive products can be for enhancing foliar silicon.

Experiment

Four different types of liquid silicon products were tested. These included: Silica Gold (TPS Nutrients), Silica Boost (Bloom City); Silica Blast (Botanicare), and Si-Tech (Agro Magen). Inexpensive and easy to acquire products were selected for testing. Pansies (Viola x wittcokiana) were used as they are commonly grown garden plants and are vulnerable to herbivory. Flowering pansy plants in 1.65-pint pots were treated with one of each of the silicon products, and untreated flowering pansy plants served as experimental controls. Each treatment included ten replicant plants plus ten control plants that were not exposed to any silicon product. The experiment involved a total of 50 plants. Plants were kept outside in Tucson, Arizona, in dappled sunlight between October and December. During the course of the study, the plants were exposed to silicon products by mixing the recommended

amount of product in water and pouring approximately ¼ cup of solution onto the soil surface each time the plants were watered (Waterman et al. 2021). Non treated control plants received the equivalent amount of water with no product during each watering session. Plants were watered every other day.

Two months after the start of the study, plant parts were separated for analysis. Leaf samples were collected by removing the topmost seven leaves of each plant with scissors; stem samples were collected by removing stems at the base of the plant with scissors and removing all attached leaves and flowers; and all flowers were removed with scissors from each pot. Finally, 4 grams of surface soil were collected from all pots. All samples were dried in an oven (~85 degrees F) for three days, after which they were crushed and submitted to an analytical lab to assess silicon content.

Results

Although variation was seen across product type and item sampled, Si-Tech was clearly and statistically significantly the most effective product for elevating silicon levels in all plant parts and the soil ($p < 0.05$; Figure 1). No other products had any significant increase in silicon when compared to untreated controls.

Conclusions

Although many products are available for greenhouse managers and restoration practitioners to enhance herbivory protection to plants, there are almost no studies comparing the effectiveness across products. This work highlights that efficiency of different commercial products to elevate foliar silicon can be widely dissimilar when considering a common greenhouse plant. Each

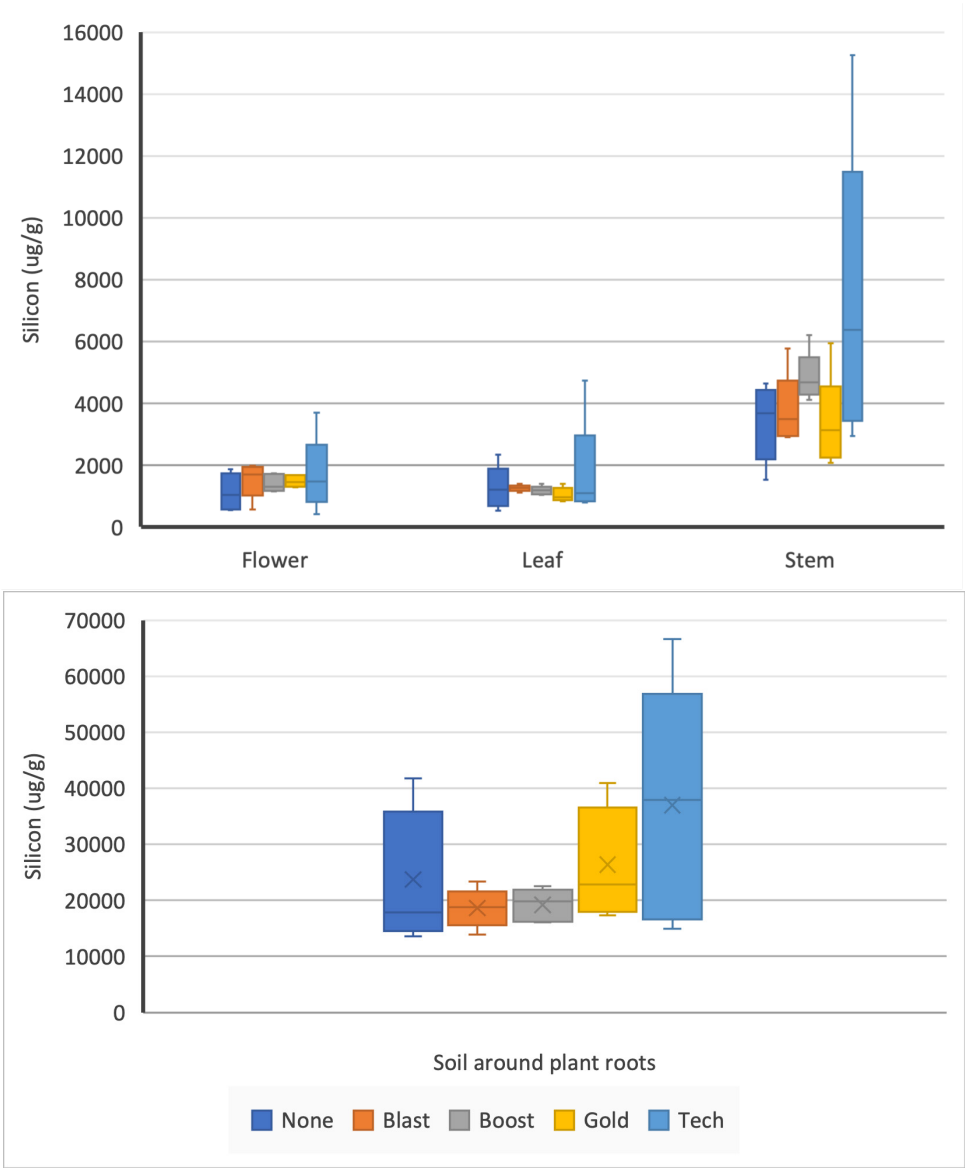

Figure 1. Boxplot of silicon content across plant parts (top) and soil (bottom) for all products tested, including control (none).

product tested is associated with secondary chemicals (e.g. Calcium), so managers should consider how these secondary chemicals might affect plant growth and herbivory. The next step for this work is to test efficacy of products to deter actual herbivory in the field.

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