Evaluating the Potential for Slag as a Source of Supplemental Silicon in Container Crop Production

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INTRODUCTION

Evidence of the potential beneficial effects of supplemental silicon in fertility programs for crop production is plentiful. Recent acceptance of silicon as a fertilizer in organic practices increased the profile of the nutrient, so the potential sources of silicon must be determined. Slag is a granular product produced during the manufacture of iron and steel, and depending on the process, can vary greatly in its composition. Within any given smelting process, the resulting slag is predictable and consistent. We sought to determine 1) if different slag types could be used as a supplemental silicon source in containerized crop production, and 2) if any heavy metals were also leached from the materials.

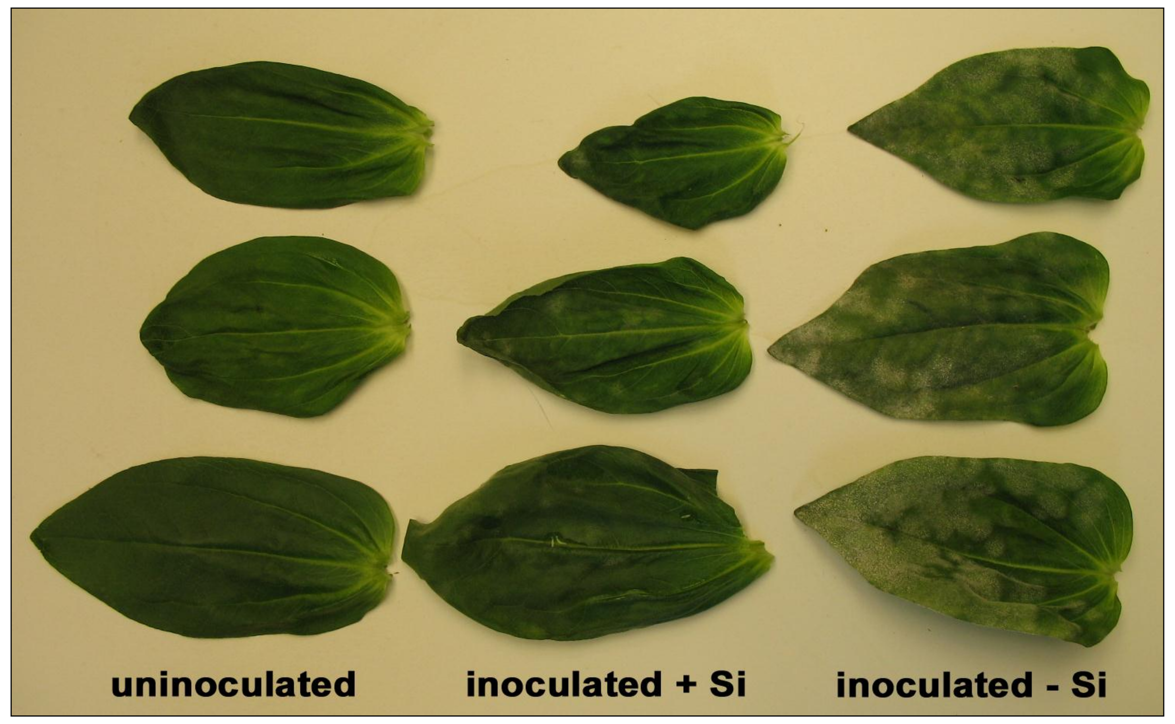

Figure 1. Zinnia leaves fed with or without Si and inoculated or not inoculated with powdery mildew. Si activates plant defense pathways that allow the plant to fight off this stress. Si application can be accomplished a number of different ways; slags provide a method that is easily adapted within existing plant production practices.

MATERIALS AND METHODS

Expt. 1: Different particle sizes of slag were extracted with water, filtered, and analyzed on ICP.
Expt. 2: Slag was mixed with a peat:perlite substrate, loaded into glass columns (Fig. 2), and extracted 10 times (1x per day) with the Saturated Media Extract procedure using water as the extractant (Fig. 3).
Expt. 3: Zinnia (*Zinnia elegans* 'Oklahoma White') were grown in containers with one of 3 rates of slag: adjusted to 2 tons per acre or field rate, 7x or 14x field rate. They were compared with no amendment (control) or a substrate drench containing 2 mM Si as potassium silicate. All containers were fertilized at each irrigation. Mature, fully expanded leaves were analyzed for total Si concentration and for heavy metals with ICP.

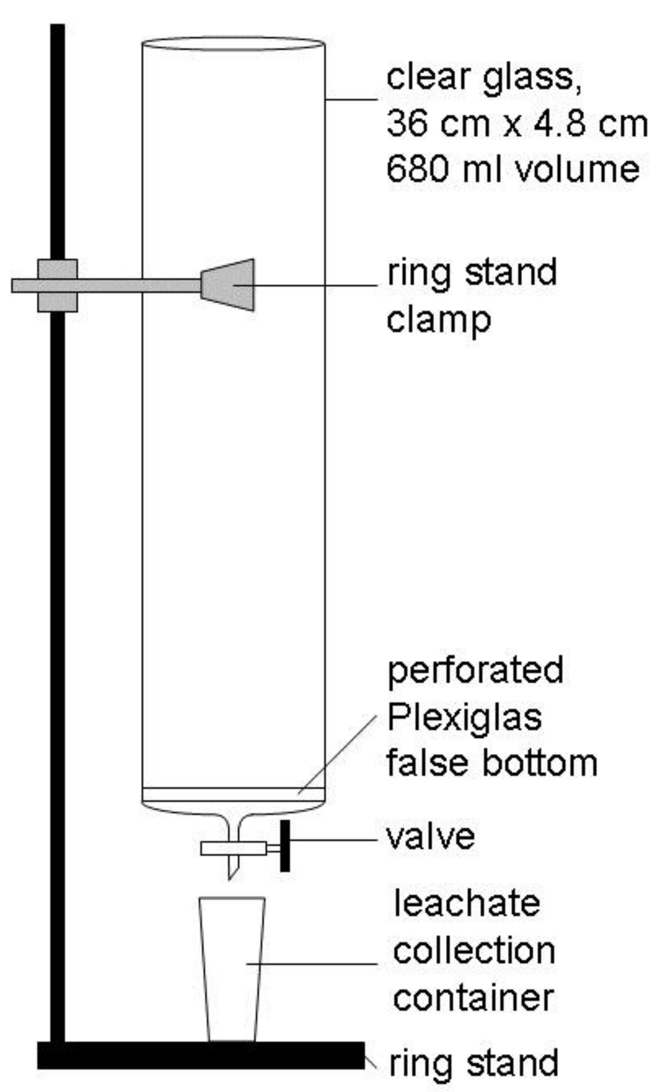

Figure 2. A diagram of a glass column setup that is used to perform series of SME on substrate mixtures. Little is known about how Si should be quantified for predictions of Si bioavailability. We filled the columns with peat:perlite mixtures and amended them with different slag types and rates of slag. Each day, we filled the columns with water, waited an hour, and collected the filtered solution out of the bottom. Resulting filtrate was analyzed with ICP for total Si.

Figure 3. During an experiment, columns containing peat:perlite mixtures amended with different amounts and types of slag were simultaneously run. Plastic bags were loosely placed on the tops of each column to prevent debris from entering the system. Solution was filtered at each collection event.

RESULTS

Expt. 1.

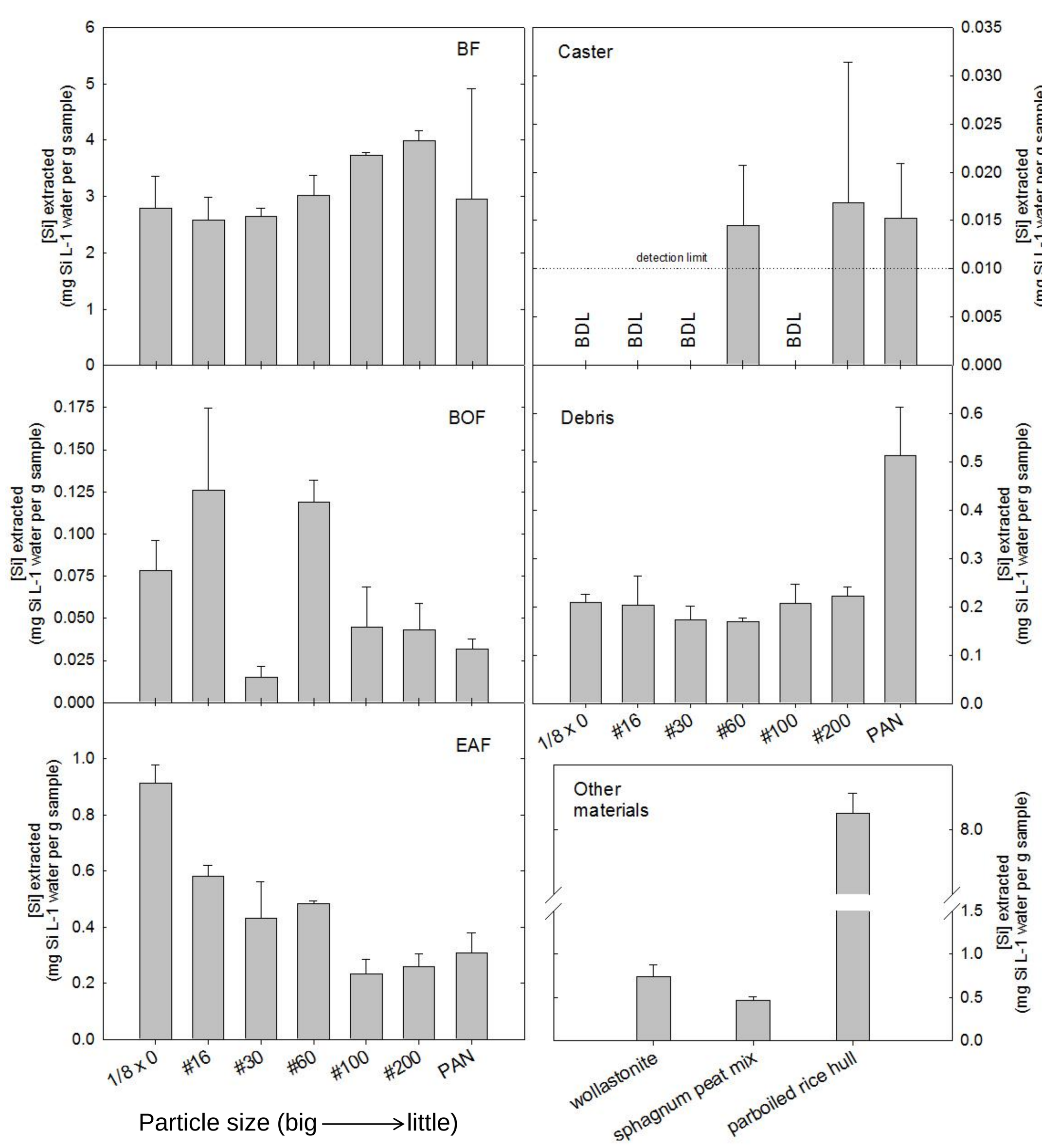

Figure 4. Amount of Si extracted with water from different slags of differing particle sizes. For comparison, other materials are also shown. We did not find a pattern of Si release based on particle sizes. Based on this test, BF-, and EAF-types have the most potential for Si release.

Expt. 2.

Slag type	field	7 x field	14 x field	Trend in time
BF	2.1de	4.46a	1.9e	increase
BOF	3.35c	3.77bc	1.31f	increase
EAF	2.56d	4.11ab	3.75bc	NC
Caster	0.21ij	0.06j	0.01j	decrease
Debris	0.47hij	0.26ij	0.03j	decrease
Wollastonite	2.17de	3.98ab	3.88b	decrease
Control	0.28ij	-	-	decrease

Table 1. Average amount of Si released in the series of SME from the columns and the trend over time in amount released. Even though the amount increased or decreased, the magnitude of change was small over the 10 extraction. Based on this analysis, BF, BOF, EAF, and Wollastonite would be able to supply Si. NC indicates "no change" over the 10 sequential extractions.

Expt. 3.

Slag app. rate	BF	BOF	EAF	Caster	Debris	Wollastonite	Control	Drench
field	2.9fg	5.4ef	5.2ef	1.0g	0.9g	8.5de	-	-
7 x field	8.2de	10.8b	14.9b	2.1fg	1.9fg	12.6bc	-	-
14 x field	9.8cd	13.3a	21.4a	2.2fg	2.3fg	12.8bc	-	-
other	-	-	-	-	-	-	1.3g	14.2b

Table 2. Total amounts of Si in zinnia leaf tissue grown with different amounts of slag. High rates of slag were used to establish a worst-case scenario for heavy metal leaching and to account for greater leaching from irrigation in containers. Growth in BOF, EAF, and Wollastonite resulted in the most Si in leaves, and had levels comparable to soluble potassium silicate (Drench treatment) at 2 mM Si. Not shown: pH increased to above 7.0 in BOF treatment. There was no significant concentration of heavy metals with most metals (except Mn and Al) being below detectable limits.

CONCLUSIONS

- Using water as an extractant, the series of SME from the columns provided the best predictions of Si availability from different materials.
- At high rates, slag may raise pH above optimal ranges.
- Based on these experiments, there is no / low risk of heavy metal leaching from these slag types, even if applied at rates much higher than 2 tones / acre.

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