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An Introduction to Silicon Nutrition of Soils and Crops with a Focus on Cucurbits

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Silicon (Si) has recently been recognized as a quasiessential element in plant nutrition. Some plant species, such as diatoms and equisetum, can not grow without silicon. Other plants benefit from silicon nutrition to various degrees depending on the environmental conditions. Rice, wheat, cucurbits, and sugarcane are examples of crops that often benefit from enhanced levels of silicon nutrition. In crop production the benefits from silicon may include increased yield, disease and insect resistance, and tolerance to stresses such as cold, drought, and toxic metals. In addition to plants, the value of silicon is gaining attention in animal nutrition where silicon has been shown to play a role in the health of bone, joints, skin, hair, and other connective tissues.

Monocot plant species generally take up more silicon than dicots. Crops may be roughly classified as accumulators, intermediate, or non-accumulators with respect to their tendency to take up silicon. Rice, wheat, and sugarcane are examples of silicon accumulators; cucurbits are intermediate; tomato is a non-accumulator. In accumulators the amount of silicon up take is large and can easily exceed the levels of up take for other major plant nutrients such as nitrogen or potassium.

Because silicon is the second most abundant element in mineral soils it may come as a surprise that silicon can be a limiting nutrient. Most of the silicon is held in the crystalline structure of sand, silt and clay size particles. Silicon can be taken up by plants from the soil solution as silicic acid (H4SiO4) as soil particles weather and release silicon into the solution. Thus, while the total soil An Introduction to Silicon Nutrition of Soils and Crops with a Focus on Cucurbits silicon content may be very large, the amount of soluble Si available for plant up take is limited. Plant residues, depending on the original species and composition, can be an agronomicly useful source of silicon that is cycled in the soil crop system. Soils vary significantly in their ability to supply available silicon for plant uptake. In general, less weathered, geologically younger soils have a better supply of silicon than highly weathered or older soils. Ultisols and Spodosols are soil orders that are common in the Eastern USA, that have been extensively weathered and tend to be somewhat silicon depleted. Oxisols that are common in the tropics are the most highly weathered soils and they are the most silicon depleted. In contrast, Mollisols, common to the USA Great Plains, are less weathered, and contain more silicon. Histosols, also known as peat or muck soils, contain little mineral material and are often Si deficient.

Soil and plant testing can be performed to determine the silicon status but so far there has been too little research to support interpretations for most soils and crops grown in temperate regions. Most of the soil fertility research in relation to silicon has focused on soils and crops of tropical regions where large responses to silicon fertilization are common in rice and sugarcane.

About five years ago I began to focus some of my soil fertility research and Extension efforts on silicon because it appeared that this nutrient had not received much attention for crops grown on temperate region soils. My first experiment was conducted on pumpkin because cucurbits are know to take up significant amounts of silicon and because the scientific literature suggested that silicon nutrition could suppress powdery mildew disease on cucumber and other crops.

The field experiment with pumpkin was conducted on a Quakertown silt loam soil that had an initial soil pH of 5.7. Plots were established in 2000 by amending the soil with either CaCO3 (calcium carbonate or common agricultural limestone) or CaSiO3 (calcium silicate, an alternative liming material) at the rate of 3.5 tons/acre of calcium carbonate equivalent (CCE). Tillage was performed to incorporate the liming materials with soil. Half of the pumpkin plots received an application of fungicide weekly

throughout the summer as is the typical practice for powdery mildew control. In late September, the pumpkin foliage was visually rated for percent of leaf surface area covered with powdery mildew. Marketable pumpkins were harvested, counted, and weighed from each plot. This experiment showed that the silicon amendment significantly increased pumpkin yield in the first season but not in the second (Table 1). In both years the pumpkin grown on the silicon amended soil exhibited a delayed on-set of powdery mildew disease and better late season leaf retention (Figure 1). The silicon treatment also enhanced the effectiveness of fungicides for powdery mildew control.

In a subsequent experiment with field corn grown in 2002 and 2003 on the previously established plots we observed a decrease in European Corn Borer tunneling in the corn stalks (unpublished data). There was, however, no significant difference in corn yield between silicon amended and nonamended soil. Plant tissue analysis revealed that in samples of pumpkin and corn plant tissues, the silicon concentrations were approximately doubled by the silicon amendment. This indicated that a single application of silicon to soil can have potentially long-term benefits.

In recent greenhouse experiments using 3 different soils from New Jersey, amending soil with silicon was found to suppress powdery mildew on Kentucky bluegrass (Table 2). Thus, although research in our region is limited to a few crops and soils it appears that silicon fertilization of soils has the potential to benefit crops both in terms of yield and resistance to pests.

Soil fertility research with silicon is needed on a wider range of soils and crops. Plant and soil test calibration research needs to be done so that plant and soil test reports can be interpreted as a basis for silicon fertility recommendations. The potential dietary influence on animals from increased silicon in plants also needs to be examined.

Research is also needed on different types and sources of silicon for use as soil amendments (i.e. silicon fertilizers). This is a particularly important research question for organic farming. In my research trials I have been using a calcium silicate material, which is a by-product of the stainless steel industry (sold as Reclime, Recmix Inc, Pa), as the source of silicon. When calcium silicate is applied to soil it has an ability to neutralize soil acidity that is similar to calcium carbonate. Thus, both calcium silicate and calcium carbonate are liming materials and they are marketed as such. But I do not know if calcium silicate is an approved material for use in organic farming. The answer to this question may depend on the source of the material. In organic farming, use of industrial by-products typically throws up a red flag. There is, however, a naturally occurring mineral source of calcium silicate know as Wollastonite. It might be satisfactory for organic production but be sure to check this out with your organic farm certifier.

Figure 1. Plot with calcium carbonate amendment on top versus plot with calcium silicate amendment on bottom illustrate the influence of silicon on leaf health and retention.

Table 1. Yield of pumpkin in response to silicon amendment of soil and fungicide application in 2000 and 2001.

Treatment	Pumpkin Yield	
	2000	2001
	——Tons/Acre——	
$CaCO_3$	6.7	3.1
$CaSiO_3$	11.9	3.3
CaCO3+Fungicide	7.8	4.8
CaSiO3+Fungicide	11.5	4.3

Table 2. Effect of liming material (calcium carbonate vs. Calcium silicate) on powdery mildew disease ratings on Kentucky bluegrass grown on three soil types. Powdery mildew disease ratings: 0 = no disease; 10 = total disease.

Treatment	Adelphia Woods	Adelphia Farm	Quakertown Farm	Average
	——Powdery Mildew Disease Rating——			
$CaCO_3$	4.1	5.6	5.7	5.1
$CaSiO_3$	1.7	3.9	5	3.5

Another option for the organic grower wanting to improve the availability of silicon in soil is the use of certain composts, plant residues, or crop rotations. Wheat and rice are crops that take up considerable amounts of silicon from soil that can become available to subsequent crops. Composts made from rice straw or rice hulls have been shown to be effective sources of plant available silicon. This might also be true for composted wheat straw. The incorporation of chopped wheat straw into soil has been shown to also improve silicon availability to subsequent crops. Burning of wheat straw, however, decreases the plant availability of the silicon. Using wheat straw as a silicon source may have possibilities for benefiting organic production of cucurbits but be prepared for counteracting nitrogen deficiency that it associated with this high carbon to nitrogen ratio material.

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calcium silicate
Wollastonite
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