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9. ABSTRACT

A report of responses to applications of calcium silicate to rice and sugarcane in the field and for other graminaceous and for several non-graminaceous crops in pots. These responses occurred on highly weathered volcanic soils of the tropics and on old alluvial terraces in Japan. Current evidence indicates that this response is due to both soil and plant effects of calcium and silicon. Soil effects include increased soil phosphorus availability, pH, calcium supply, and cation exchange capacity, as well as decreased concentrations of toxic elements. Plant effects include improved phosphorus metabolism, calcium nutrition, nutrient and enzyme balance, and increased mechanical strength.

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PLANT, MINERAL NUTRITION OF
by Dr. J. A. Silva

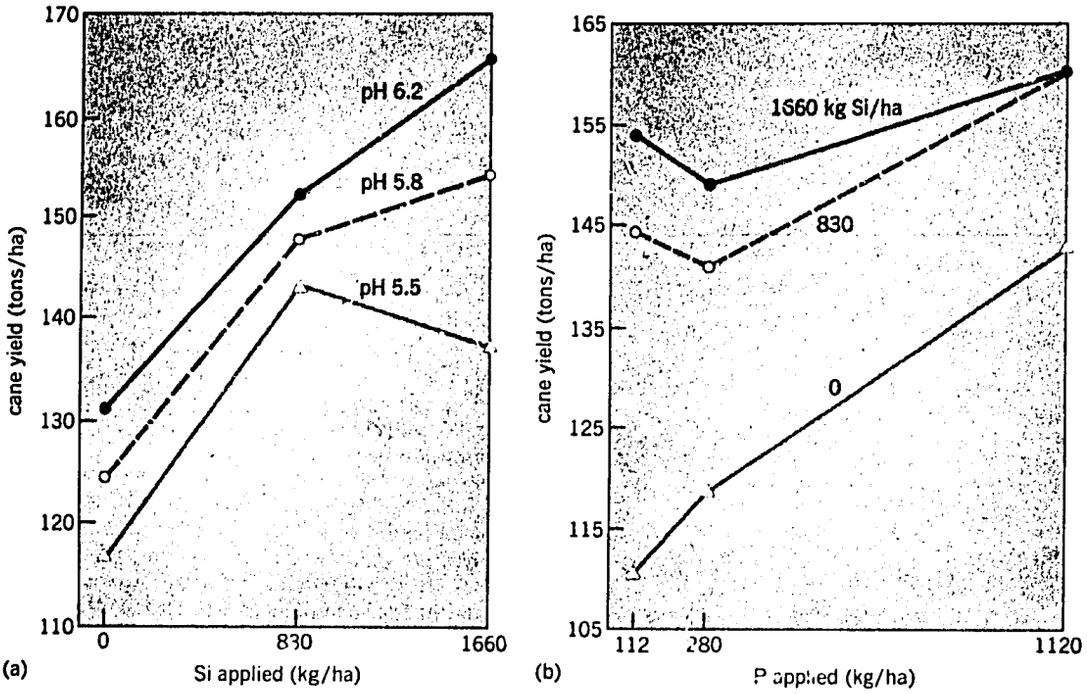
Plant, mineral nutrition of

Responses to applications of calcium silicate have been reported for rice and sugarcane in the field and for other graminaceous and for several nongraminaceous crops in pots. These responses have occurred on highly weathered volcanic soils of the tropics and on old alluvial terraces in Japan. Current evidence indicates that this response is due to both soil and plant effects of calcium and silicon. Soil effects include increased soil phosphorus availability, pH, calcium supply, and cation exchange capacity, as well as decreased concentrations of toxic elements. Plant effects include improved phosphorus metabolism, calcium nutrition, nutrient and enzyme balance, and increased mechanical strength.

Crops. Rice has been reported to respond markedly to calcium silicate applied to certain soils in Japan. These responses have been 10–20% of the yield without added silicate. Applications of this material are now standard for these soils, resulting in the use of about 1,000,000 tons of calcium silicate annually in Japan. Other areas reporting response by rice are Taiwan, Ceylon, and India. Yields of cane and sugar in Hawaii have been increased 10–50% on soils low in silicon, and many sugar plantations regularly apply calcium silicate to responsive fields. Increased yields of sugarcane in fields have been reported in Mauritius and Puerto Rico (5–35%), while in South Africa several sources of silicate increased sugarcane yields in pots. Other graminaceous crops, such as sorghum, millet, oats, wheat, rye, and corn, have given yield responses of 5–90% in pots, while Kikuyu grass, Guinea grass, Sudan grass, and Bermuda grass have produced yield increases of 5–200% in pots. Several nongraminaceous species, including trefoil, *Desmodium* sp., alfalfa, beans, tomatoes, lettuce, head cabbage, and papaya have given dry-matter yield increases of 20–100% with calcium silicate in pots. Apparently benefits from calcium silicate are not limited to graminaceous plants, at least in pots, but field trials are needed to verify this.

Soils. Responses to calcium silicate generally have been reported on tropical soils which are extremely weathered and highly leached, with low pH, extractable silicate, and base saturation, as well as low silica-sesquioxide ratios. Their clay minerals are predominantly hydrated aluminum and iron oxides (gibbsite and goethite or hematite) and kaolinite, which have high phosphorus sorption (fixation). Many have a low cation exchange capacity, and some have high manganese levels. In addition, the charge on many of these soils varies with pH. The responsive sugarcane soils of Hawaii and Mauritius are of volcanic origin and are generally in the Ultisol and Oxisol orders of the New United States Soil Taxonomy System. Soils of old alluvial terraces in Japan, where rice responds to calcium silicate, are hydromorphic members of the order Ultisol. In Hawaii a volcanic-ash soil, formed under high rainfall (5100 mm per year) and classed as a Hydrandept, is also responsive. In Taiwan rice has responded on acid sandstone and shale alluvial soils.

Silicon is currently considered essential only for diatoms and horsetail (*Equisetum*) and possibly rice. However, increased growth results when it is applied to other species of plants. This is shown with sugarcane in illustration *a*, where pH effects are separated from silicate effects and yield increases with calcium silicate applications within pH levels suggest that silicon is responsible for the increased growth. In illustration *b* yields with a given amount of phosphorus are considerably



Yield response of 9-month-old sugarcane (*a*) to applied silicate and pH and (*b*) to applied phosphate and silicate. (*From J. A. Silva, The role of research in sugar production, Hawaiian Sugar Technologists: 1969 Reports, 1969*)

higher in the presence than in the absence of applied silicate. The response to silicate is greater at lower levels of applied phosphorus, and an interaction between phosphorus and silicon is suggested. Possible explanations for growth increases from applications of calcium silicate include both soil and plant effects.

Soil effects. The effects of calcium silicate in soil may be separated into those of silicate and calcium. The major effect of added silicate is the increase in soil phosphorus availability, either through reduction of phosphorus sorption (fixation) or through increasing the desorption (release) of soil phosphorus. This is shown in the table, in which added silicate reduced the quantity of phosphorus required to supply soil with adequate phosphorus for crop growth and also increased the concentration of phosphorus in solution (desorbed). Phosphorus sorption is highest in soils with a high content of iron and aluminum oxides, namely, Kapaa and Akaka. Silicate is more effective in decreasing phosphorus sorption and also in increasing phosphorus desorption on soils which are largely kaolinite and sorb phosphorus least, namely, Leilehua and Wahiawa. The exact mechanism of these effects is not known, and since soluble silica in soil is in the form of monosilicic acid, $Si(OH)_4$, the mechanism of anion exchange is considered inappropriate. Added silicate also reduces the activity of toxic elements (aluminum, iron, and man-

Influence of added silicate on phosphate sorption (fixation) and desorption (release) from four Hawaiian soils

		$CaSiO_3$ added, ppm Si					
		0	250	500	0	250	500
Soil series	Soil subgroup	P requirement, μg/g*			P desorbed, ppm in solution†		
Leilehua	Humoxic Tropohumult	187	125	100	5.35	5.90	6.13
Wahiawa	Tropeptic Eutrorthox	425	325	250	3.36	4.80	4.64
Kapaa	Typic Gibbsihumox	725	625	550	0.46	0.55	0.56
Akaka	Typic Hydrandept	1150	1050	1050	0.14	0.15	0.16

*P sorbed at 0.2 ppm P in supernatant solution.
†P added initially, 1000 μg/g
SOURCE: A. C. Roy et al., Influence of calcium silicate on phosphate solubility and availability in Hawaiian Latosols, *Proc. Int. Symp. Soil Fert. Eval. New Delhi*, 1:757–765, 1971.

ganese) in soil. This is not only the result of increased pH due to calcium added but also due to reactions with silicon.

Calcium effects include an increased calcium supply and pH resulting from this form of calcium. Above pH 5.0 concentrations of toxic elements in soil are reduced and phosphorus availability is also increased. Increased pH in tropical soils which have pH-dependent charge increases cation exchange capacity.

There is some evidence that cation exchange capacity in these soils may also be increased by silicate.

Plant effects. In sugarcane and lettuce silicate applications have resulted in increased efficiency in the utilization of plant phosphorus. This is evidenced by higher yields with silicon than without at the same concentration of plant phosphorus. Root absorption of phosphorus in certain species is increased by the presence of silicon. Effects of toxic amounts of manganese in plants are reduced by silicon largely through improving the microdistribution of manganese in leaves, which prevents "leaf freckling." Silicon increases the oxidation power of rice roots, thereby enhancing oxidation of reduced forms of manganese and iron to insoluble forms which precipitate on roots and thus preventing excessive uptake of these elements. The ratio of Mn/SiO_2 in tissues has been considered a measure of manganese toxicity; however, recent evidence suggests that it is of limited value for this purpose.

The formation of enzyme-silicon complexes in sugarcane which act as protectors or regulators of photosynthesis and enzyme activity has been proposed by A. G. Alexander. Silicon can suppress activity of invertase, peroxidase, polyphenol oxidase, phosphatase, and adenosinetriphosphatase in sugarcane. Suppression of invertase activity results in increasing sucrose production, while reduction in phosphatase activity is believed to provide a greater supply of essential high-energy precursors needed for optimum cane growth and sugar production.

High levels of plant silicon result in increased strength and rigidity of tissues and produce higher yields, particularly in rice, due to reduced lodging and better light interception by the more erect leaves. It has been reported that the silica layer formed between epidermal cells and the cuticle in rice leaf blades is very effective in reducing water loss and as a protection against disease and insect attack. Increased resistance to several diseases of rice, especially rice blast, and of corn, for example, corn smut, has resulted from applications of calcium silicate.

For background information *see* PLANT, MINERAL NUTRITION OF; SOIL, SUBORDERS OF in the McGraw-Hill Encyclopedia of Science and Technology.

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Bibliography: A. G. Alexander, R. Montalvo-Zapata, and A. Kumar, *J. Agr. Univ. P. R.*, 54:82–95, 1970; J. D'Hoore and J. K. Coulter, in *Soils of the Humid Tropics*, in press; A. C. Roy et al., *Proc. Int. Symp. Soil Fert. Eval. New Delhi*, 1:757–765, 1971; J. A. Silva, *Proc. Int. Symp. Soil Fert. Eval. New Delhi*, 1:806–814, 1971.

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