<u>Effect of Silicate on Phosphorus Availability</u>

Several opinions exist as to the nature of phosphorus-silicon interactions in soils. However, beneficial effects of silicate applications to soils have been attributed by several workers to increased P availability. Hall and Morrison (1906) believed the seat of reaction was in the plant rather than in the soil, while Fisher (1929) indicated that the main effect of silicate was to increase the availability of soil P and had nothing to do with P metabolism in the plant. Raleigh (1953) reported increased P uptake with silicate applications only on soils deficient in P.

Tiulin (1936) suggested increased P availability due to replacement of phosphate anions by silicate ions in the soil colloidal system. Increased yields in barley associated with silicate application was due to increased availability of soil P rather than fertilizer P (Cooke, 1956). De Datta (1958) showed increased yield and greater P uptake by barseem due to high application of sodium silicate to Indian soils. Raupach and Piper (1959) reported increased soil P release by silicate application. Khan and Roy (1964) found increased P uptake by jute plant by silicate application to some East Pakistan soils.

Toth (1939) suggested that silicate anions released fixed phosphate from soils in a manner similar to the acidoid displacement by organic anions like citrate and tartrate. Many workers (Schollenberger, 1922; McGeorge and Breazeale, 1924; Gile and

Smith, 1925; Scarseth, 1935; Midgley and Kelly, 1943; Dewan and Hunter, 1949; Laws, 1950; Noda and Saito, 1952) have suggested anionic exchange of silicate for phosphate in soils for increased P availability. Mattson (1931) found that phosphate anions strongly displace silicate anions, but apparently there was not a reverse displacement of phosphate ions by silicate ions.

Gile and Smith (1925) indicated that silica-gel exerts a solvent action on phosphorus and thus renders it more available. Increased diffusion of P in the form of SiO_2-P_2O_5 complex at the soil-solution-root interface was suggested by Akhromeiko (1934). Sreenivasan (1935) found that oxide gels of Fe and Al adsorbed both silicate and phosphate ions, and retention of KH_2PO_4 decreased when soils were pretreated with sodium silicate. According to Taranovskaya (1941), calcium and magnesium silicates are more effective than lime for mobilizing P and reducing the soluble Al contents. Similar results were obtained by Bastisse (1950) and Noda and Saito (1952).

Brenchley _et al_. (1927) stated that Si can perform in the plant some functions of P, and is a means of economizing on the use of phosphate fertilizer. Okuda and Takahashi (1962) suggested that in rice plants Si inhibits luxury consumption of P. Silicate applications increased availability of soil P but not fertilizer P, was reported by Hunter (1965). He believed this effect to be anion exchange in soils and did not find any evidence of Si

substitution for P in the plant.

Investigations on the effect of silicate on yield and P uptake by plants in Hawaiian soils have been conducted by several workers. McGeorge (1924), followed by Sherman et al. (1955), observed that plants responded to silicate application in Humic Latosols but not in Low Humic Latosols, Dark Magnesium clays, and Humic Ferruginous Latosols. Increased P assimilation in the presence of silicate was associated with the mineral composition of soils. Phosphate fixing capacity of a Humic Latosol was decreased by silicate treatments (Ikawa, 1956).

Clements (1965) obtained decreased P concentration in cane by application of TVA slag to an aluminous Humic Ferruginous Latosol. This he attributed to a dilution effect associated with increased cane growth. Phosphorus concentrations of cane grown on Hydrol Humic Latosols at Paauhau and Akaka Falls were increased by slag applications. At these locations increased yields by slag applications was believed to be partly due to increases in P absorption. Phosphorus uptake by sugarcane growing on an aluminous Humic Ferruginous Latosol was increased from 18 to 29 lbs of plant P per acre by silicate applications (Ayres, 1966). He believed increased cane growth was not because of increased P uptake since P percentage of the plant was sufficient and additions of P over control did not increase yield.

Ali (1966) grew sugarcane on a Humic Latosol in pots. He obtained a two-fold increase in total P uptake by silicate application when no P was applied. He suggested that silicate increased the availability of soil P, which under conditions of P deficiency would be accompanied by increased yield. He further observed that for similar P concentrations in the plant, silicate treated plants grew best, indicating that Si probably helped to meet internal P requirements of cane by more efficient utilization of limited soil P and/or substituting for P in the plant.

Effect of Silicate on Growth and Yield of Plants

Silicon has not yet been shown to be essential for plant nutrition, although it has been demonstrated experimentally that this element can influence growth and development in plants, especially the members of the Gramineae family. Silicate increased the yield of barley to a considerable extent, and the effect was most marked in the absence of P (Fisher, 1929). Similar results were reported by Brenchley *et al*. (1927). Increased plant growth due to silicate applications were reported by several workers (Hall and Morrison, 1906; Barnette, 1924; Gile and Smith, 1925; Raleigh, 1939; Lipman, 1938; Toth, 1939; and others).

Raupach and Piper (1959) observed that silicate applications significantly increased yields at low P levels, but the effect disappeared with the second crop. Suehisa *et al*. (1963) reported

increased yield of Sudan grass grown on a Humic Latosol to which silicate had been applied. Monteith and Sherman (1963) reported that in a Hydrol Humic Latosol both $CaCO_3$ and $CaSiO_3$ increased yields of Sudan grass up to pH 6.8. Above this pH yield was depressed. In a Humic Ferruginous Latosol lime depressed yields at high pH values, but silicate at high rates still slightly increased yields.

Mitsui and Takatoh (1963) found that 100 ppm silicate added to a culture solution increased the production of new roots and tillers in rice plants and advanced the time of head sprouting. When Si content was less than 0.5 percent of total dry matter plants showed retarded growth during both vegetative and reproductive stages. Sterility was greatest in Si deficient barley and rice.

Khan and Roy (1964) found increased P uptake and yields of jute plant by silicate applications to lateritic and alluvial soils. Silicate treatments increased fineness of fibre cells. Sudan grass grown in amorphous and differentially crystallized sub-soils of Akaka soil responded best to $CaSiO_3$, intermediate to coral stones, and not at all to olivine sand (Dias, 1965).

Clements (1965) reported yield increases in sugarcane when TVA slag was applied to Hydrol Humic Latosols at Paauhau and Akaka Falls. Ayres (1966) reported that silicate did not benefit cane growth in pots where water containing 50 ppm SiO_2 was

used, but pronounced increases in growth was obtained using the same soil and distilled water. Pure $CaSiO_3$ greatly increased cane yields over control treatment which received equivalent amounts of Ca as nitrate. He concluded that Si *per se* was the main factor in increasing cane yields over control.

Ali (1966) grew sugarcane on a Humic Latosol in pots. Cane yields were increased about two-fold by silicate application when no P was applied. When plant P was brought to sufficiency the effect of silicate mostly disappeared. The yields of corn and kikuyu grass grown in pots on a Kapaa soil were increased significantly by silicate applications (Manuelpillai, 1967). In corn and sedge grass, increases in yields by silicate applications were accompanied by a decrease in P requirements. Ibrahim (1968) reported that though silicate did not increase grain yields in rice, it was effective in increasing straw weight by greater production of tillers. Teranishi (1968) reported increased cane yields by both silicate and phosphate applications to a Kapaa soil. Increased yields as a result of silicate applications was attributed only partly to increased P uptake, since P uptake decreased at the highest Si rate yet this treatment produced best. TVA slag applied to Kapaa soil increased sugar yields by 12 tons per hectare. In this experiment phosphate extractable soil Si and trichloro acetic acid (TCA) extractable Si of sugarcane leaf sheaths were about 20 ppm Si (Fox et al., 1967). Phosphate or lime application to this

soil did not alleviate leaf freckle, while slag did so to a considerable extent.

Silicate and Trace Elements in Plants

Rhoads et al. (1956) demonstrated decreased Mn uptake by avocado seedlings by silicate application. The decrease was attributed to increased soil pH and not Si uptake. Silicon decreased Mn necrosis in barley by preventing localization of Mn in small spots on the leaves (Williams and Vlamis, 1957). Vlamis and Williams (1967) showed that Si application increased yields in barley, oats, wheat and rye in the presence of Mn and decreased Mn concentrations in these plants. Clements (1965) believed that part of the response of sugarcane to TVA slag was due to decreased Mn concentration and lower Mn/Si ratio in the cane which reduced the incidence of "freckling", a physiological disease of sugarcane.

Ayres (1966) showed decreased Mn uptake by cane due to slag application. This was explained by higher soil pH and decreased solubility of Mn in soils. Leaf freckle of sugarcane was alleviated to a considerable extent by slag applications to Kapaa soil (Fox et al., 1967). Rice plants grown in Fe + Mn solution without Si produced brown spots on the leaf blades (Okuda and Takahashi, 1962). Slightly decreased Zn uptake by cane due to silicate application was reported by Ali (1966).

Teranishi (1968) did not find significant effects of silicate on Al and Mn content of sugarcane. However, the Mn/Si ratio was decreased with silicate application. The lowest Mn/Si ratio was associated with the highest cane yields.

Silicon Uptake and Distribution in Plant

Schollenberger (1922) reported that deposition of silica causes hardening of outer walls of plant stems, sharpening of edges of leaf blades, and stiffening of hairs. Absorption of Si was increased by excess nitrogen and was limited by potassium deficiency in plants (Germer, 1934). Germer also reported that Si deposition varies directly with transpiration. Raleigh (1939) found that barley plants deficient in Si were severely attacked by mildew, and that Si application corrected damping off in beet seedlings. Whittenberger (1945) indicated that under natural conditions Si is probably absorbed by plants as soluble silicic acid.

Engel (1953) indicated the presence of organic complexes of Si in rye straw. Silicon initially accumulated in the roots and later transported to the stalks of wheat seedlings and remained there when the supply was stopped. Most plant Si exists in inorganic form, although a part of the Si in higher plants was reported to be present in combination with protein (Ozaki and Higashiro, 1957).

Rothbuhr and Scott (1957) using radioactive Si showed that

added P slightly decreased Si uptake by wheat, while Si enhanced P absorption. Fletcher and Kurtz (1964), in agreement with the above authors, stated that P and Si have an inverse relationship, and that plant P + Si in milliequimoles tended to remain constant. Silicon levels in cane leaf sheaths increased with increasing levels of TVA slag applications (Clements, 1965). In many cases, slag induced ten-fold increases in Si yields in millable cane. Increased Si uptake by slag applications were demonstrated by several workers (Ali, 1966; Manuelpillai, 1967; Ibrahim, 1968; Teranishi, 1968; and others).

Jones and Handreck (1965) indicated that Si absorption both in graminaceous and leguminous species decreased with increasing soil pH. Oats grown in different soils of the same pH contained different amounts of Si at maturity. Silicon uptake was lowered by the presence of sesquioxides in soils. Mitsui and Takatoh (1963) used radioactive Si to demonstrate that 75 percent of Si in rice plants was transported to the shoots. They concluded that Si absorption by roots was performed by utilizing the energy released during the respiration by roots. Yoshida et al. (1962a) reported on the distribution of Si in leaf blades, leaf sheaths, stems and husks of rice. In leaf blades the density of silicified cells was maximum within one centimeter from the tip and decreased towards the base. They further demonstrated that the mobility of Si in plants is very low, and once deposited, its

redistribution is unlikely. Using infrared absorption and solubility tests in hot water, they found that about 90 percent of plant Si was in the form of silica-gel and poly-silicic acid, with only 10 percent in the form of dispersed state Si and colloidal silicic acid.

Fox _et al_. (1969) suggested that soluble Si in plant tissues can give useful information about the Si status of plants. Total and soluble Si was higher in sugarcane leaf sheaths than in leaf blades. Total Si was much greater in leaf sheaths and leaf blades than in the internodal tissue. Soluble Si was highest in the least mature tissues, whereas total Si was highest in the recently mature tissues. They concluded that Si deposition in sugarcane is associated with growth.

Resistance to blasts in rice corresponds to an increase in the Si content of the leaves (Volk _et al_., 1957). Sasamoto (1957) indicated that Si accumulation is an important factor in the resistance to rice bohler.