INFLUENCE OF SILICON AND PHOSPHORUS AND THEIR INTERACTION ON YIELD AND CHEMICAL COMPOSITION OF PLANTS

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By

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INTRODUCTION

In humid tropical climates, silicate minerals undergo rapid chemical weathering. This leads to the replacement of metallic cations by hydrogen, resulting in the release of Si, Al, iron, titanium and other components. The loss of silica is accelerated by heavy rainfall. Wolff (1880) and Russel (1961) mention that the amount of silica returned to the soil by forest leaves and litter may exceed 100 kg. per acre. Thus there seems to be evidence of a silica cycle between plant and soil, which may have a greater significance in plant nutrition than has been recognized to date.

Though it has often been demonstrated that the application of silicates results in increased yield, especially of the gramminaceous species, Si is not considered essential for plant growth. Plants which normally accumulate large amounts of Si have been grown and have developed normally in the virtual absence of this element. The increased yields are generally attributed to the effect of Si on the availability of P, but the nature of the P - Si interaction has not been conclusively established.

Hawaiian soils are noted for their high P-fixing capacity. Ayres (1934) reported that certain Hawaiian soils fix as much as 90% of applied P fertilizer within 48 hours after application. The relative abundance of reactive agents such as Fe, Al, amorphous sesquioxides and clay minerals determine the extent of P fixation.

Phosphorus has a tendency to combine with these soil constituents through ionic reaction and displacement or surface adsorption. Their degree of solubility is governed by pH, ions in solution, moisture and mineral composition. Often the end products cannot be readily utilized by plants.

A study of the effect of soluble silicate on the availability of soil P or the reduction of P fixation by soils could contribute much to the efficiency of P fertilization in Hawaiian soils. This research was initiated to investigate the interaction of P and Si on the yields and composition of several plant species.

Preliminary pot studies were conducted by the writer with different species, both gramminae (sugarcane, corn, Sudan grass, California grass, pangola grass and kikuyu grass) and non-gramminae (tomato, Desmodium intortum, Desmodium canum, amaranthus alfalfa, sedge, fern and Mimosa pudica), grown on soil of the Honolua series, collected from the Helemano area, and watered with rain water. All pots were adjusted to an initial pH of 6 with $CaCO_3$. It was found that P uptake remained constant for four levels of silicate application and that increased yield, especially in the gramminae, corresponded to an increase in the uptake of Si, which in turn increased with the age of the plant. It seemed that yield increase was independent of P. However, Ali (1966) obtained evidence that Si in the plant decreased the internal P requirement, and, Hunter (1965), among other workers, indicated the importance of Si in increasing the external P supply.

Kapaa soil, which is low in extractable P and Si, was selected as the experimental soil. Ayres (1966) reports that sugarcane grown on Kapaa soil benefited from the application of silicates. Cultivated Kapaa soils may have received heavy applications of P fertilizer. To exclude the possibility of bias from fixed fertilizer P, virgin Kapaa soil was used.

The hypothesis under investigation in the current experiment was that Si influences P availability and uptake and the internal P requirements by plants. Placement studies were included to study the nature of the P - Si interaction in the plant and in the soil.

REVIEW OF LITERATURE

Though the essentiality of silicon in plant nutrition has not yet been established, there have been numerous reports that plants do better in the presence of silicon. Many workers agree that the beneficial effects are due to increased P availability to plants, but differ in their theories regarding the nature of the P - Si interaction.

Hall and Morrison (1906) believed that Si increases the assimilation of P by plants and that the seat of action was in the plant rather than in the soil. Fisher (1929) believed that the increase in yield was due to increased availability of P in the soil and had nothing to do with P metabolism in the plant.

Taylor (1960) said that increased P availability was due to an exchange reaction in which Si displaces P from soil colloids. Unlike chloride ions, nitrite ions and sulphite ions, phosphate ions are not easily dissociated from the soil complex. Toth (1939) suggested that silicate anions released fixed phosphates from soil colloids in a reaction similar to the acidoid displacement by organic anions such as citrate and tartrate. Monovalent $H_2PO_4^-$ ions can be removed only by other strongly-adsorbed ions such as divalent arsenate or silicate (Russel, 1961).

Sreenivasan (1934) found that Si had some stimulating action on plants and that the application of Si to the soil facilitates the uptake of P from the more insoluble mineral phosphates. He concluded that this effect may be due to a "peptizing action" of colloidal SiO_2. Noda and Saito (1952) showed that there was an improvement in P utilization when colloidal silica was used as an amendment with P application.

Akhromeiko (1934) suggested that SiO_2 hastens the diffusion of P_2O_5 from difficultly-available sources by the formation of an SiO_2-P_2O_5 complex at the soil-root interface, and that this effect increased with decreasing amounts of P_2O_5. Gile and Smith (1925) examined the reactions between soluble silicates and various phosphate salts and minerals and found that phosphate solubility increased with concentration of silicate solution, length of time and lowering of pH.

Batisse (1950) found that Si always increases the solubility of the products of reactions of phosphate solutions with aluminum and iron hydroxides. Raupach and Piper (1959) concluded that Si did not change the type of reaction by which P is fixed but altered the equilibrium constants involved.

Brenchley et al. (1927) believed that Si can perform in the plant some of the functions of P and is a means of economizing on the use of that element. They obtained a significant yield increase from silica where P was inadequate but found that silica was of little value when phosphate fertilizer was used. Okuda and Takahashi (1962) suggested that Si inhibits the luxury consumption of P by rice plants.

Hunter (1965) experimented with four varieties of crops and found that the addition of calcium silicate resulted in increased availability of indigenous soil P but had no effect on phosphate fertilizer. He suggested that this was due to an anion exchange in the soil and found no evidence of Si substituted for P inside the plant.

Lemmermann *et al.* (1925) grew various crops in sand culture and found that when P_2O_5 was deficient, the addition of colloidal SiO_2 greatly increased the yield of dry matter and grain. They concluded that SiO_2 cannot replace P_2O_5 in the plant nor make up the total mineral constituents necessary but not satisfied by P_2O_5, and that increased yields were due to the presence of SiO_2 rendering the P_2O_5 more available to plants. Duchon (1925) attributed the increase in yield obtained by the above workers to the improvement in the physical condition of the soil and added that in natural soils containing sufficient colloidal material the addition of SiO_2 had no effect. Raleigh (1953) found that the application of sodium and potassium silicates increased the uptake of P only for soils with low or moderate P levels and was ineffective on soils highly deficient in P or heavily treated with phosphates.

Many workers have found that the solubility of silica is affected by the presence of other minerals, particularly phosphates.

Reifenberg and Buckwold (1954) reported that the ortho-phosphate anion was capable of effecting a significant release of silica from soils and clay minerals over and above the silica dissolved in water. Fine textured soils release more Si than coarse textured ones. The displacement of P was least at pH 7.5, and, on the acid side, silicate displacement was accompanied by phosphate fixation.

Aquaye and Tinsley (1965) observed that phosphate lowers the pH for precipitation of silica from 3 to 2 in the presence of iron and from 4 to 3 in the presence of aluminum. At pH values between 4 and 7 the silica was slightly more soluble in the presence than in the absence of phosphates. Molybdates showed effects similar to phosphates.

Iler (1955) found that silicic acid polymerizes most rapidly at pH 5 and that its solubility is affected by many polyvalent metallic ions, particularly by aluminum, a small amount of which readily precipitates polymerized silicic acid.

Jones and Handrek (1965) noted that the Si in the soil solution is present as monosilicic acid at pH below 9 and as a silicate ion above 9. Its concentration decreases with increasing pH or with increasing amounts of sesquioxides, the more so as the oxides become more amorphous.

Some work has been done to investigate the effects of Si on yield and P availability in Hawaiian soils. McGeorge (1924), followed by Montieth and Sherman (1955), observed that plants responded to silicate treatment when grown on Humic Latosols, but not on Low Humic Latosols, Dark Magnesium Clays, and Humic Ferruginous Latosols. They concluded that the increase in P uptake was associated with the mineralogical composition of the soil. Reduction in the P-fixing capacity of Humic Latosol by the application of silicon is reported by Ikawa (1956).

Suehisa *et al*. (1963) obtained no benefits when various soluble silicates were applied together with phosphate on Kapaa soil (Aluminous Ferruginous Latosol), but noted significant changes in yield and P uptake in the siliceous (15 to 25% SiO_2) Humic Latosol. The yield of Sudan grass grown on the latter was three times greater when soluble Si was applied with P than when P was applied alone. The less soluble phosphates produced greater yield increase than did the more soluble phosphates when applied together with Si.

Montieth and Sherman (1963) also reported that lime depressed yields at high pH values while calcium silicate increased yields. In a field experiment using electric furnace and basic slags on Humic, Hydrol Humic, and Aluminous Ferruginous Latosols, Ayres (1965) reported a highly-significant gain in yields of cane and sugar following the application of electric furnace slag to soil of the last named great soil group, while limestone depressed yields.

Several other workers have compared the effects of $CaSiO_3$ with those of $CaCO_3$. Toth (1939) found that the amount of electro-dialyzable phosphate was greater with the application of silicate than with lime. Dix and Rautberg (1934) reported that the availability of P was reduced by $CaCO_3$ and increased by $CaSiO_3$. Taranovskaya (1941) found that silicates of calcium and magnesium were more effective than lime in mobilizing P and reducing the aluminum content of plants. Schollenberger (1922) observed that crops with applications of $CaSiO_3$ or $CaSiO_3$ with $CaCO_3$ gave greater yields than those with $CaCO_3$ alone. Clements (1965) suggested that coral stone has an adverse effect on sugarcane grown on low silicate areas as it reduces the absorption of Si. Iler (1965) predicted that the solubilities of various forms of SiO_2 were probably negatively correlated with their densities. This was proved later by several workers. McKeaque and Cline (1963) investigated the adsorption of monosilicic acid and concluded that at least some of the amorphous silica in soils occurs as coatings at the surface of iron oxides and other substances. Law and Black (1947, 1950) observed that when phosphate solution was added to kaolinite, phosphate was fixed and silica was released. Gifford and Frugoli (1964) believed that the immediate source of Si in soil solution was solid silicic acid.

It is generally accepted that species differ widely in their capacity to absorb and benefit from Si. The gramminae are among the best accumulators. Jennings (1919) grew wheat seedlings in various colloidal jellies and found that silica jelly was of great benefit to growth. Hall and Morrison (1906) believed that Si hastened the formation of cereal grains in barley. Lipman (1938) found that sunflower and barley definitely benefited from the presence of Si, especially as regards seed production. Okuda and Takahashi (1965) found that Si had no effect on the growth of upland crops such as tomato, radish, Chinese cabbage and green onion, and that the Si uptake of rice plants was ten times that of wheat. Toth (1939) found that Si improved the yield of Sudan grass and barley but had no beneficial effect on soybean and rape. Jones et al. (1965) suggested that the leguminous species must have some mechanism for rejecting Si at the root surface.

Rice plants are particularly sensitive to Si, and the results of extensive research done by Japanese workers have led them to conclude that Si may be essential to the growth of rice plants.

Not only do species differ in Si uptake, but plants of one species absorb different amounts of Si when grown on different soils. Jones et al. (1965) reported that Si absorption in both gramminaceous and leguminous species decreased on raising the pH, but oat plants grown on different soils of the same pH contained at maturity different proportions of Si. They also found that sesquioxides lowered the Si uptake and that the proportion of Si in the plant increased progressively with age. Germer (1934) reported that the absorption of Si was increased by an excess of nitrogen and limited by potassium deficiency in the plant.

Rothbuhr and Scott (1947) showed by radio-isotope studies on wheat that added P had a "quenching" effect on Si uptake, while the presence of Si increased P uptake by 25%. Fletcher and Kurtz (1964) agreed with them that P and Si in the plant have an inverse relationship and that plant Si+P in milliequimoles tended to remain constant. Consequently, a decrease in Si uptake would cause an increase in P uptake and vice versa, showing a close relationship in their metabolism.

Mitsui and Takatoh (1963) performed radio-isotope studies on wheat and rice seedlings and found that 75% of absorbed Si was translocated to the shoots, while most of the absorbed P ramained in the roots with only 6% present in the shoots. They concluded that Si absorption by roots was performed by utilizing the energy generated by the respiratory reactions of roots.

By analyzing leaves of rice plants at different positions, Yoshida et al. (1962b) found that the mobility of Si within the plant was very slow, and, once deposited, its reutilization was very unlikely. This indicated that Si must be supplied throughout the entire period of growth. Using the infrared absorption spectrum and the solubility test in hot water, they found that a great proportion (90%) of the Si in the plant was in the form of silicagel and polysilicic acid, with only 10% in the form of dispersed-state silicon and colloidal silicic acid.

Engel (1953) demonstrated that organic complexes of silica were present in rye straw. The SiO_2 initially accumulated in the roots and later in the stalks of wheat seedlings, where it remained when the supply was stopped. In contrast, P was fairly equally distributed in the various tissues and rapidly disappeared from the lower leaves as soon as the supply became deficient.

Histo-chemical studies on rice plants by the HF etching method (Yoshida et al., 1962a) reported that Si was deposited in the leaf blade, leaf sheath, stem, roots and husk. In the leaf blade, the density of silicified bulliform cells was maximum at 1 cm. from the tip and decreased towards the base. Baba (1957), while agreeing with the above, also mentioned that these cells were concentrated in the surface rather than in the dorsal epidermis. In the leaf sheath and stem, Si was localized in the vascular bundles and along the cell walls with the heaviest deposition in the outer epidermis. Root Si was heaviest in the exodermis and central cylinder. In the husk 20% of the dry matter is Si and acts as a cementing agent filling up the interspaces in the spiral structure of the epidermal cells. The fact that Si content is high in the transpiratory organs of the plants and remarkably low in the absorptive organs, suggests that Si localization is related to transpiration.

Germer (1934) found that Si deposition varies directly with transpiration. Richardson *et al.* (1959) agree with Jones *et al.* (1965) who observed the passive uptake of Si in the transpiration stream of oat plants.

Silicon is considered to have many beneficial effects, quite apart from its influence on P availability. According to Schollenberger (1922), deposition of silica causes hardening of outer walls of plant stems, sharpening of edges of leaf blades, and stiffening of hairs, all of which are protecting agents.

Okuda and Takahashi (1965) found that the presence of Si inhibits iron and manganese uptake of plants, thus increasing the P:Fe and P:Mn ratios in plants. Halais and Parish (1964) experimented with sugarcane in Mauritius and found that the manganese content in the plant was moderately low for basalt-derived soils on which the sheaths show a high silica content. Khan and Roy (1964) found that Si increased yield and quality of fibre in jute plants.

Raleigh (1934) reported that barley plants deficient in silica were severely attacked by mildew and that damping off of beet seedlings was corrected by the addition of Si. Grosse and Brauckmann (1958) found that mildew in barley was controlled by repeated soil treatments with sulphur and soluble silicon dioxide. Leaf freckle and ring spot, in sugarcane, in low silicate areas were corrected by silicate applications (Clements, 1965).

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

Volk et al. (1957) found that the resistance to blast corresponds to an increase in the silicon content of the leaf. Silicon accumulation is an important factor in the resistance to rice bohler (Sasamoto, 1957).

Japanese workers have found that "Akiochi", a well-known physiological disease affecting rice plants was corrected by silicate application. They believe that the presence of a double layer of cuticular silicon and a silica cellulose membrane, deposited in the husk and the outer epidermal cells and leaves, acts as a protective measure in resisting pathological organisms and entomological pests.

MATERIALS AND METHODS

The experiment was divided into two parts: (1) Several plant species were grown in Kapaa soil to which various combinations of P and Si had been added. Phosphorus and silicon composition and yields were measured. (2) Kikuyu grass was used to measure the availability of P and Si when these elements were mixed together in bands or in the soil as compared with separate band or soil placement.

Description of the Experimental Soil:

The soil used was a Kapaa silty clay, classified by Sherman (1958) as an Aluminous Ferruginous Latosol. It was originally classified by Cline et al. (1955) under the Halii series.

Kapaa soils are deep and well drained and occur at altitudes of 200 to 1000 feet with a mean annual rainfall ranging from 60 to 100 inches. These soils are used mainly for pasture, non-irrigated sugarcane and pineapples.

The aluminum content of this soil is high and occurs chiefly in the form of crystalline gibbsite throughout the soil profile. The upper soil profile typical of this series is described thus by Plucknett (1961):

0-6" Dark yellowish-brown clay that feels like silty clay; strong, very fine granular structure; extremely hard, firm, sticky, plastic; many roots; porous mass; few hard angular pebbles.

6-11" Dark yellowish-brown clay that feels like silty clay; many coarse and fine dark yellowish-red mottles; very fine granular structure, with mottled material moderate; very fine subangular blocky structure; firm, sticky, very plastic; many roots; very few fine pores; few worm casts; hard angular pebbles more numerous with depth.

Table 1. Mechanical and Chemical Analyses of 0-6" Virgin Kapaa Soil*

Mechanical Analysis:	
Moisture content	53.78%
Inorganic fraction	90.02%
Sand	13.51%
Clay (<2μ)	54.70%
Fine silt (<5μ)	9.29%
Medium silt (<20μ)	0.21%
Plastic index	5.65
Specific gravity	3.00
Bulk density	1.02
Moisture equivalent	46.82%
15 bar (HOH)	28.30%
Mineralogy: X-ray identified only gibbsite	
Chemical Analysis:	
pH	4.3
Exchangeable P	5.88 ppm
Exchangeable Si	25.6 ppm

*Average of 3 samples.

Experimental Design:

Two complete factorial experiments with two replications were laid out in randomized block designs and rerandomized occasionally to minimize variability from light and positional effects. The first test was a 3x4x5 experiment in which the variables were three rates of P, four rates of Si, and five species. The second was a 2x2x3 experiment using kikuyu grass in which the variables were two rates of P, two rates of Si, and three placements.

Potting Procedure:

The experimental soil was obtained from the bauxite reclamation area in Kauai. It was screened through a 1/4-inch mesh sieve and stored in polyethylene bags. Samples were drawn for moisture determination and for the preparation of titration curves with $CaCO_3$ and $CaSiO_3$.

Rates and concentration of the blanket applications and variable treatments are given in Tables 2 and 3. In order to adjust the initial pH to 6 in all pots, $CaCO_3$ was added in appropriate amounts to the various levels of Si ($CaSiO_3$) treatments. Soils were mixed with the appropriate amount of lime and fertilizer in a cement mixture. Phosphorus and silicate were added as follows:

Experiment 1: The quantity of silicate treated soil for each pot (2838 grams) was spread evenly on a thick polyethylene sheet, 25 ml. of a phosphoric acid solution of the required strength was

Table 2. Rates and Concentrations of Blanket Applications of Fertilizer Added to Kapaa Soil on an Oven Dry Soil Basis

Element	Rate	Concentration	Source
N	200 lbs/A	100 ppm	Urea
K	400 lbs/A	200 ppm	Muriate of Potash
B	3.2 lbs/A	1.6 ppm	Boric Acid
Mg	100 lbs/A	50 ppm	Magnesium Sulphate
Zn	40 lbs/A	20 ppm	Zinc Sulphate

Table 3. Rates and Concentrations of Variable P and Si Treatments Applied to Kapaa Soil on an Oven Dry Soil Basis

Element	Rate	Concentration	Source
P	200 lbs/A	100 ppm	Phosphoric Acid
	500 lbs/A	250 ppm	
	2000 lbs/A	1000 ppm	
Si	0.1 tons/A	100 ppm	Calcium Silicate
	1.0 tons/A	1000 ppm	
	4.0 tons/A	4000 ppm	

added and mixed thoroughly with the soil by rolling the plastic sheet.

Experiment 2:

Placement 1: Si and P mixed with the whole soil.

Placement 2: Si and P were mixed into a common layer. A 1 cm. layer of soil was taken and mixed with solid $CaSiO_3$ and P as a solution. The treated soil was then placed 2 cm. below the surface.

Placement 3: Si and P in separate layers - A thin layer of soil mixed with P was placed 2 cm. below the surface and a layer of $CaSiO_3$ was placed 5 cm. below it.

The pots used were one gallon galvanized cans (15 cm. diameter x 17 cm. high) lined with polyethylene bags, and each contained 2270 grams on an oven dry basis. They were watered with distilled water, brought to field capacity over a period of 7 to 10 days and thereafter adjusted to near field capacity by daily weighings. Two treatments, P-none - Si-none and P-none - Si-4 tons were included in the experimental design but were not included in the statistical interpretation.

Planting:

Single node cuttings of kikuyu grass from healthy stems were pre-rooted between layers of moist paper towels. Six cuttings were planted in each pot, and all plants were trimmed to a uniform height of 2 cm. at the time of thinning. Six seeds of corn (Texas 26) were dibbled 4 cm. below the surface of each pot. Six uniform corms of sedge obtained from the Quonset area were buried 3 cm. below the surface of each pot. Seeds of Desmodium intortum, tomato (Hybrid N57), and Mimosa pudica were sown 2 cm. below the surface.

Age and number of plants in each pot at time of thinning are given in Table 4.

Harvesting:

Plants were harvested leaving a stubble of 2 cm. after the final harvest roots of corn plants were collected for analysis. Time of harvest and number of cuttings taken are given in Table 4. Harvested plants were rinsed in a 0.01% detergent (Dreft) solution. This was followed with three rinsings in distilled water. The samples were then placed in labeled paper bags and dried for three days in an oven at 75°C. They were then weighed, ground in a Wiley mill and stored in tightly sealed glass bottles.

Subsequent Fertilizer Treatments:

The second crop of kikuyu grass was given an additional 100 ppm of nitrogen in the form of urea, and the third crop a further 100 ppm of nitrogen and 200 ppm of potassium in the form of muriate of potash, applied in 25 ml. solution, pipetted into each pot.

Table 4. Planting and Harvesting Schedule for Species Under Study

Species	Date of Planting	Age at Thinning	Plants Per Pot	Age at Harvest	
Kikuyu grass	6.24.1966	22 days	3	1st cutting	42 days
			3	2nd cutting	26 days
			3	3rd cutting	23 days
Corn - Texas 28 (Maize)	6.24.1966	9 days	3	1st harvest	30 days
			2	2nd harvest	40 days
Desmodium intortum	8.15.1966	8 days	6	1st cutting	35 days
			5	2nd cutting	28 days
Sedge (*Cyprus rotundus*)	7.29.1966	12 days	3	1st cutting	45 days
			3	2nd cutting	60 days
Tomato Hybrid N-57	8.15.1966	7 days	7		27 days
Mimosa pudica	9.17.1966	16 days	6		75 days

Since the plant crop of Desmodium had shown symptoms of micro-nutrient deficiency, a foliar spray of the following composition was used on the second crop:

0.026 % of Fe as iron chelate
0.024 % of Mn as manganese chelate
0.028 % of Zn as zinc chelate
0.0058% of Cu as copper chelate
10 ppm of Mo as sodium molybdate

Mimosa pudica showed symptoms of nitrogen deficiency and was treated with 100 ppm of nitrogen in the form of urea.

Analytical Methods:

1. Plant Analysis: Plant material was analyzed to determine concentrations of phosphorus, silicon, calcium and aluminum.

The wet digestion method was used in the determination of total P, Ca and Al. One gram of dried ground plant sample was weighed into a micro-Kjeldahl flask, to which 15 ml. of 2:1 nitric-perchloric acid mixture was added. The mixture was swirled to wet the sample and allowed to stand overnight. It was digested for thirty minutes at low heat on a micro-Kjeldahl digestion rack. When all the copious nitric oxide fumes were driven out, the temperatures were raised. Perchloric acid begins to boil at 203°C (dense white fume stage). After 10 minutes of boiling in the white fume stage, heat was reduced and the flasks allowed to cool. The digest was diluted with distilled water and made to volume in a 50 ml. volumetric flask and stored in plastic vials.

Phosphorus content was determined by the vanadate-molybdate yellow method. A suitable aliquot was transferred to a 50 ml. volumetric flask and distilled water added until the flask was two-thirds full. Five ml. of vanado-molybdate solution (Barton's reagent) (Chapman and Pratt, 1961) was added and made to volume, shaken, and read on a Coleman spectrophotometer at a wavelength of 430 millimicrons after a lapse of thirty minutes. The concentration was obtained by reference to a standard curve.

Calcium content was determined by EDTA titration using ammonium purpurate as the indicator (Diehl et al., 1959). The EDTA solution was standardized with standard calcium solution. One ml. of 4N sodium hydroxide was added to a 10 ml. sample and titrated with the EDTA solution with ammonium purpurate as the indicator. Color change is from orange red to lavender or purple. When near the end point the EDTA was added at the rate of about one drop every 5 to 10 seconds. As the color change is not instantaneous, a blank standing nearby containing sodium hydroxide ammonium purpurate, with a drop or two of EDTA, aids in distinguishing the end point.

The aluminon method as described by Chapman and Pratt (1961) was used to determine the Al content. A suitable aliquot was transferred to a 50 ml. volumetric flask and diluted to 20 ml. with distilled water. Two ml. of 1% thioglycolic acid and 10 ml.

of aluminon reagent were added. The mixture was poured into a 50 ml. beaker, adjusted to pH 4.2 with 1:1 NH_4OH and returned to the same flask. Color was developed by heating the solution in a steam bath for 16 minutes. Flasks were allowed to cool to room temperature and made to volume. Color intensity was measured on a Coleman spectrophotometer at 537.5 millimicrons. The concentration of aluminum was obtained by reference to a standard curve.

The extract for the determination of total Si was prepared by the modified fusion method (R. L. Fox, unpublished). One-half gram samples of oven dried plant material were weighed into nickel crucibles and ashed overnight in a muffle furnace at 550°C. Five ml. of 15% NaOH was added to the cooled ash and evaporated to dryness overnight at low heat. The crucible was covered and heated with a Meeker burner to dull redness for 5 minutes and then rotated with nickel tongs to solidify the melt on the sides. The melt was allowed to dissolve overnight in 40 ml. of distilled water. The digest was transferred to a 250 ml. plastic beaker containing 10 ml. of 6N HCl and 100 ml. of distilled water. This was allowed to stand for 10 minutes, stirred, and poured into a 250 ml. volumetric flask and made to volume. A 50 ml. aliquot was stored in a plastic vial.

Silicon was determined by the blue silico-molybdate method (Kilmer, 1965). A suitable aliquot was taken in a 50 ml.

volumetric flask and distilled water was added until the flask was about two-thirds full. One ml. of ammonium molybdate solution[1] was added and mixed during addition. Thirty minutes were allowed for color development. Three ml. of 10% oxalic acid solution were added, care being taken to allow it to run down the ground glass neck of the flask to destroy any phospho-molybdate compound formed there. After two minutes, 1 ml. of reducing solution[2] was added with force and mixed well. Distilled water was added to volume and mixed again. Thirty minutes were allowed for color development, and the optical density was read at 660 millimicrons. The concentration was obtained with reference to a standard curve.

A trichloroacetic acid (TCA) extraction method (R. L. Fox, unpublished) was used to determine the soluble P and Si in the corn plants harvested at 30 days and in the sheaths of corn plants harvested at 40 days. A 5 g sample was extracted with 100 ml. of 2% TCA in a Waring blender (Osterizer) for 10 minutes and filtered through No. 42 Whatman filter paper. The

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[1] 7.5 g of ammonium molybdate was dissolved in 75 ml. of water. Ten ml. of 18N H_2SO_4 was added, and the solution was diluted to a volume of 100 ml. with water.

[2]-0.7 g of sodium sulphite was dissolved in 10 ml. of water. 0.15 g of 1-amino-2-napthal-4-sulphuric acid was added and stirred to dissolve. To this was added 9 g of sodium bisulphite dissolved in 90 ml. of water.

extract was stored in plastic vials in a refrigerator. A 5 ml. aliquot of the TCA extract and about 35 ml. of water was added. Five ml. of ammonium persulphate was added, and color was developed for Si by the blue silico-molybdate method used in the determination of total Si. The vanadate-molybdate yellow method described earlier was used to determine the P content.

Since the quantity of plant material obtained from the check pots was small, the concentrations of both P and Si had to be estimated from a single digestion. A modification of the lithium metaborate method developed by Suhr and Ingamells (1966) was used. Two-thirds gram of 20 mesh ground oven dried sample was placed in a platinum crucible and left overnight in a muffle furnace at 550°C. After cooling, 1 gram of lithium metaborate was added and mixed thoroughly with a platinum rod. The mixture was transferred to a graphite crucible and placed in a muffle furnace at 950°C for 15 minutes. The melt was poured into a 250 ml. beaker containing 25 ml. of dilute nitric acid (1:25). A further 50 ml. of nitric acid were added and stirred with a magnetic stirrer. The clear solution was transferred to a 100 ml. volumetric flask and made to volume. A 50 ml. aliquot was stored in a plastic vial. The concentration of P and Si was determined by the vanadate-molybdate yellow method and the blue silico-molybdate method, respectively.

2. Soil Analysis was done to determine the extractable native P and extractable Si before and after the application of blanket treatment and $CaSiO_3$ and $CaCO_3$.

Soil samples were air dried and passed through 2 mm mesh sieves and stored in glass jars. The soil was extracted by the modified Truog method of Ayres and Hagihara (1952). To 1 gram of oven dried soil in a 500 ml. Erlenmeyer flask, 100 ml. of extracting solution (0.02N H_2SO_4 + 3 g $(NH_4)_2SO_4$/litre) was added. The flask was stoppered and shaken in a mechanical shaker for half an hour. The suspension was filtered through No. 42 Whatman filter paper and the filtrate stored in plastic vials. Silicon was determined by the blue silico-molybdate method.

The Dickman and Bray method as described by Chapman and Pratt (1961) was followed to determine extractable soil P.

Titration curves with $CaSiO_3$ and $CaCO_3$: Twenty-five grams of oven dried soil were weighed into 150 ml. beakers to which were added $CaCO_3$ at the rates of 0, 1, 2, 4, and 8 tons per acre, and $CaSiO_3$ at the rates of 0, 0.1, 1.0, and 4.0 tons per acre. Water was added to maintain a soil:water ratio of 1:2.5, the mixture stirred and allowed to equilibriate for eight days. The pH of the soil contained in each beaker was determined by the use of a Beckman pH meter. Titration curves are given in Figure 1.

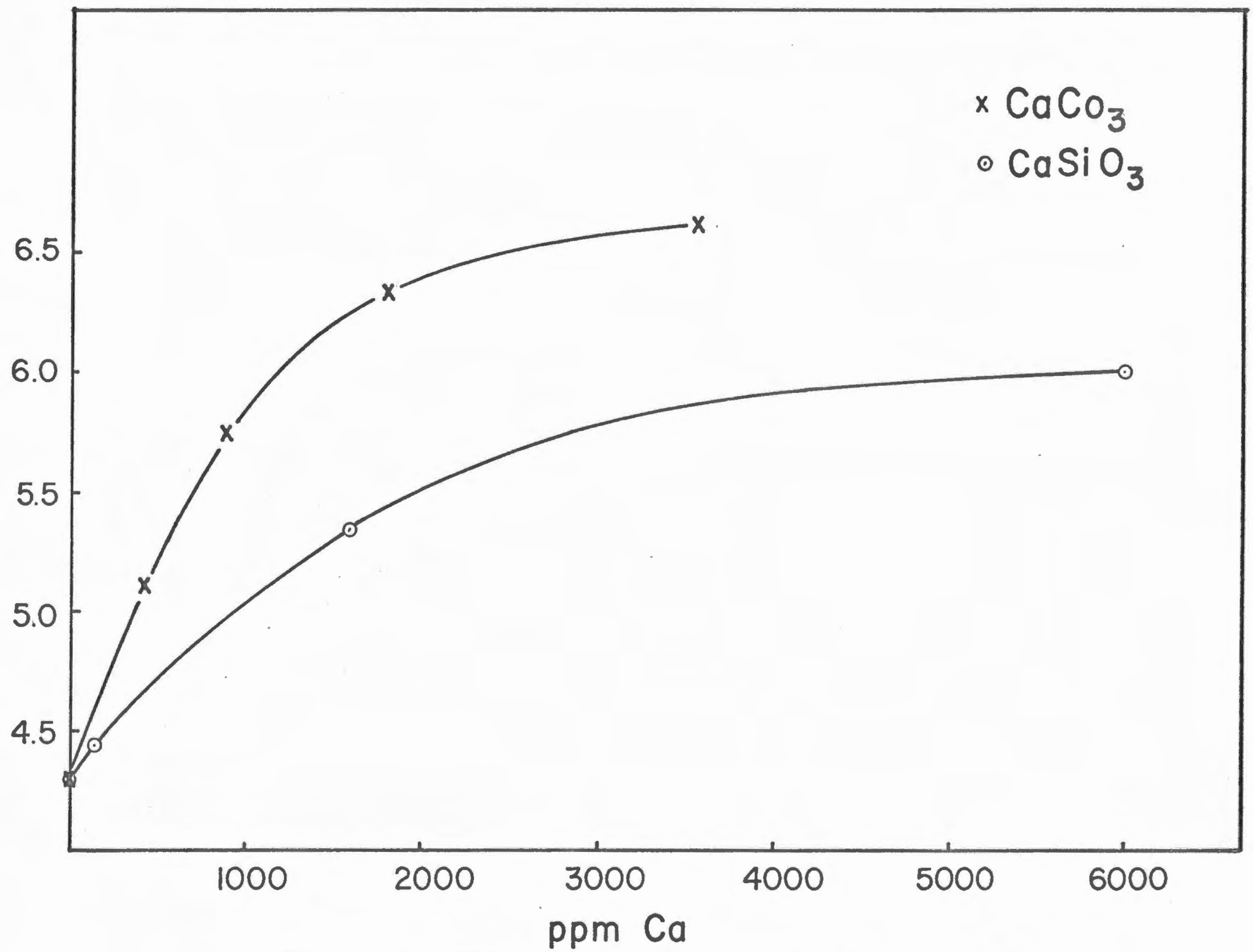

Figure 1. Titration Curve Using $CaCO_3$ and $CaSiO_3$

Soil pH was determined from a composite sample obtained from all pots after harvesting. To a 25 gram sample of field moist soil, 25 ml. of water were added. The suspension was stirred at regular intervals for 1 hour and the pH measured with a glass electrode (Beckman Model-N).

RESULTS AND DISCUSSION

Yield:

The first cutting yield of kikuyu grass was increased by P fertilization (Table 5, Figure 2). The greatest yield increase between P rates of 200 and 2000 lbs. per acre was at the Si rate of 0, followed by 4 tons. At the 200 lbs. rate of P, there was no marked response for Si, as the yields for all four rates were nearly equal. Plants receiving 500 lbs. of P showed a marked increase for the 4 tons of Si. Of the plants receiving 2000 lbs. of P, the yields were highest at 0 Si. The over-all yields were lowest with the 1 ton rate of Si. Moreover, Figure 2 suggests that with P rates of 500 lbs. the 4 ton rate of Si increased the fertilizer P availability to the plant.

Second cutting yields did not correspond to rates of P application, greater than the 200 lbs. of P. The highest yields were obtained from pots receiving P rates of 200 and 500 lbs. with 0.1 ton of Si (Table 5, Figure 3).

Third cutting - 500 lbs. rate of P resulted in higher yields than 200 lbs. P, but the yields decreased when P applications were increased to 2000 lbs., with the exception of yields at 0 Si (Table 5). At each increment of P, yields were highest with 4 tons rate of Si, including the yields of the check pots (Figure 4). Furthermore, this suggests that silicate response was pronounced

Table 5. Effect of Calcium Silicate and Phosphorus on the Yield, Phosphorus Content and Silicon Content of Kikuyu Grass Grown on Kapaa Soil[1/]

Treatment		Yield	Phosphorus		Silicon		
Si tons/A	P lbs/A	g/pot	%	mg/pot	%	mg/pot	P/Si
			First Cutting				
None	0*	0.95	0.168	1.596	0.058	0.551	2.896
	200	2.73	0.268	7.31	0.066	1.80	4.06
	500	4.27	0.218	9.30	0.080	3.42	2.73
	2000	8.17	0.380	31.05	0.098	8.01	3.88
0.1	200	2.86	0.282	8.06	0.154	4.40	1.83
	500	4.75	0.252	11.97	0.128	6.08	1.97
	2000	6.75	0.456	30.37	0.176	11.88	2.59
1.0	200	2.03	0.288	5.85	0.514	10.43	0.56
	500	4.15	0.262	10.87	0.394	16.35	0.66
	2000	4.99	0.428	21.36	0.400	19.96	0.93
4.0	0*	0.81	0.196	1.587	0.138	1.118	1.42
	200	2.33	0.258	6.01	0.904	21.06	0.29
	500	6.38	0.260	16.59	0.820	52.32	0.32
	2000	7.03	0.430	30.23	0.724	52.85	0.59
			Second Cutting				
None	0*	1.01	0.138	1.394	0.056	0.566	2.46
	200	6.14	0.214	13.13	0.038	2.33	5.63
	500	5.88	0.346	20.34	0.042	2.47	8.24
	2000	6.72	0.336	22.58	0.102	6.85	3.29
0.1	200	6.85	0.210	14.38	0.092	6.30	2.28
	500	7.46	0.324	24.17	0.102	7.61	3.18
	2000	5.73	0.332	19.02	0.174	9.97	1.91
1.0	200	4.93	0.246	12.13	0.324	15.97	0.76
	500	6.73	0.330	22.21	0.288	19.38	1.15
	2000	5.20	0.316	16.43	0.430	22.36	0.73
4.0	0*	1.06	0.168	1.78	0.124	1.31	1.35
	200	6.08	0.238	14.47	0.554	33.68	0.43
	500	6.29	0.368	23.15	0.730	45.92	0.50
	2000	6.91	0.350	24.19	0.852	58.87	0.41

* Check pots - not included in experimental design.

[1/] Mean of two replicates. For complete details see Appendix tables.

Table 5. Effect of Calcium Silicate and Phosphorus on the Yield, Phosphorus Content and Silicon Content of Kikuyu Grass Grown on Kapaa Soil[1/] (Continued)

Treatment		Yield	Phosphorus		Silicon		
Si tons/A	P lbs/A	g/pot	%	mg/pot	%	mg/pot	P/Si
			Third Cutting				
None	0*	0.72	0.138	0.99	0.032	0.23	4.31
	200	6.08	0.220	13.38	0.092	5.59	2.39
	500	7.78	0.266	20.69	0.098	7.62	2.71
	2000	8.85	0.212	18.76	0.164	14.51	1.29
0.1	200	7.71	0.194	14.96	0.220	16.96	0.88
	500	8.56	0.264	22.60	0.192	16.43	1.38
	2000	7.96	0.238	18.94	0.232	18.47	1.03
1.0	200	6.92	0.244	16.88	0.554	38.34	0.44
	500	9.31	0.254	23.65	0.456	42.45	0.56
	2000	6.39	0.332	21.21	0.554	35.40	0.60
4.0	0*	1.21	0.156	1.89	0.140	1.69	1.11
	200	8.90	0.292	25.99	0.798	71.02	0.37
	500	9.56	0.248	23.71	0.840	80.30	0.30
	2000	9.46	0.270	25.54	1.068	101.03	0.25

* Check pots - not included in experimental design.

[1/] Mean of two replicates. For complete details see Appendix tables.

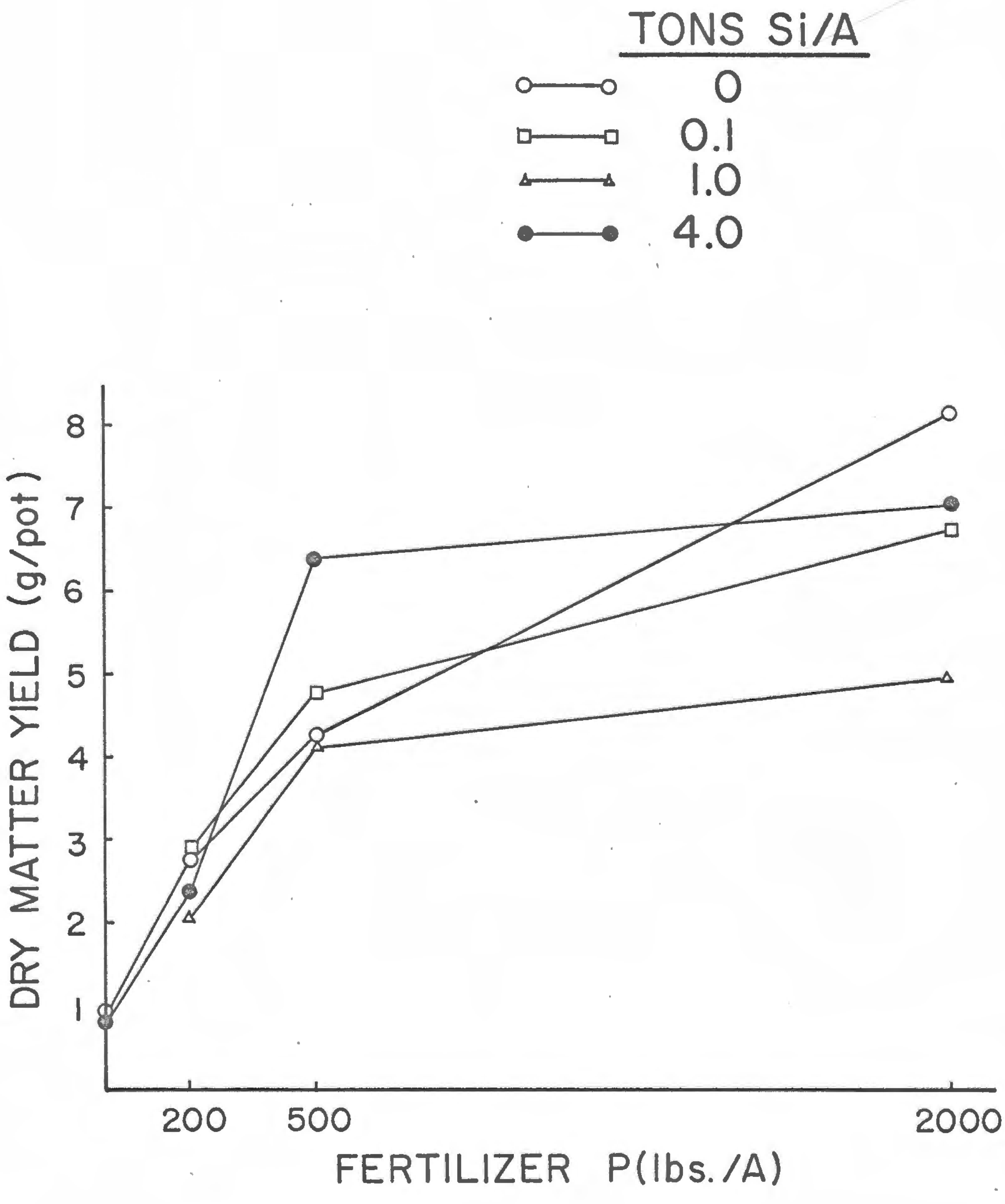

Figure 2. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of Kikuyu Grass - 1st Cutting

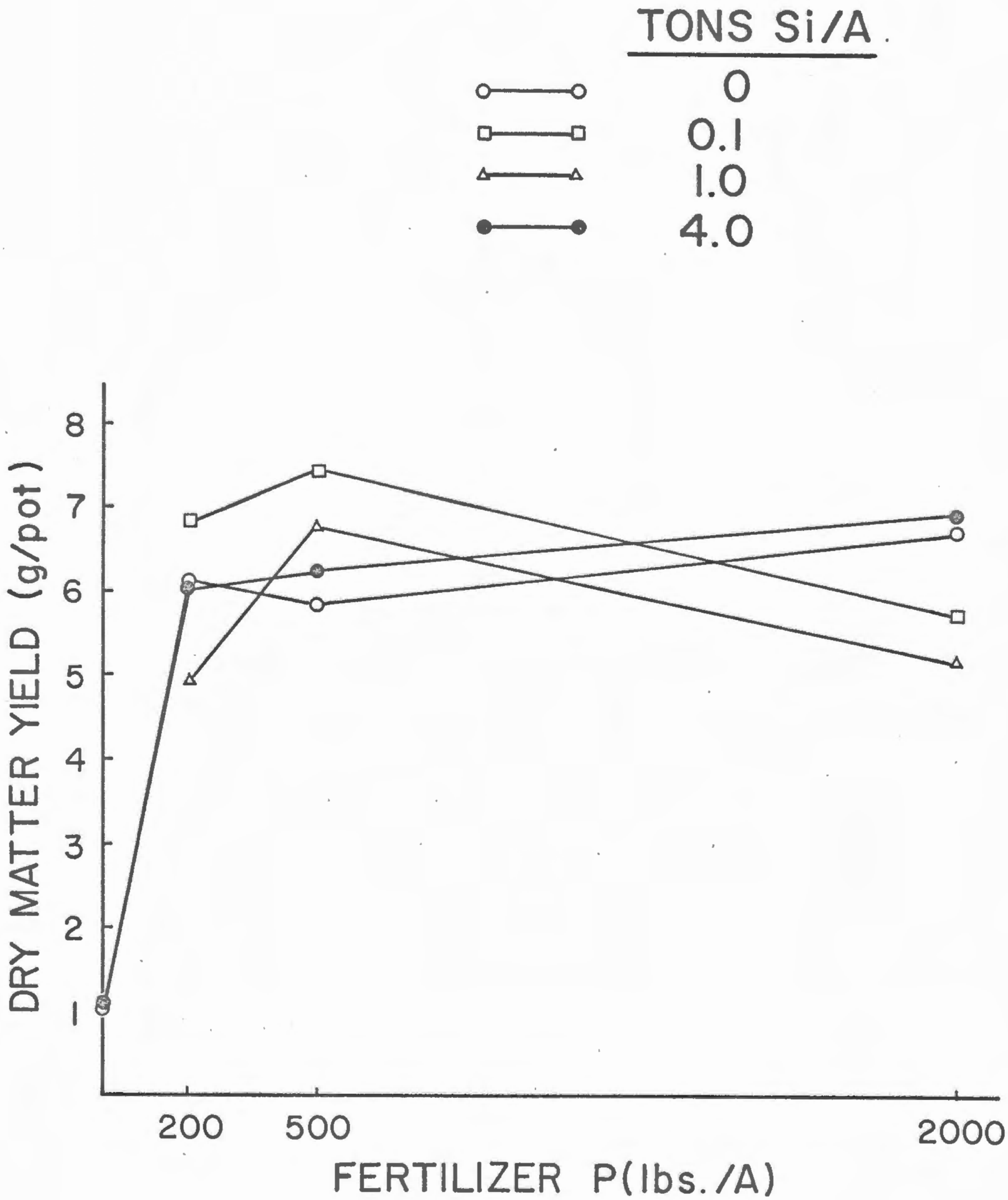

Figure 3. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of Kikuyu Grass - 2nd Cutting

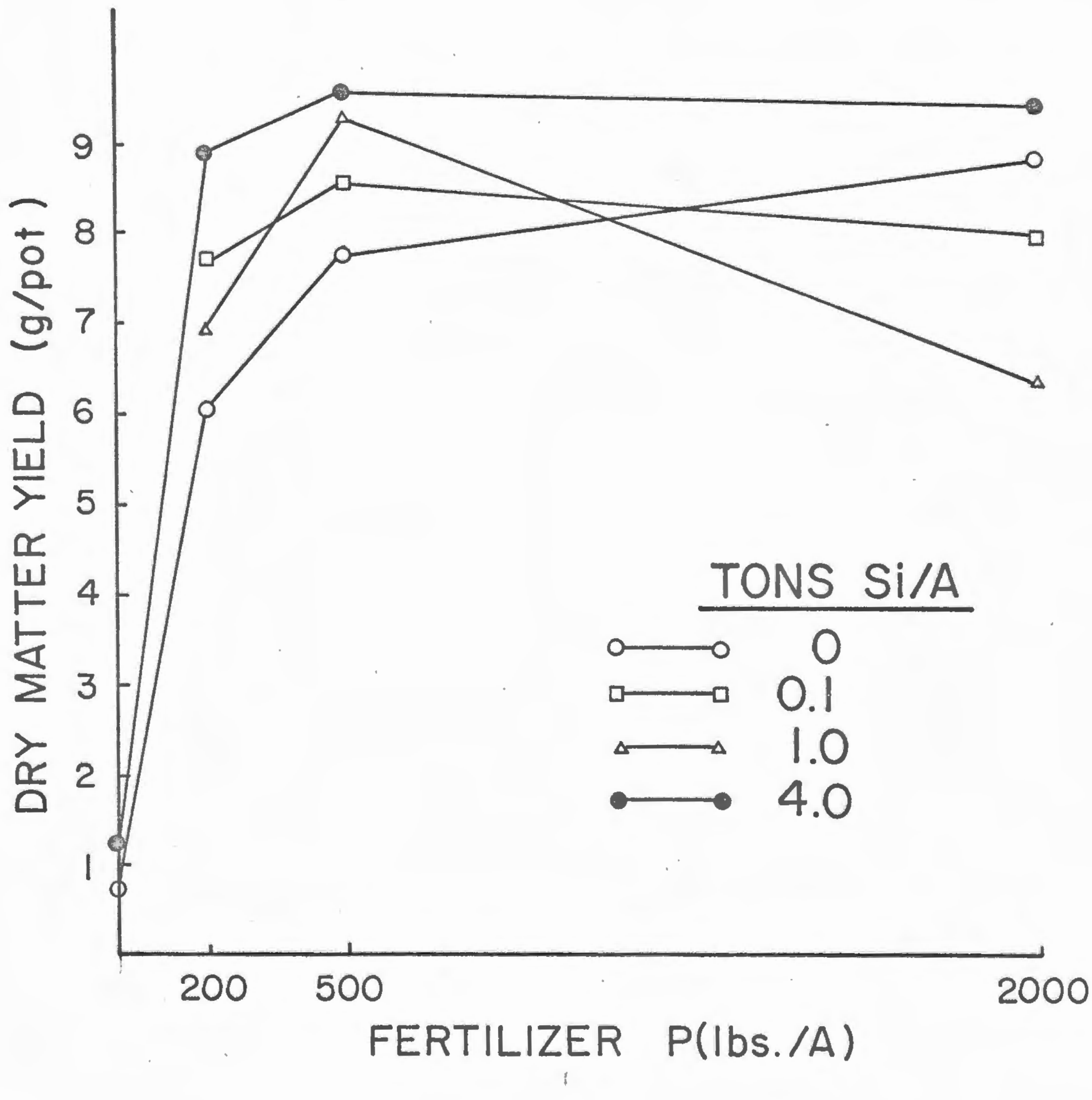

Figure 4. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of Kikuyu Grass - 3rd Cutting

with time, which was more or less independent of the P applied.

Corn plants harvested at 30 days showed a yield response for increases in P application. Over-all yields were highest with plants receiving 0 Si and lowest with 4 tons Si, with the exception of the check pots, where plants receiving 4 tons of Si gave 3-fold increase over 0 Si (Table 6, Figure 5).

Corn plants harvested at 40 days yields increased with increasing P applications (Tables 7 and 8). At the 500 lbs. rate of P, the 0.1, 1.0, and 4.0 tons rate of Si gave higher yields than 0 Si, but with 2000 lbs. of P, 0 Si gave the highest yield. The 0 Si plant showed an appreciable increase in yield, when P was increased from 500 lbs. P to 2000 lbs. of P; moreover the Si treated plants did not show this difference (Figure 6). This indicates that Si decreased the internal P requirement of the corn plant.

The first cutting yield of Desmodium intortum was increased by P fertilization (Table 9, Figure 7). At P rates of 500 lbs. there were increases in yield for the Si application, yields at 4 tons > 1 ton > 0.1 ton > 0.

The second cutting yield of Desmodium intortum did not appear to increase with P application. Of the three rates of P, 500 lbs. gave the highest yields, with yields increasing with increasing Si applications. However, at the 200 lbs. and the 2000 lbs. rates of P, yields decreased with Si application (Table

Table 6. Effect of Calcium Silicate and Phosphorus on the Yield, Phosphorus and Silicon Content (Total and TCA[1] Extractable) of Corn (30 Days) Grown on Virgin Kapaa Soil

Treatment				Phosphorus		Silicon		
Si tons/A	P lbs/A	Yield g/pot	Extract	%	mg/pot	%	mg/pot	P:Si
None	0*	0.22	Total	0.168	0.37	0.024	0.05	7.00
	200	1.73	TCA	0.028	0.485	0.002	0.035	14.00
			Total	0.180	3.114	0.184	3.183	0.98
	500	3.09	TCA	0.022	0.679	0.002	0.062	11.00
			Total	0.186	5.747	0.196	6.056	0.95
	2000	5.62	TCA	0.010	0.562	0.003	0.168	3.33
			Total	0.220	12.364	0.142	7.980	1.55
0.1	200	1.80	TCA	0.020	0.359	0.002	0.036	10.00
			Total	0.202	3.636	0.348	6.264	0.58
	500	2.63	TCA	0.016	0.421	0.003	0.079	5.33
			Total	0.194	5.102	0.354	9.310	0.55
	2000	4.64	TCA	0.022	1.018	0.003	0.139	7.33
			Total	0.302	14.013	0.234	10.858	1.29
1.0	200	1.97	TCA	0.024	0.472	0.004	0.079	6.00
			Total	0.166	3.270	1.480	29.156	0.11
	500	2.84	TCA	0.018	0.511	0.005	0.142	3.60
			Total	0.224	6.362	1.092	31.013	0.21
	2000	5.53	TCA	0.012	0.663	0.005	0.276	2.40
			Total	0.234	12.940	0.524	28.977	0.45
4.0	0*	0.62	Total	0.174	1.08	0.118	0.73	1.47
	200	1.56	TCA	0.026	0.404	0.003	0.047	8.66
			Total	0.184	2.870	1.768	27.581	0.10
	500	1.97	TCA	0.020	0.393	0.006	0.118	3.33
			Total	0.178	3.507	1.342	26.437	0.13
	2000	5.00	TCA	0.018	0.900	0.004	0.200	4.50
			Total	0.254	12.700	1.388	69.40	0.18

* Check pots - not included in experimental design.

[1] All values pertaining to TCA extractable P and Si are on a fresh weight basis.

NOTE: Both replications were composited for corn plant harvested at 30 days.

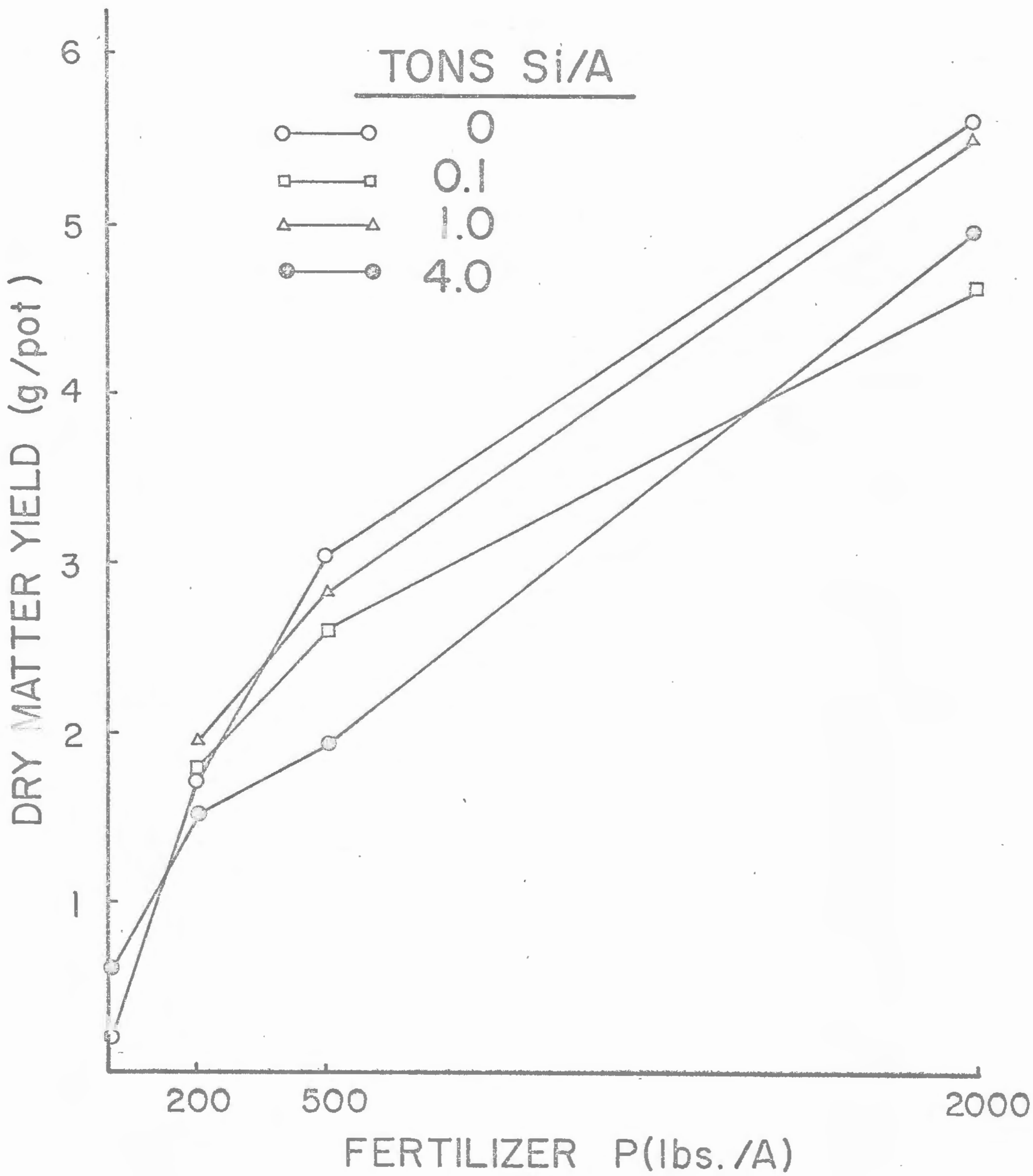

Figure 5. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of Corn - Harvested at 30 Days

Table 7. Effect of Calcium Silicate and Phosphorus on the Yield, Phosphorus and Silicon Content (Total and TCA[1/] Extractable) of Corn (Sheaths - 40 Days Old) Grown on Kapaa Virgin Soil*

Treatment				Phosphorus		Silicon		
Si tons/A	P lbs/A	Yield g/pot	Extract	%	mg/pot	%	mg/pot	P:Si
None	200	1.65	TCA	0.005	--	0.001	--	5.00
			Total	0.088	1.452	0.162	2.675	0.54
	500	2.24	TCA	0.005	--	0.001	--	5.00
			Total	0.105	2.352	0.178	3.987	0.59
	2000	3.06	TCA	0.006	--	0.002	--	3.00
			Total	0.092	2.815	0.314	9.608	0.29
0.1	200	1.91	TCA	0.005	--	0.002	--	2.50
			Total	0.068	1.299	0.298	5.692	0.23
	500	2.69	TCA	0.007	--	0.002	--	3.50
			Total	0.074	1.991	0.352	9.469	0.21
	2000	3.04	TCA	0.008	--	0.002	--	4.00
			Total	0.080	2.432	0.426	12.950	0.19
1.0	200	2.11	TCA	0.005	--	0.003	--	1.66
			Total	0.084	1.772	0.774	16.331	0.11
	500	2.55	TCA	0.005	--	0.003	--	1.66
			Total	0.090	2.295	0.918	23.409	0.09
	2000	2.76	TCA	0.006	--	0.004	--	1.50
			Total	0.086	2.374	0.866	23.902	0.09
4.0	200	1.96	TCA	0.006	--	0.004	--	1.50
			Total	0.074	1.450	1.740	34.104	0.04
	500	2.76	TCA	0.005	--	0.004	--	1.25
			Total	0.076	2.098	1.700	46.920	0.04
	2000	3.43	TCA	0.009	--	0.004	--	2.25
			Total	0.096	3.293	1.404	51.450	0.07

* Mean of two replicates. For complete details see Appendix tables.

[1/] All values pertaining to TCA extractable P and Si are on a fresh weight basis.

Table 8. Effect of Calcium Silicate and Phosphorus on the Yield, Phosphorus Content and Silicon Content of Corn Grown on Kapaa Soil at 40 Days[1/]

Treatment			Phosphorus		Silicon		
Si tons/A	P lbs/A	Yield g/pot	%	mg/pot	%	mg/pot	P/Si
			Leaf and Stalk				
None	0*	2.35	0.124	2.91	0.014	0.33	8.86
	200	9.37	0.210	19.68	0.102	9.56	2.06
	500	10.52	0.258	27.14	0.114	11.99	2.26
	2000	14.20	0.204	28.97	0.200	28.40	1.02
0.1	200	11.20	0.190	21.28	0.222	24.86	0.86
	500	13.39	0.220	29.45	0.282	37.76	0.78
	2000	13.32	0.206	27.44	0.272	36.23	0.76
1.0	200	10.00	0.208	20.80	0.690	69.00	0.30
	500	13.33	0.224	29.86	0.740	102.91	0.30
	2000	13.96	0.206	28.76	0.772	107.77	0.26
4.0	0*	1.90	0.130	2.47	0.312	5.93	0.42
	200	11.16	0.218	24.33	1.516	169.18	0.14
	500	12.97	0.212	27.50	1.358	176.13	0.16
	2000	13.70	0.220	30.14	1.776	243.31	0.12
			Roots				
None	0*	1.38	0.126	1.74	0.016	0.22	7.88
	200	5.12	0.152	7.78	0.064	3.28	2.38
	500	6.85	0.162	11.10	0.158	10.82	1.03
	2000	8.99	0.152	13.66	0.180	16.18	0.84
0.1	200	6.85	0.108	10.14	0.092	6.30	1.61
	500	8.73	0.146	12.75	0.130	11.35	1.12
	2000	8.96	0.158	14.16	0.116	10.39	1.36
1.0	200	5.44	0.144	7.83	0.100	5.44	1.44
	500	7.44	0.182	13.54	0.180	13.39	1.01
	2000	8.31	0.158	13.13	0.140	11.63	1.13
4.0	0*	1.05	0.112	1.18	0.018	0.19	6.22
	200	5.47	0.164	8.97	0.226	12.36	0.73
	500	7.84	0.144	11.29	0.234	18.34	0.62
	2000	9.38	0.154	14.44	0.270	25.33	0.57

* Check pots - not included in experimental design.

[1/] Mean of two replicates. For complete details see Appendix tables.

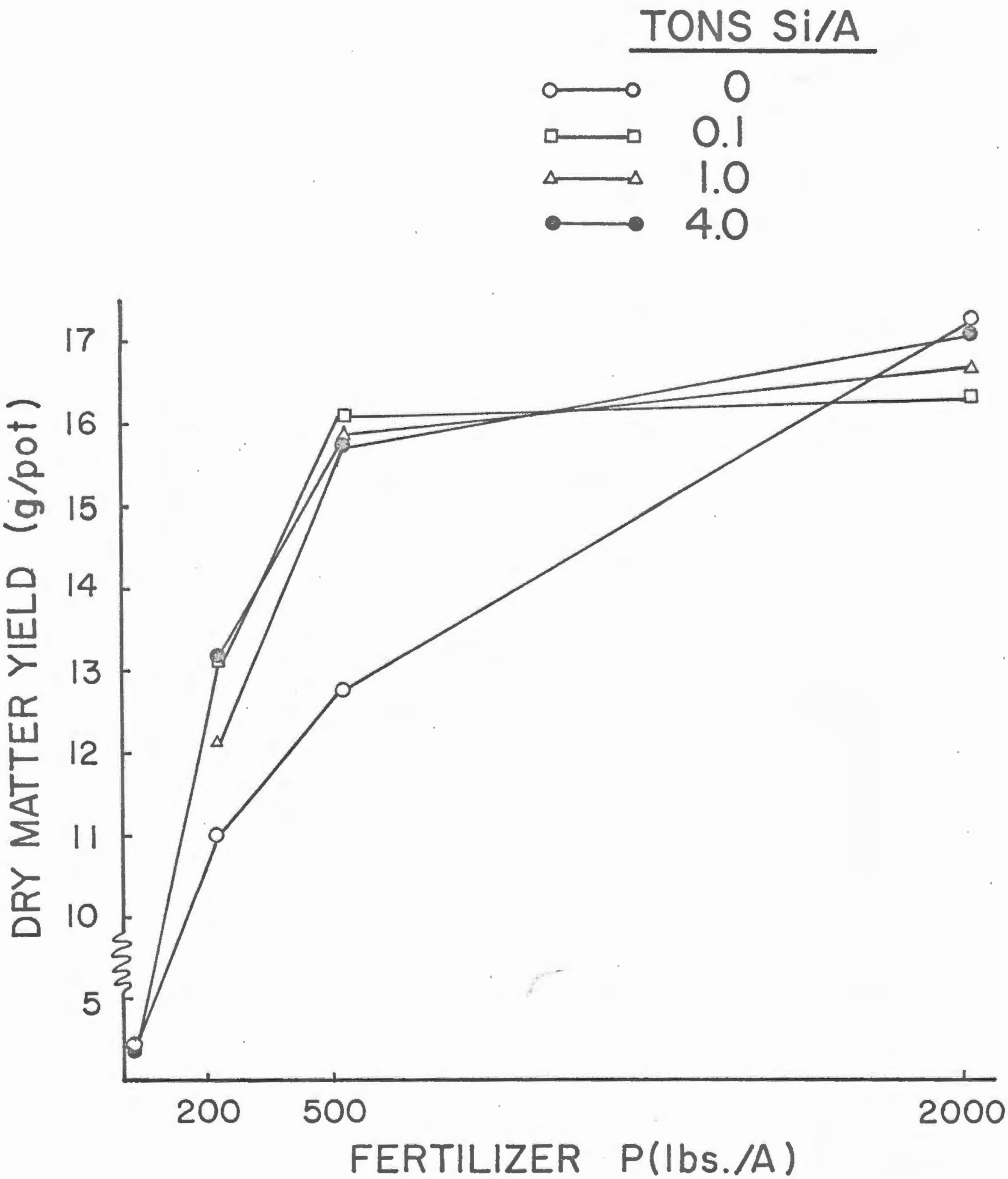

Figure 6. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of Corn - Harvested at 40 Days

Table 9. Effect of Calcium Silicate and Phosphorus on the Yield, Phosphorus Content and Silicon Content of *Desmodium intortum* Grown on Kapaa Soil[1/]

Treatment			Phosphorus		Silicon		
Si tons/A	P lbs/A	Yield g/pot	%	mg/pot	%	mg/pot	P/Si
			First Cutting				
None	0*	0.00	0.000	0.00	0.000	0.00	0.00
	200	0.56	0.306	1.71	0.068	0.38	4.50
	500	1.22	0.268	3.27	0.070	0.85	3.83
	2000	2.69	0.308	8.28	0.096	2.58	3.21
0.1	200	0.38	0.260	0.99	0.124	0.47	2.10
	500	1.28	0.268	3.43	0.150	1.92	1.79
	2000	2.92	0.320	9.34	0.216	6.31	1.48
1.0	200	0.28	0.252	0.71	0.692	1.94	0.36
	500	1.36	0.262	3.56	0.782	10.64	0.33
	2000	2.75	0.338	9.30	0.856	23.54	0.39
4.0	0*	0.00	0.000	0.00	0.000	0.00	0.00
	200	0.30	0.300	0.90	0.932	2.80	0.32
	500	1.50	0.272	4.08	1.046	15.69	0.26
	2000	2.59	0.282	7.30	1.398	36.21	0.20
			Second Cutting				
None	0*	0.28	0.210	0.59	0.028	0.08	7.50
	200	8.84	0.152	13.44	0.090	7.96	1.69
	500	9.14	0.194	17.73	0.090	8.23	2.16
	2000	8.91	0.252	22.45	0.130	11.58	1.94
0.1	200	8.21	0.200	16.42	0.184	15.11	1.09
	500	9.00	0.210	18.90	0.202	18.18	1.04
	2000	8.42	0.270	22.73	0.254	21.39	1.06
1.0	200	8.59	0.202	17.35	0.728	62.54	0.28
	500	9.36	0.230	21.53	0.578	54.10	0.40
	2000	7.71	0.276	21.28	0.878	67.69	0.31
4.0	0*	0.20	0.192	0.38	0.134	0.27	1.43
	200	7.46	0.208	15.52	1.214	90.56	0.17
	500	9.49	0.236	22.40	1.020	96.80	0.23
	2000	7.09	0.252	17.87	1.334	94.58	0.19

* Check pots - not included in experimental design.

[1/] Mean of two replicates. For complete details see Appendix tables.

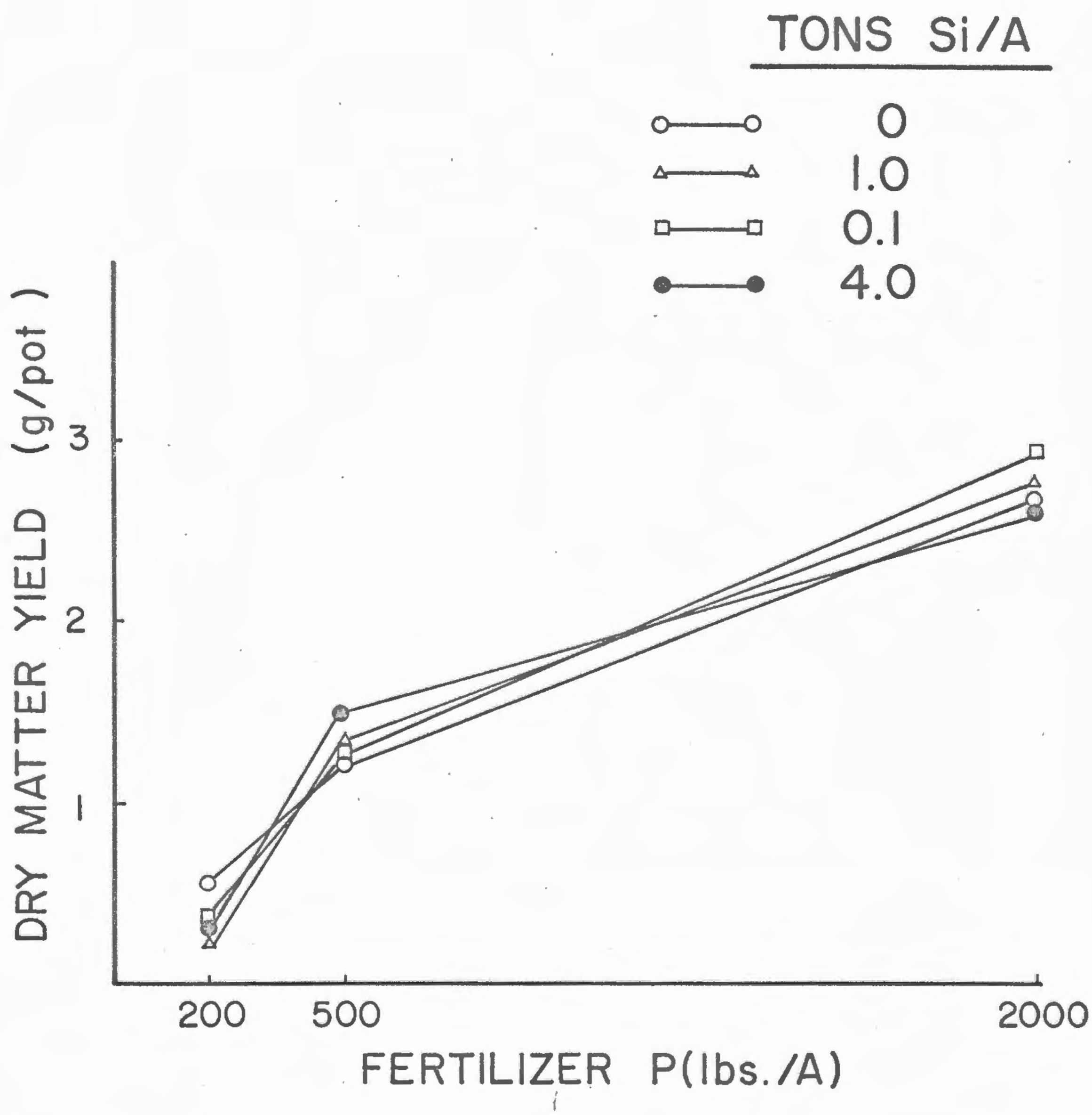

Figure 7. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of *Desmodium intortum* - 1st Cutting

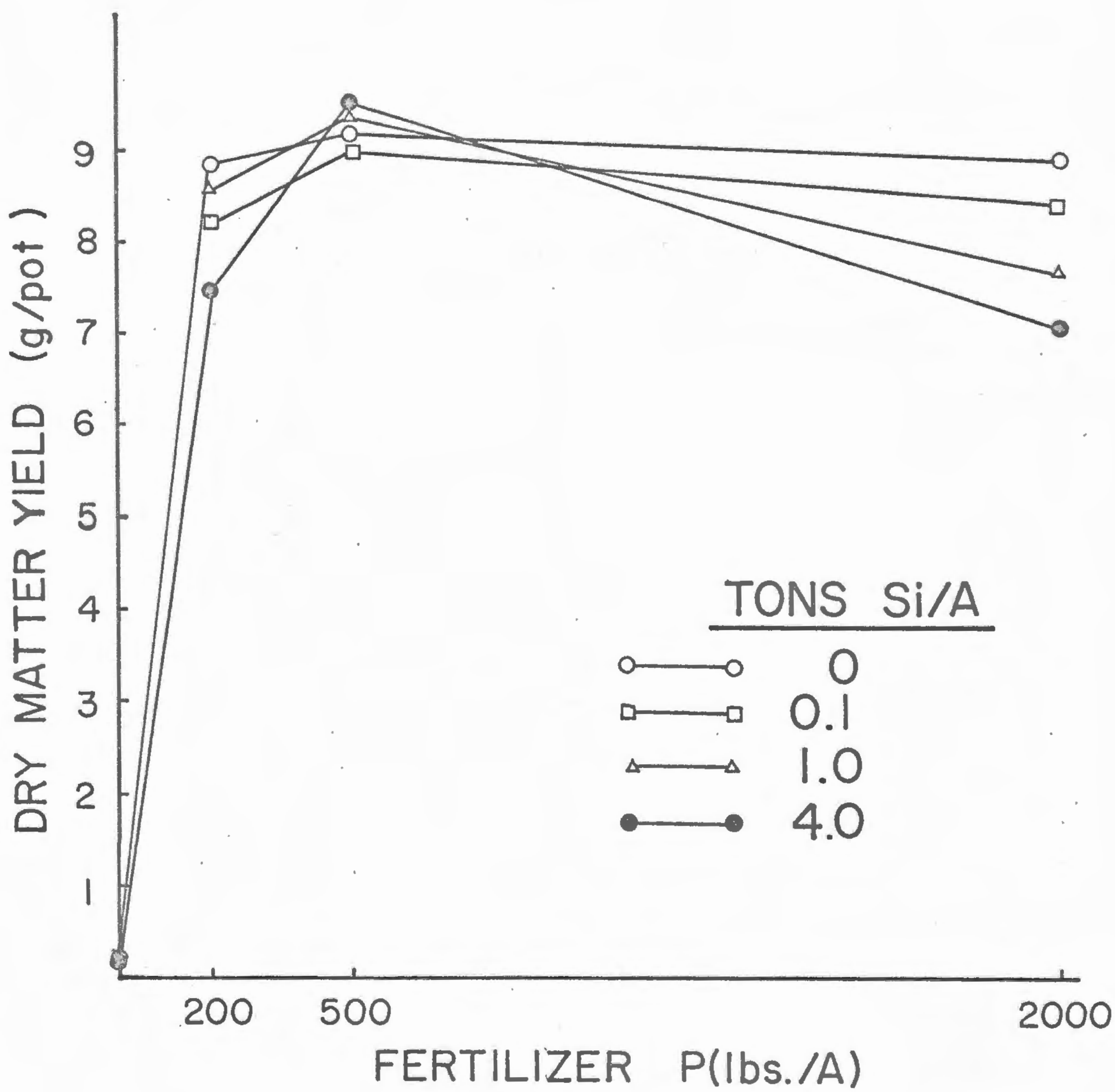

Figure 8. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of Desmodium intortum - 2nd Cutting

9, Figure 8).

Yields of the first cutting of sedge increased with increasing P applications. Silicon applications increased yields of the check pots and plants receiving 200 lbs. P. The highest yields were obtained at 4 tons of Si for P rates of 200 and 2000 lbs. (Table 10, Figure 9).

Second cutting of sedge, yields increased with P applications at the lower rates of Si (0 and 0.1 tons) and yields increased with Si applications at the lower rates of P (200 and 500 lbs.). Highest yield was at 200 lbs. P with 4 tons Si. At the 4 ton rate of Si, yields were nearly equal at all rates of P, an indication that Si may have decreased the internal P requirement of the plant (Table 10, Figure 10).

Tomato plants were highly responsive to P application. There was no response to Si at the lower rates of P (200 and 500 lbs.), but a slight increase in yield for Si application at the P rate of 2000 lbs. (Table 11, Figure 11).

Mimosa pudica yields were highest at P rates of 200 lbs. There was no apparent response for Si (Table 12, Figure 12).

Statistical Interpretation of Yields:

The analysis of variance for dry matter yields in Experiment 1 (Table 13) shows a highly significant response to P fertilization (F value = 168.18) and an interaction between P and species which influenced yields at the 1% level of significance

Table 10. Effect of Calcium Silicate and Phosphorus on the Yield, Phosphorus Content and Silicon Content of Sedge Grown on Kapaa Soil[1/]

Treatment			Phosphorus		Silicon		
Si tons/A	P lbs/A	Yield g/pot	%	mg/pot	%	mg/pot	P/Si
			First Cutting				
None	0*	0.52	0.124	0.65	0.092	0.48	1.35
	200	3.20	0.200	6.40	0.104	3.33	1.92
	500	5.11	0.224	11.45	0.096	4.91	2.33
	2000	6.99	0.384	26.84	0.162	11.32	2.37
0.1	200	3.54	0.200	7.08	0.220	7.79	0.91
	500	6.17	0.230	14.19	0.160	9.87	1.44
	2000	6.30	0.418	26.33	0.228	14.36	1.83
1.0	200	4.13	0.186	7.68	0.716	29.57	0.26
	500	5.62	0.230	12.93	0.568	31.92	0.40
	2000	6.15	0.406	24.97	0.564	34.69	0.72
4.0	0*	0.58	0.132	0.77	0.242	1.40	0.54
	200	4.81	0.220	10.58	1.346	64.74	0.16
	500	5.02	0.238	13.85	1.250	72.75	0.19
	2000	7.12	0.416	29.62	1.165	82.95	0.36
			Second Cutting				
None	0*	0.34	0.138	0.47	0.030	0.10	4.60
	200	4.90	0.190	9.31	0.184	9.02	1.03
	500	7.42	0.212	15.73	0.144	10.39	1.47
	2000	8.76	0.274	24.00	0.184	16.12	1.49
0.1	200	5.23	0.176	9.20	0.362	18.93	0.49
	500	7.29	0.228	16.62	0.276	20.12	0.83
	2000	8.79	0.304	26.72	0.346	30.41	0.88
1.0	200	5.53	0.178	9.84	1.168	64.59	0.15
	500	8.45	0.224	18.93	0.848	71.66	0.26
	2000	7.93	0.276	21.89	0.832	65.98	0.33
4.0	0*	0.20	0.154	0.31	0.100	0.20	1.54
	200	8.96	0.194	17.38	1.484	132.96	0.13
	500	8.45	0.234	19.77	1.470	124.22	0.16
	2000	8.01	0.296	23.71	1.504	120.47	0.20

* Check pots - not included in experimental design.

[1/] Mean of two replicates. For complete details see Appendix tables.

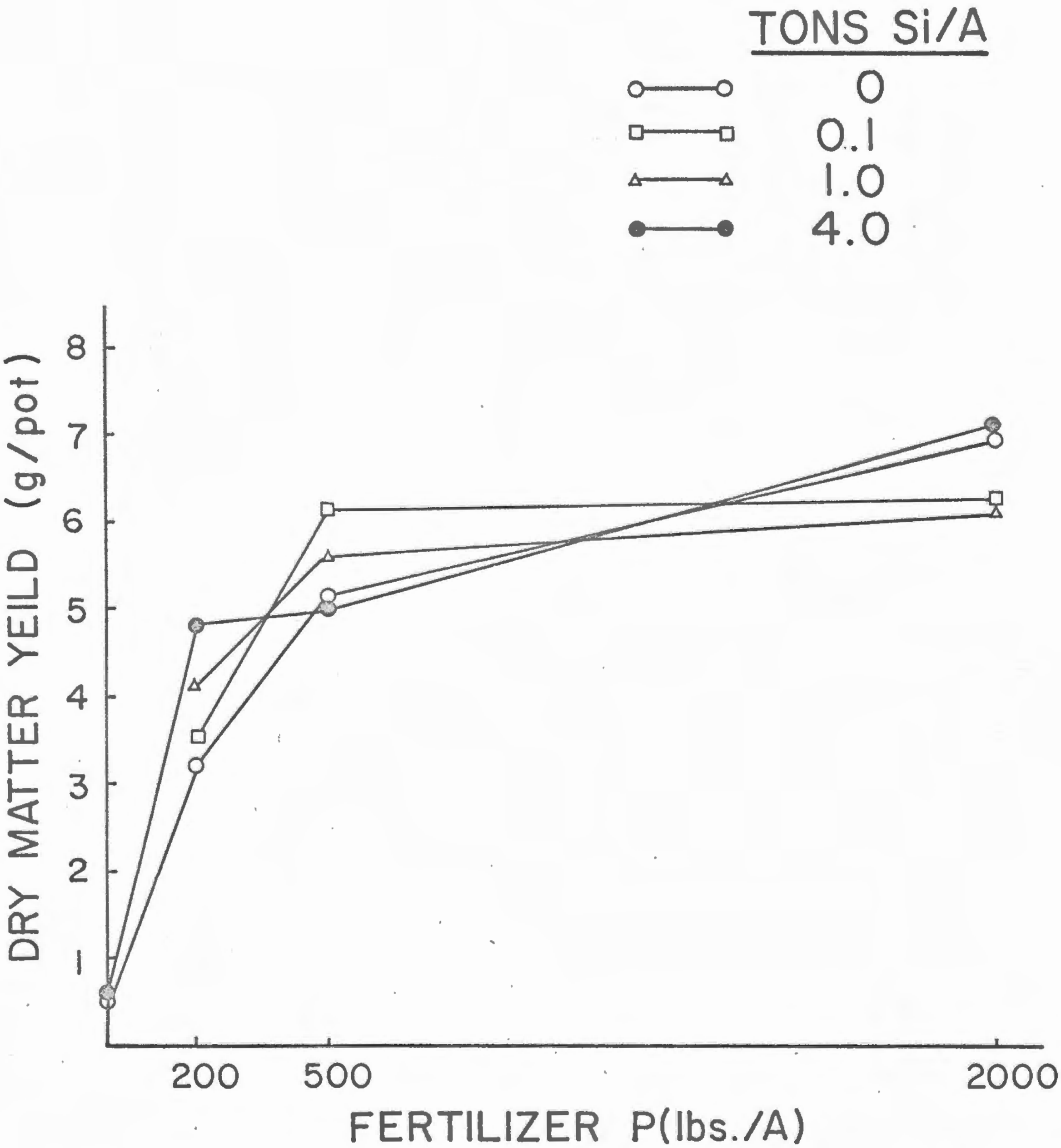

Figure 9. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of Sedge - 1st Cutting

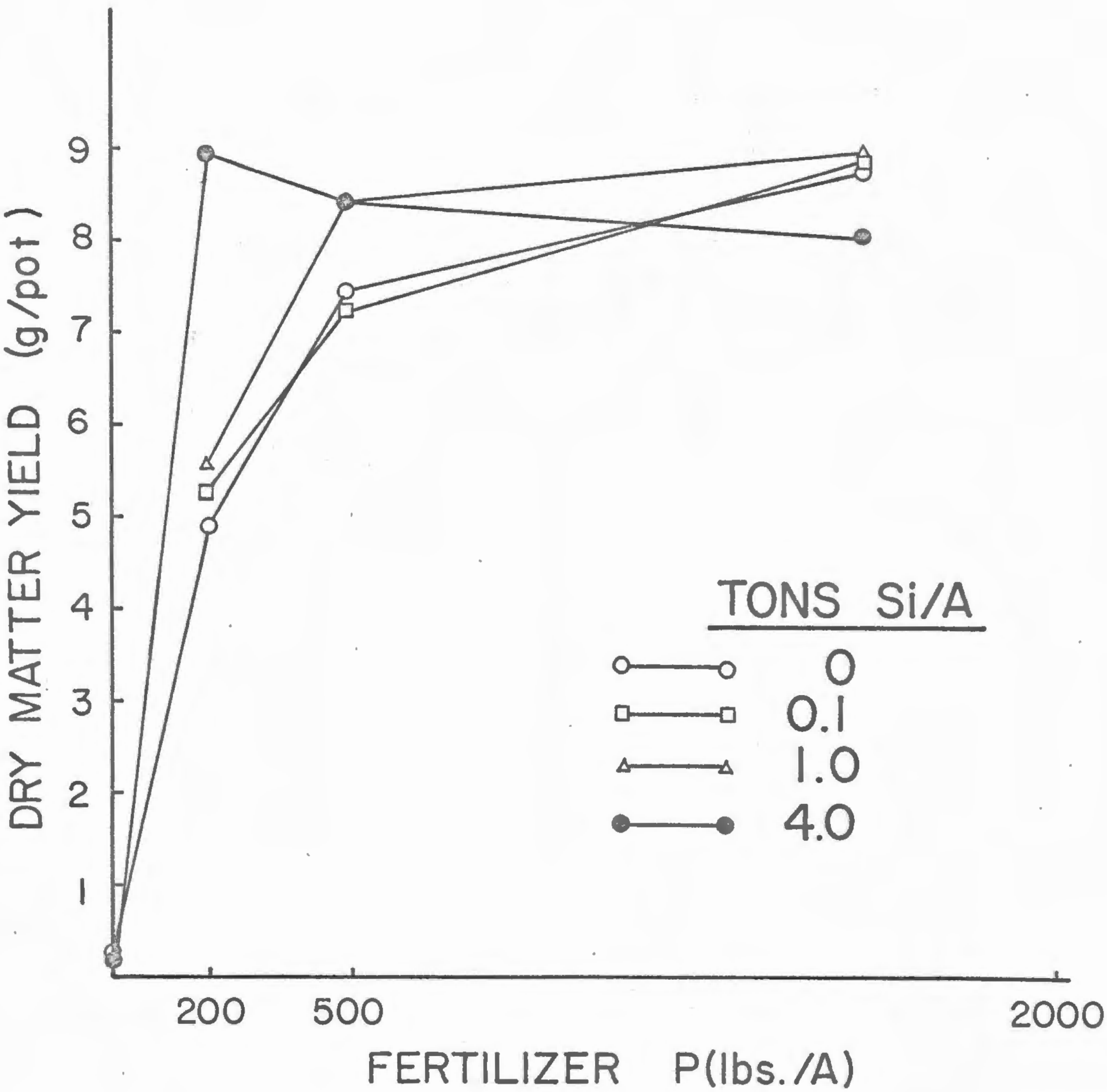

Figure 10. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of Sedge - 2nd Cutting

Table 11. Effect of Calcium Silicate and Phosphorus on the Yield, Phosphorus Content and Silicon Content of Tomato Grown on Kapaa Soil[1/]

Treatment			Phosphorus		Silicon		
Si tons/A	P lbs/A	Yield g/pot	%	mg/pot	%	mg/pot	P/Si
None	0*	0.23	0.094	0.22	0.010	0.02	9.40
	200	2.43	0.188	4.57	0.028	0.68	6.71
	500	4.61	0.228	10.51	0.026	1.19	8.77
	2000	4.88	0.546	26.64	0.030	1.46	18.20
0.1	200	2.25	0.196	4.41	0.040	0.90	4.90
	500	4.54	0.224	10.17	0.030	1.36	7.47
	2000	5.01	0.500	25.05	0.030	1.50	16.67
1.0	200	2.77	0.180	4.99	0.070	1.94	2.57
	500	4.54	0.264	11.98	0.062	2.81	4.26
	2000	5.54	0.542	30.03	0.066	3.66	8.21
4.0	0*	0.19	0.126	0.24	0.024	0.05	5.25
	200	2.58	0.190	4.90	0.090	2.32	2.11
	500	4.60	0.274	12.60	0.072	3.31	3.81
	2000	5.55	0.538	29.86	0.080	4.40	6.73

* Check pots - not included in experimental design.

[1/] Mean of two replicates. For complete details see Appendix tables.

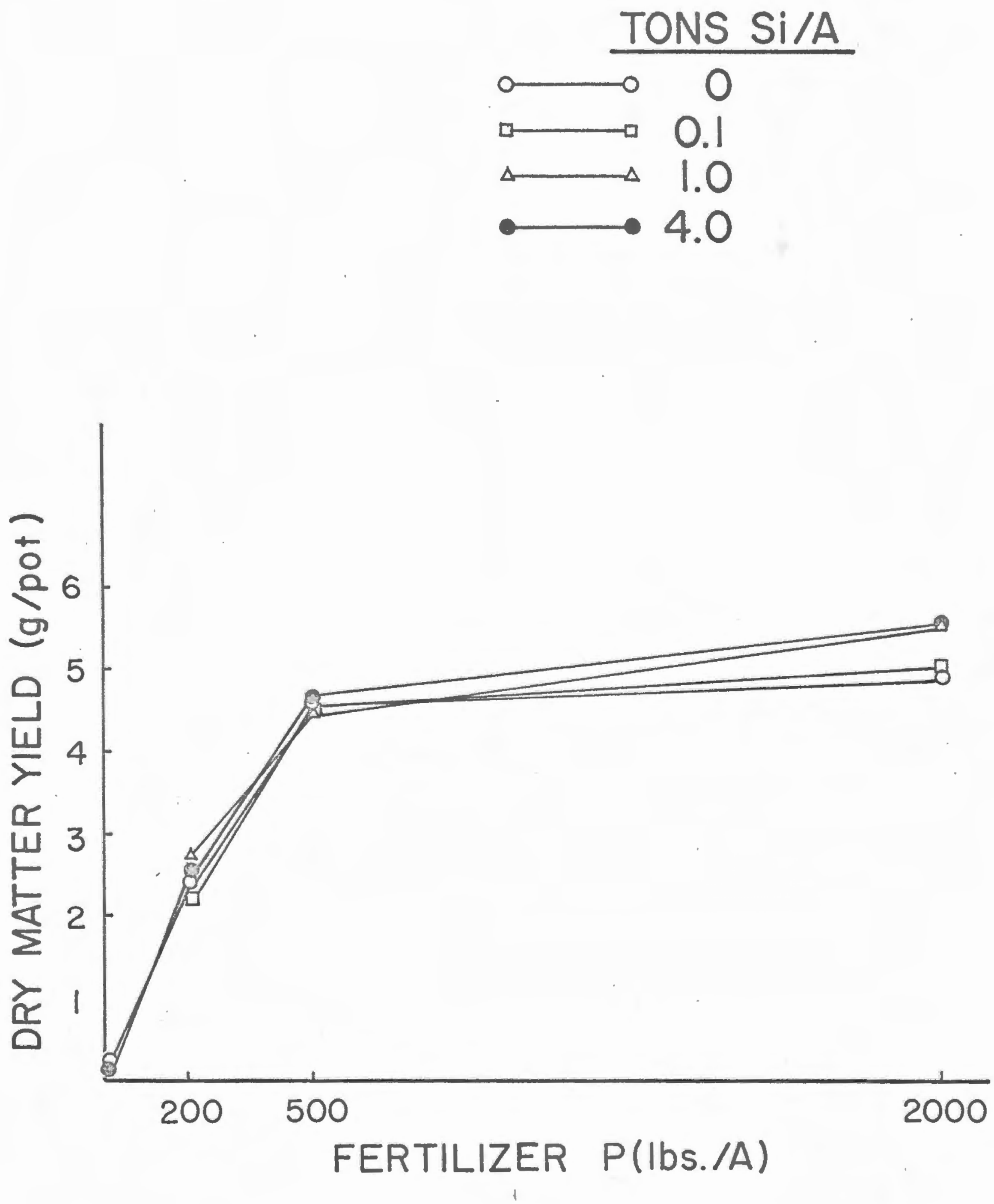

Figure 11. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of Tomato

Table 12. Effect of Calcium Silicate and Phosphorus on the Yield, Phosphorus Content and Silicon Content of *Mimosa pudica* Grown on Kapaa Soil[1/]

Treatment			Phosphorus		Silicon		
Si tons/A	P lbs/A	Yield g/pot	%	mg/pot	%	mg/pot	P/Si
None	0*	0.74	0.120	0.89	0.010	0.07	12.00
	200	8.64	0.194	16.76	0.026	2.25	7.46
	500	6.11	0.260	15.89	0.026	1.59	10.00
	2000	6.87	0.286	19.65	0.032	2.20	8.94
0.1	200	9.47	0.156	14.77	0.030	2.84	5.20
	500	5.43	0.256	13.90	0.032	1.74	8.00
	2000	7.25	0.280	20.30	0.042	3.05	6.67
1.0	200	8.57	0.200	17.14	0.048	4.11	4.17
	500	6.33	0.246	15.57	0.046	2.91	5.35
	2000	7.12	0.288	20.51	0.070	4.98	4.11
4.0	0*	0.72	0.126	0.91	0.018	0.13	7.00
	200	9.23	0.202	18.64	0.074	6.83	2.73
	500	6.45	0.268	17.29	0.058	3.74	4.62
	2000	7.34	0.296	21.73	0.074	5.43	4.00

* Check pots - not included in experimental design.

1/ Mean of two replicates. For complete details see Appendix tables.

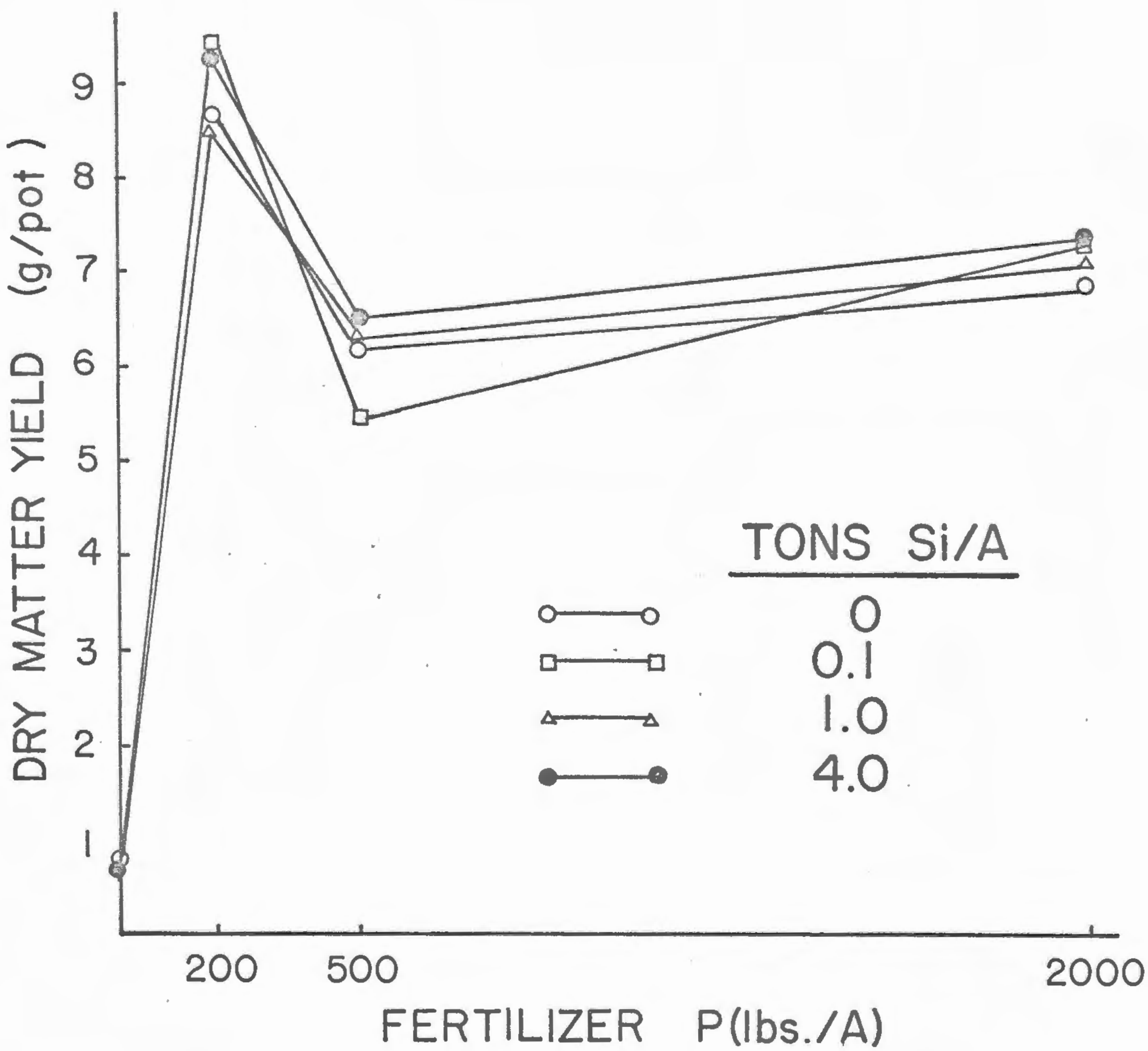

Figure 12. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of <u>Mimosa pudica</u>

(F value = 3.24).

A summary of the analyses of variance (F values) for each species and each cutting are given in Table 14. Results of Duncan's multiple range tests for treatment means are given in Tables 15 and 16. Table 15 shows the degrees of significance of the differences in yield between each of the rates of P and Si. Table 16 facilitates a comparison of the yields of individual treatment combinations. No analysis of variance was performed on the corn plants harvested at 30 days, since both replicates were composited to determine the TCA extractable P and Si content.

Phosphorus fertilization caused a highly significant increase in the yield of all plant crops. Of the second cuttings, sedge showed a highly significant response, while the yields of kikuyu grass and _Desmodium intortum_ were nonsignificant. It is probable that kikuyu grass was affected by K deficiency. As indicated by the check pots, the experimental soil was of a low base saturation and extremely deficient in K. It appeared that the blanket treatment of 400 lbs. per acre of K was not sufficient for the second crop of kikuyu grass. An additional 400 lbs. per acre of K was applied to the third crop. The plant crop of _Desmodium intortum_ showed symptoms of micronutrient deficiency. Mottling of leaves, upward curling of lower leaf margins, and dying off of older leaves were more pronounced in the pots receiving 2000 lbs. per acre of P. Only 6 of the 7 plants in

Table 13. Analysis of Variance of Experiment 1
3 x 4 x 5 Complete Factorial

Source	d.f.	SS	MS	F
Replication	1	3.6296		
Treatment	(59)	(2760.6656)		
Phosphorus	2	236.1565	118.0782	168.178**
Silicon	3	5.1355	1.7118	2.438
Species	4	2472.5089	618.1272	880.397**
P x Si	6	7.8438	1.3073	1.8619
P x Sp	8	18.1723	2.2715	3.235**
Si x Sp	12	14.8202	1.2350	1.759
P x Si x Sp	24	19.0077	0.7919	1.127
Error	59	41.4275	0.7021	
Total	119			

* Significant at P = 0.05
**Significant at P = 0.01

Table 14. Experiment 1 - Summary of Analyses of Variance (F Values) for Dry Matter Yields

Species	Sources		
	P d.f. = 2	Si d.f. = 3	P x Si d.f. = 6
Kikuyu grass			
1st Cutting	77.75**	5.92*	3.30*
2nd Cutting	ns	ns	ns
3rd Cutting	4.42*	4.66*	ns
Corn	48.87**	3.95*	ns
Desmodium intortum			
1st Cutting	175.50**	ns	ns
2nd Cutting	ns	ns	ns
Sedge grass			
1st Cutting	89.07**	ns	5.03**
2nd Cutting	12.49**	ns	ns
Tomato	220.02**	ns	ns
Mimosa pudica	22.55**	ns	ns

* Significant at the 5% level.
**Significant at the 1% level.

Table 15. Experiment 1 - Summary of Duncan's Multiple Range Test for Treatment Means. (Effect of P and Si on Total Yield)

Species	Cut.	P-lbs/A			Si-tons/A			
		200	500	2000	0	0.1	1.0	4.0
Kikuyu grass	1	2.48c	4.89b	6.73a	5.24a	5.05a	4.78a	3.72a
	2	4.00a	4.39a	4.09a	3.12a	3.34a	2.81a	3.21a
	3	7.42a	8.80a	8.16a	7.57a	8.07a	7.55a	8.99a
Corn	-	12.33b	15.11a	16.87a	13.68a	15.18a	14.90a	15.52a
Desmodium intortum	1	0.37c	1.34b	2.73a	0.74a	0.78a	0.73a	0.73a
	2	5.51a	6.16a	5.35a	4.48a	4.27a	4.27a	4.01a
Sedge grass	1	3.90b	5.48a	6.64a	2.55a	2.67a	2.64a	2.82a
	2	3.08b	3.95a	4.18a	1.76a	1.78a	1.83a	2.20a
Tomato	-	2.51c	4.57b	5.24a	3.97a	3.93a	4.28a	4.24a
Mimosa pudica	-	8.98a	6.08b	7.15ab	3.60a	3.69a	3.67a	3.83a

Treatment means followed by different letters differed by a value greater than the LSD at 5% level of significance.

Table 16. Experiment 1 - Summary of Duncan's Multiple Range Test for Means of Individual Treatment Combinations

Treatment		Species									
Si tons/A	P lbs/A	Kikuyu grass			Corn	Desmodium intortum		Sedge grass		Tomato	Mimosa pudica
		1	2	3		1	2	1	2		
0	200	2.73ef	6.14a	6.08c	11.02b	0.56c	8.84a	3.20e	2.45e	2.43c	8.64abc
	500	4.27de	5.88a	7.78abc	12.76b	1.22b	9.14a	5.11cd	3.71cd	4.61b	6.11d
	2000	8.17a	6.72a	8.85ab	17.26a	2.69a	8.91a	6.99ab	4.38a	4.88b	6.87cd
0.1	200	2.86ef	6.85a	7.71abc	13.11b	0.38c	8.21a	3.54e	2.62e	2.25c	9.47a
	500	4.75cd	7.46a	8.56ab	16.08a	1.28b	9.00a	6.17ab	3.65d	4.54b	5.43d
	2000	6.75ab	5.73a	7.96abc	16.36a	2.92a	8.42a	6.30ab	4.40a	5.01ab	7.25bcd
1.0	200	2.03f	4.93a	6.92bc	12.11b	0.28c	8.59a	4.13de	2.77e	2.77c	8.57abc
	500	4.15de	6.73a	9.31a	15.88a	1.38b	9.36a	5.62bc	4.23ab	4.54b	6.33d
	2000	4.99cd	5.20a	6.39c	16.72a	2.75a	7.71a	6.15ab	3.97cd	5.54a	7.12bcd
4.0	200	2.33f	6.08a	8.90ab	13.12b	0.30c	7.46a	4.81d	4.48a	2.58c	9.23ab
	500	6.38bc	6.29a	9.56a	15.73a	1.50b	9.49a	5.02cd	4.23ab	4.60b	6.45cd
	2000	7.03ab	6.90a	9.46a	17.13a	2.59a	7.09a	7.12a	4.01bc	5.55a	7.34abcd

each of these 8 pots were harvested. Six of the remaining 8 plants were each treated with a foliar spray of Fe, Cu, Zn, Mo, Mn or a mixture of all 5 elements, and 2 were left untreated as check pots. Fe and Mn appeared to be the most effective. The remaining plants were harvested and discarded and all pots were trimmed to a uniform height. An appropriate mixture of micronutrients was applied to the second crop as a foliar spray. This test for micronutrients may have affected the second cutting of Desmodium intortum. The yields of the third cutting of kikuyu grass were significant at the 5% level.

Table 15 permits a more detailed analysis of the abovementioned results. Only 3 plant crops--tomato, Desmodium intortum and kikuyu grass--showed a significant improvement in yield for increments of P. The yield of Desmodium intortum increased 8-fold between P treatments of 200 and 2000 lbs. per acre. In corn and in the two cuttings of sedge, the yields at 500 and 2000 lbs. of P were not significantly different from each other but were significantly higher than the yield at 200 lbs. Table 15 shows that the yields of the third cutting of kikuyu grass were at the same level of significance for all 3 rates of P, and that at 2000 lbs. the yield was lower than at 500 lbs.

Mimosa pudica gave its highest yield at the 200 lbs. rate of P. This plant which was grown to study the residual effects of the treatments after the tomato plants were harvested was the only crop that did not respond to the higher rates of P application. In spite of the introduction of an inoculum at the germination stage, the plants showed signs of N deficiency and stunted growth.

Response to Si application was significant only on two crops, corn and the first and third cutting of kikuyu grass (Table 14). Corn harvested at 30 days showed no noticeable yield increase for Si (Table 6). However, corn yields at 40 days improved with increases in Si. Kikuyu grass yield increase if any, the response for Si is negative. Increases in Si treatment were accompanied by higher P concentrations in the plant. The yield response to Si in the third cutting of kikuyu grass was positive, although the yield increase did not correspond to each addition of Si (Table 15). It is possible that the positive response to Si in the third cutting may have been due to the delayed action of Si on the availability of fertilizer P, since the P fixing capacity of the experimental soil was high.

In spite of the lack of a statistically significant response to Si in most crops, certain values in Table 16 suggest that some instances of yield increase are attributable to Si. The yield of the first cutting of kikuyu grass in plants receiving treatments of 500 lbs. of P and 4 tons of Si were significantly higher than the yields of plants receiving the same rate of P in the absence of Si. Also, lower rates of P have produced yields that are at the same level of significance as the yields at the higher rates when the rates of Si treatment and the Si content of the plant were higher. In the plant crop of sedge, yields were the same at 200 lbs. of P with 4 tons of Si as at 500 lbs. of P with no Si. The plant Si content was 64.74 mg. and 4.91 mg., respectively. Likewise, in the second cutting the same yields were obtained for 200 lbs. of P with 4 tons of Si and 2000 lbs. of P with no Si. The Si content was 132.96 mg. and 16.17 mg., respectively. This suggests that if there is a requirement for Si *per se* it must be very low.

The difference between corn yields at 500 lbs. of P with 1 ton of Si and at 200 lbs. of P with no Si were nonsignificant (Table 16). The plant P content was 32.16 mg. and 31.79 mg., respectively. An evidence that when P is limiting Si increases the fertilizer P availability to the corn plant. Tomato plants receiving 2000 lbs. of P also produced significantly higher yields to 1 and 4 ton rates of Si than in the absence of Si.

Significant interaction effects between P and Si on yield were noted for the plant crops of kikuyu grass and sedge (Table 14). Values in Table 15 indicate that the interaction of Si with P gives a negative yield response in kikuyu grass and a beneficial response in sedge.

Chemical Composition:

For comparison of the chemical composition of dry matter yields, percentages have been used in most instances. Since species were very different in size, absolute amounts of Si present would not be very helpful. Variations in the concentrations of P and Si with respect to treatments and yield can be seen in Figures 13-21. In Table 17 are given the average values of the P and Si content (% and mg/pot) and the P:Si ratios of all species.

In kikuyu grass, Desmodium intortum and sedge, P percentage decreased and Si percentage increased with successive cuttings. Concentrations of both elements were higher in corn at 40 days than at 30 days. The P yield of Mimosa pudica was comparable to that of other second crops. Mimosa pudica and tomato had the least Si content which was extremely low in comparison to that of corn which was the highest. Tomato had the highest P content and corn the lowest (Figures 22 and 23).

Of all species growing in check pots which received neither P nor Si, tomato had the lowest (0.094%) P content and kikuyu grass the highest (0.168%). Silicon absorption was lowest in tomato and Mimosa pudica (0.01%) and highest in sedge grass (0.09%). The addition of 200 lbs. P increased Si absorption and the addition of 4 tons of Si increased P absorption in all crops, the only exceptions being the second cuttings of kikuyu grass and Desmodium intortum, respectively (Tables 8-17).

In all species the percentage P content in plants increased

Table 17. Experiment 1 - Mean* Chemical Composition of Species

Species	Cut.	Phosphorus %	Phosphorus mg/pot	Silicon %	Silicon mg/pot	P:Si
Kikuyu grass	1	0.315	15.74	0.371	17.38	0.849
	2	0.300	18.85	0.310	19.30	0.967
	3	0.252	20.52	0.439	37.34	0.574
Corn	30 days	0.084	7.14	0.761	21.35	0.110
	40 days	0.299	28.41	1.431	104.72	0.208
Desmodium intortum	1	0.286	4.41	0.535	8.61	0.534
	2	0.223	18.96	0.558	45.72	0.480
Sedge grass	1	0.279	15.99	0.548	30.68	0.509
	2	0.232	17.75	0.733	57.07	0.316
Tomato	-	0.322	14.64	0.052	2.13	6.192
Mimosa pudica	-	0.244	17.67	0.046	3.47	5.304

*Mean values of the 12 treatment combinations.

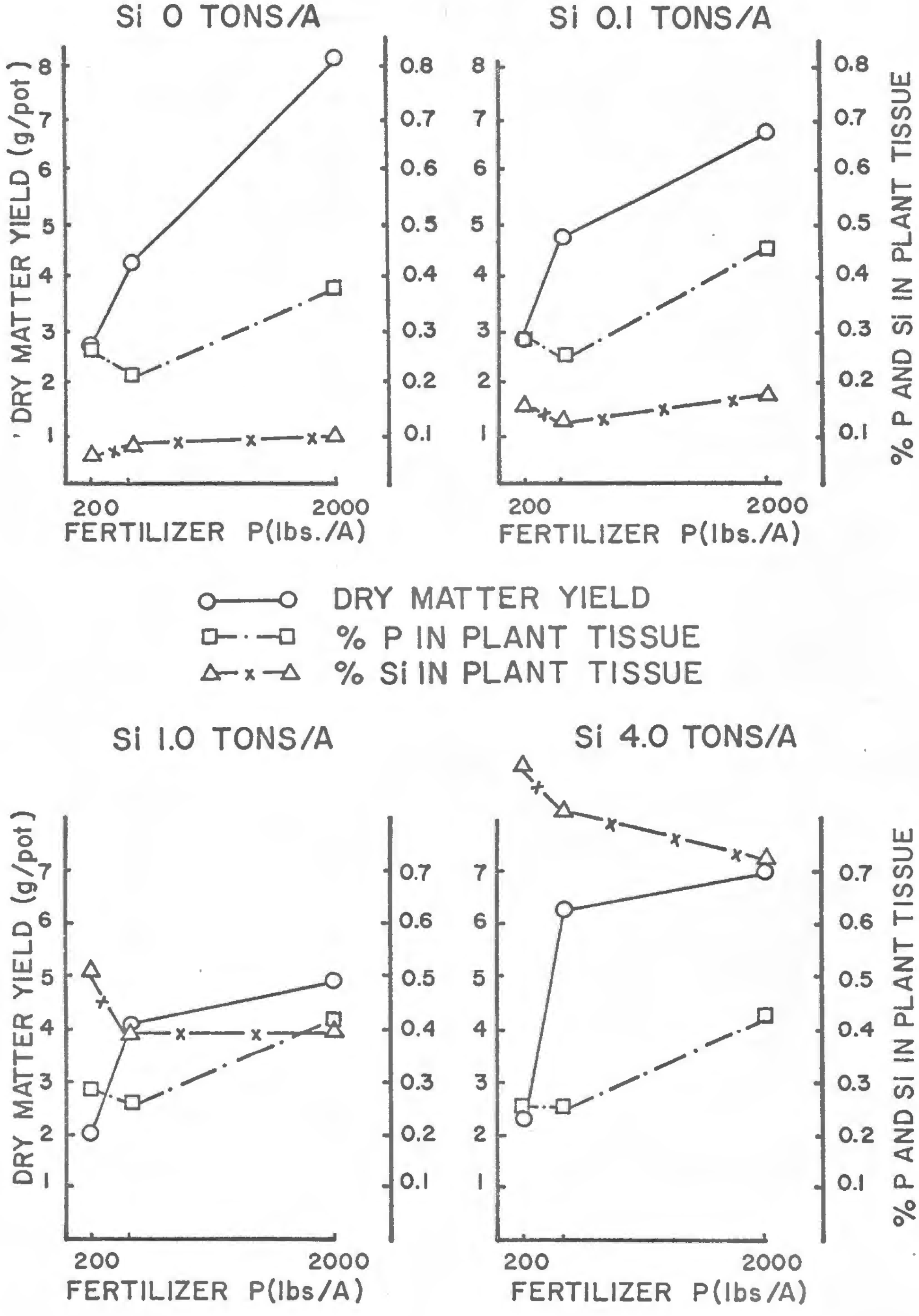

Figure 13. Effect of Calcium Silicate and Phosphorus on Yield, Percentage P, and Percentage Si in Kikuyu Grass - 1st Cutting

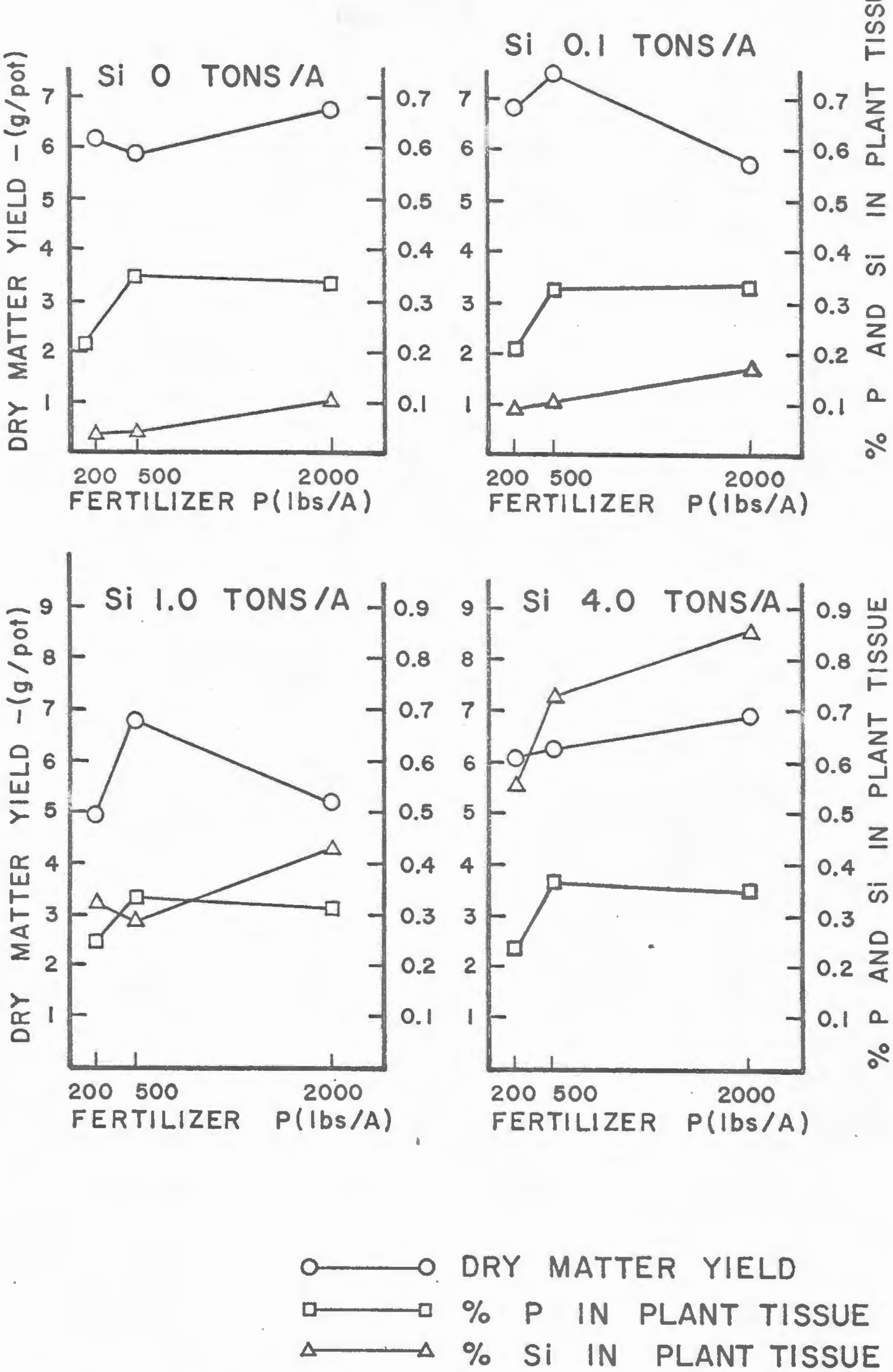

Figure 14. Effect of Calcium Silicate and Phosphorus on Yield, Percentage P, and Percentage Si in Kikuyu Grass - 2nd Cutting

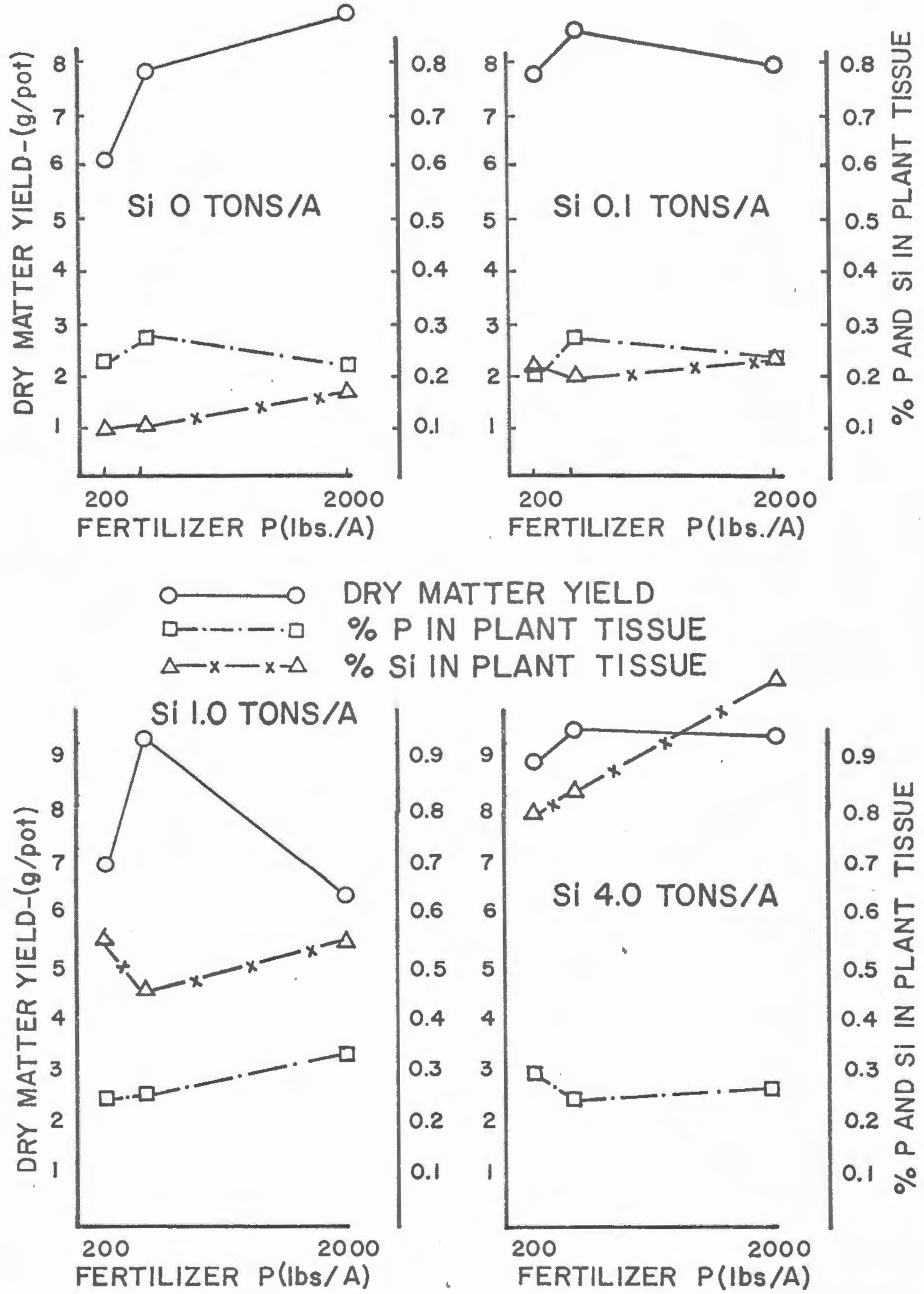

Figure 15. Effect of Calcium Silicate and Phosphorus on Yield, Percentage P, and Percentage Si in Kikuyu Grass - 3rd Cutting

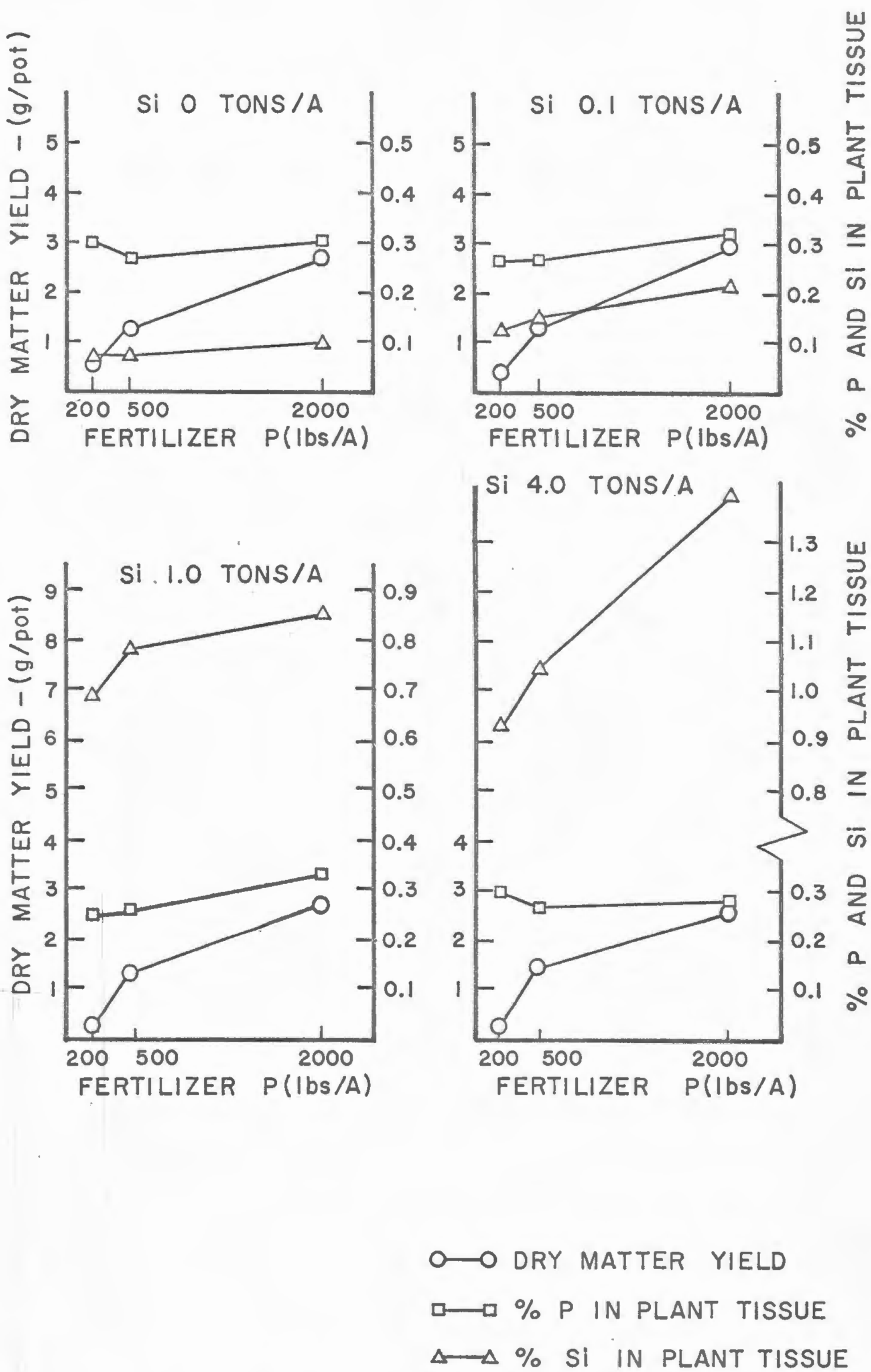

Figure 16. Effect of Calcium Silicate and Phosphorus on Yield, Percentage P, and Percentage Si in Desmodium intortum - 1st Cutting

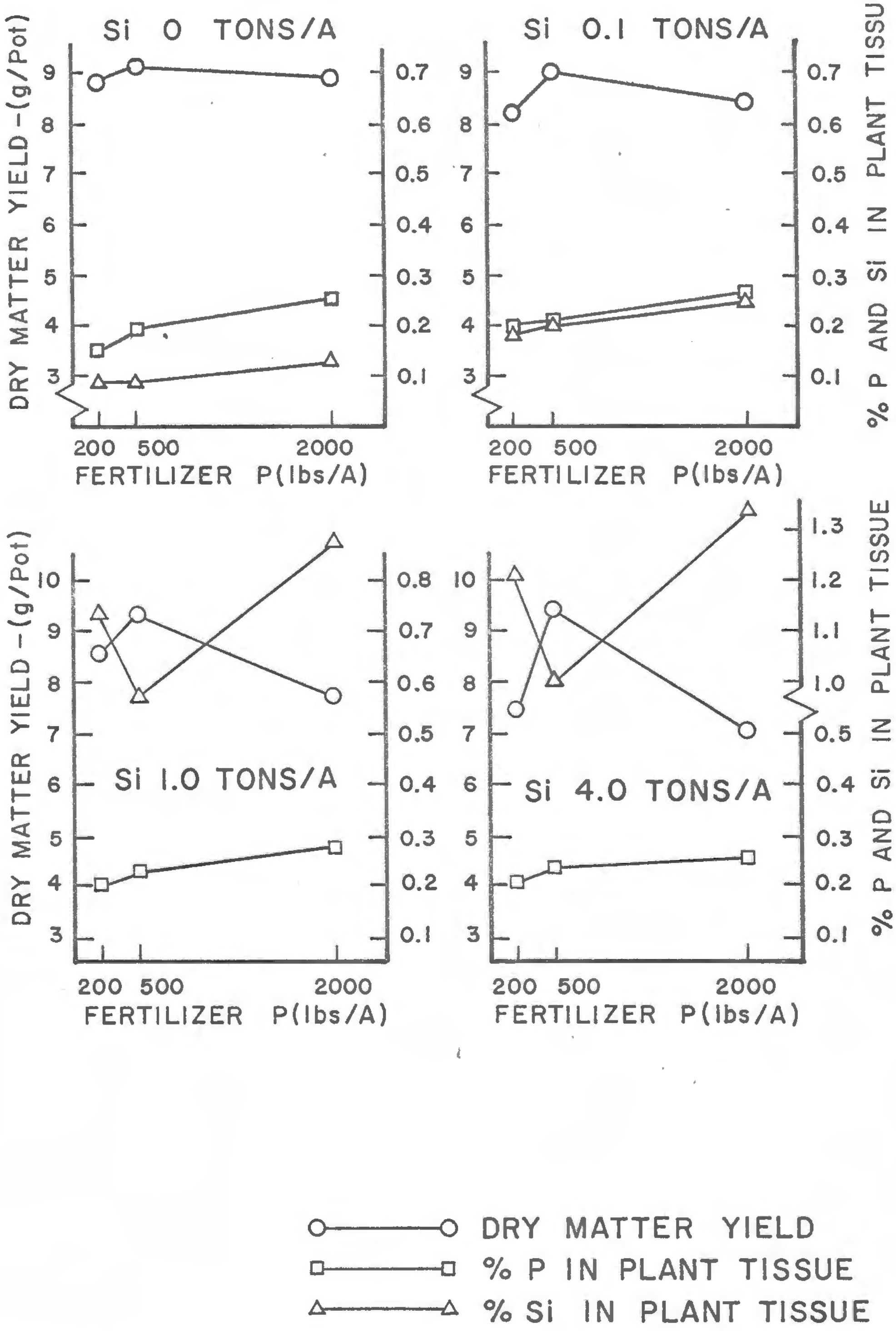

Figure 17. Effect of Calcium Silicate and Phosphorus on Yield, Percentage P, and Percentage Si in Desmodium intortum - 2nd Cutting

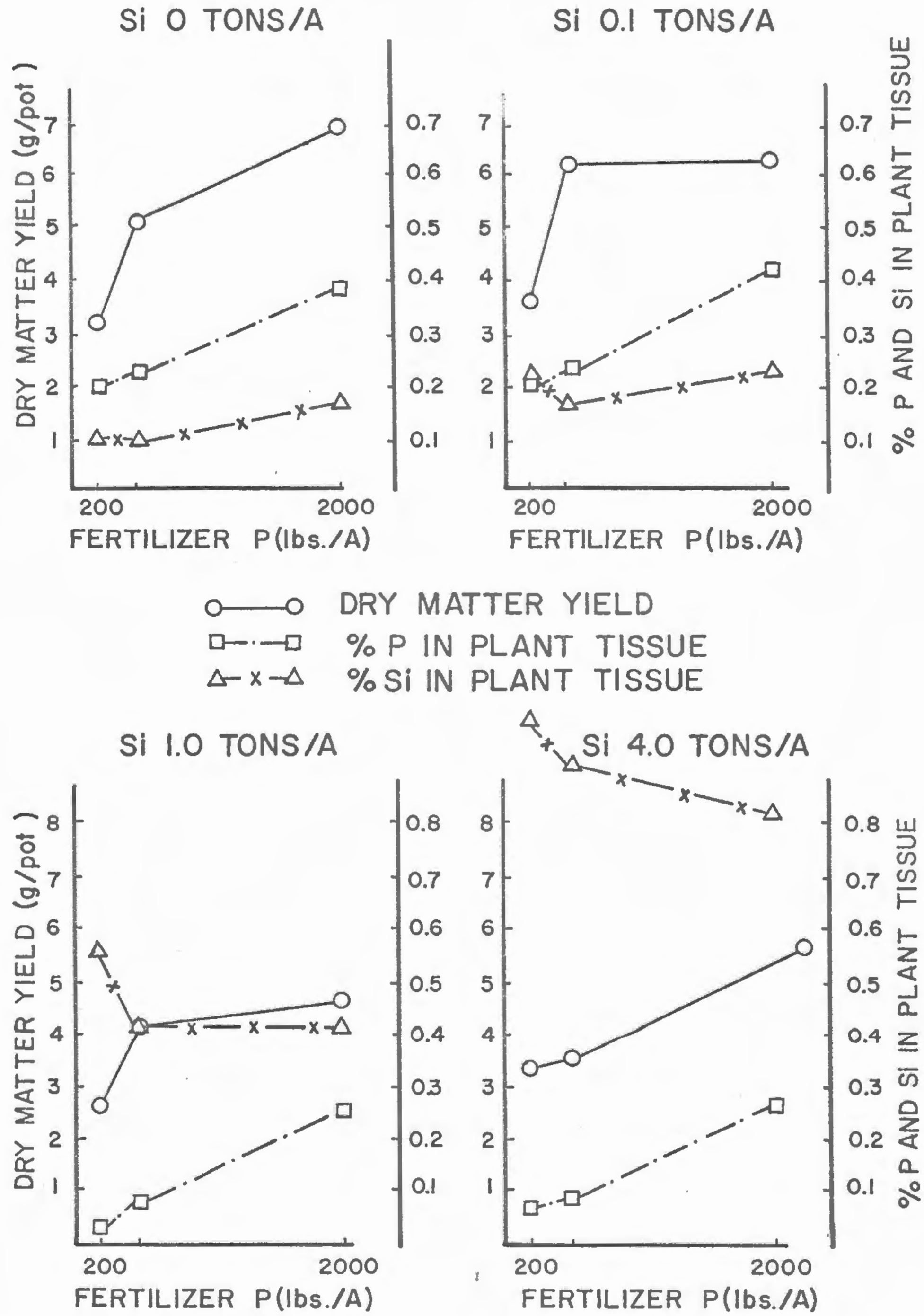

Figure 18. Effect of Calcium Silicate and Phosphorus on Yield, Percentage P, and Percentage Si in Sedge - 1st Cutting

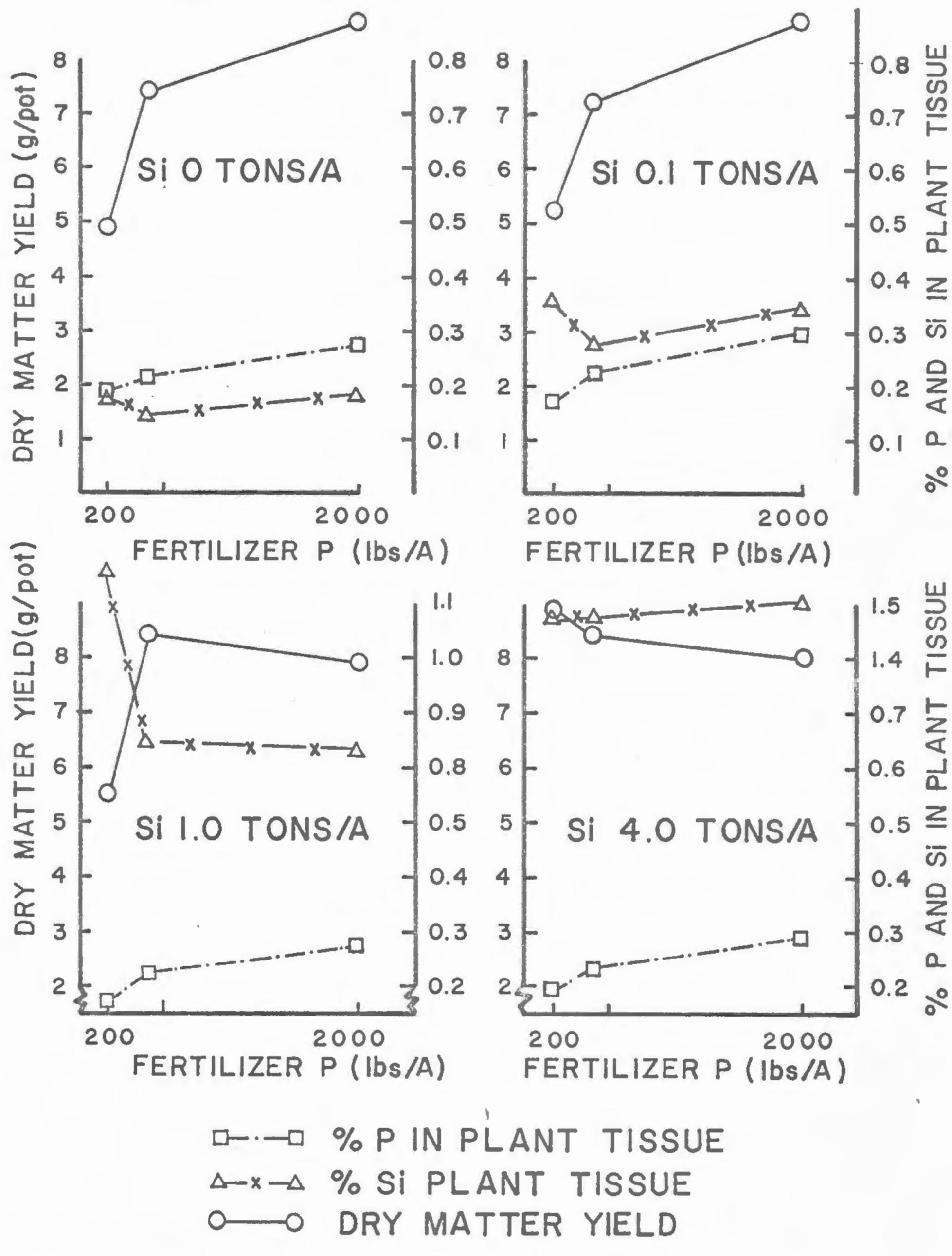

Figure 19. Effect of Calcium Silicate and Phosphorus on Yield, Percentage P, and Percentage Si in Sedge - 2nd Cutting

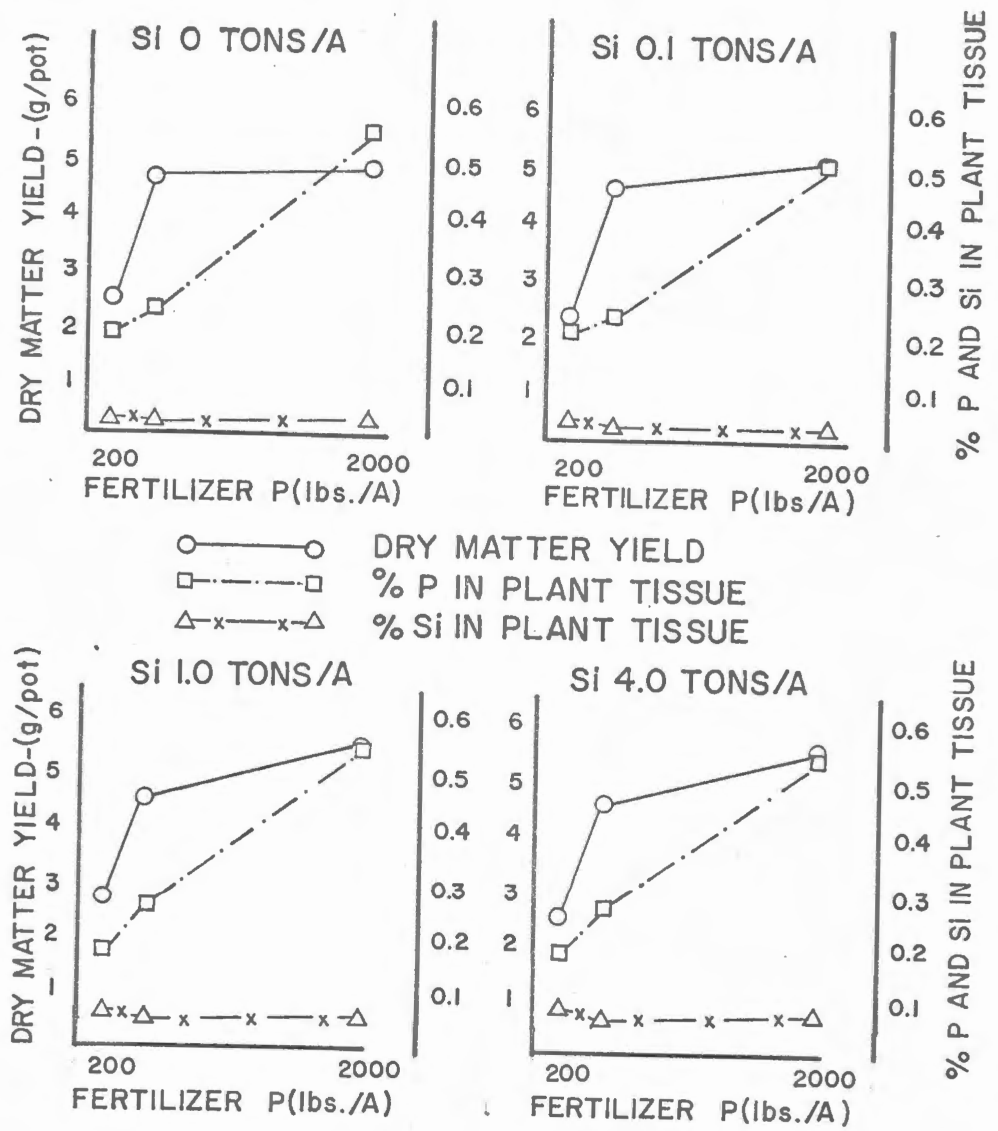

Figure 20. Effect of Calcium Silicate and Phosphorus on Yield, Percentage P, and Percentage Si in Tomato

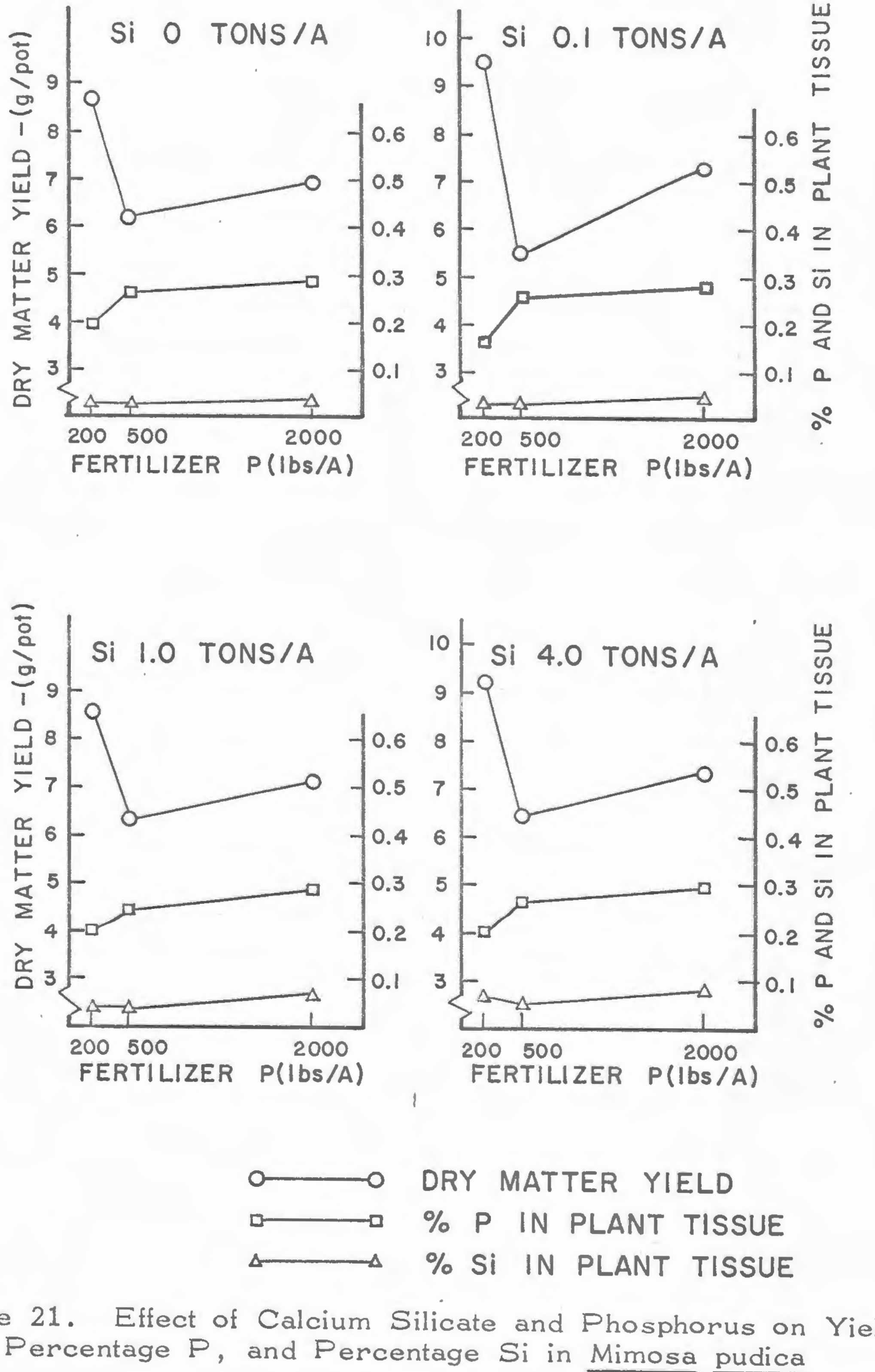

Figure 21. Effect of Calcium Silicate and Phosphorus on Yield, Percentage P, and Percentage Si in *Mimosa pudica*

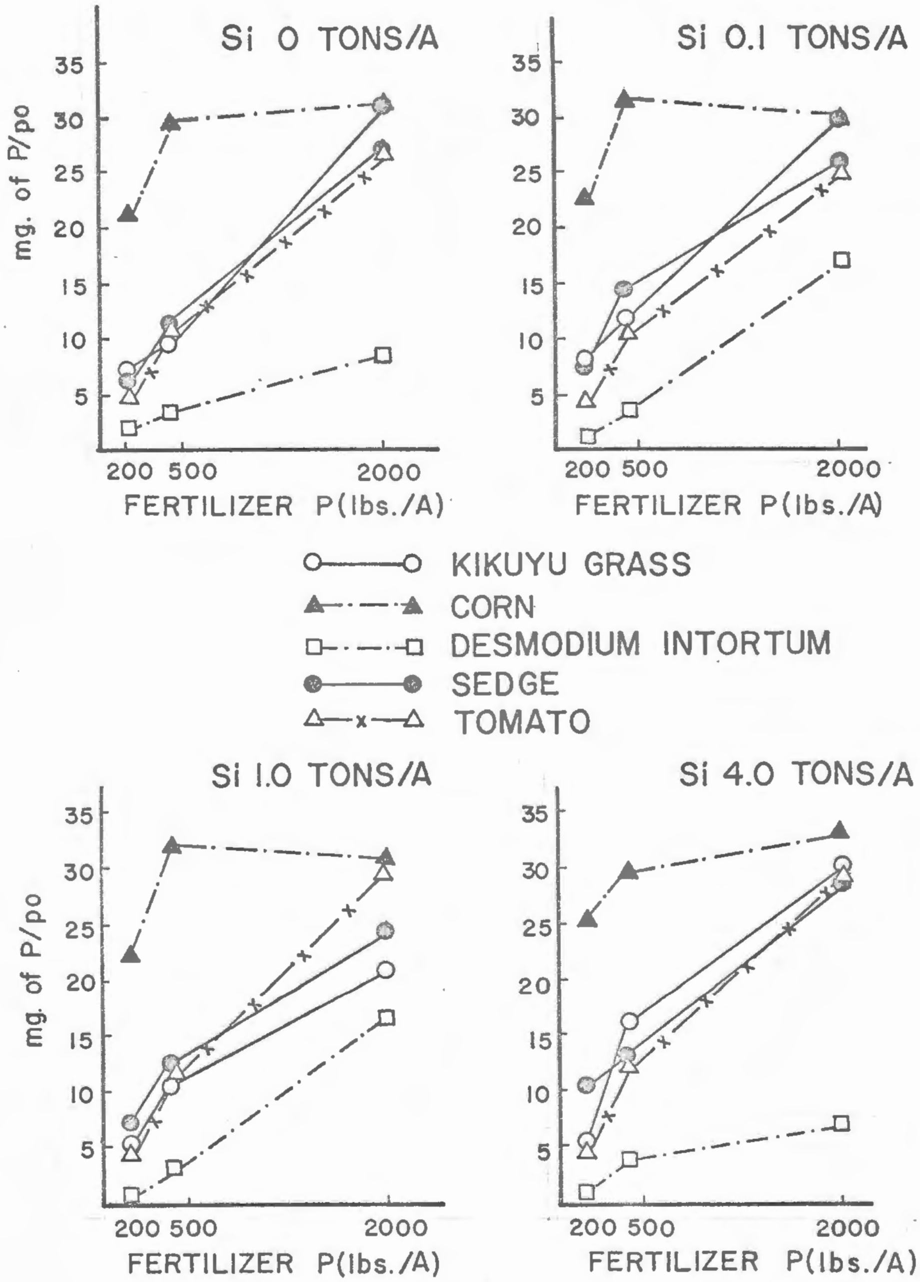

Figure 22. Effect of Calcium Silicate and Phosphorus on P Uptake by Different Species

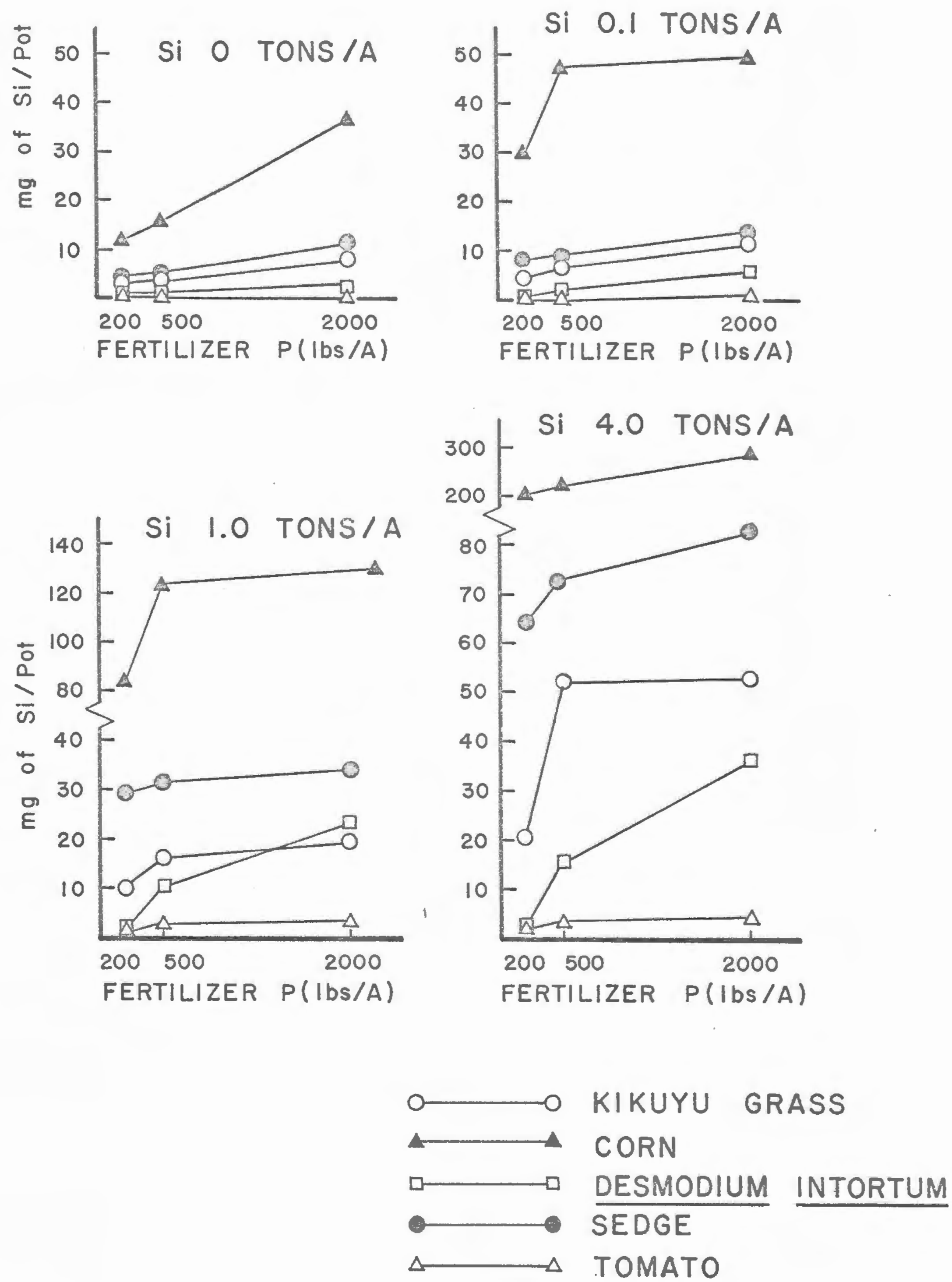

Figure 23. Effect of Calcium Silicate and Phosphorus on Si Uptake by Different Species

with the addition of P fertilizer. A good relationship between yield and P content existed in most instances, but it is to be noted that in spite of the less significant yield response in the third cutting of kikuyu grass, there was no corresponding decrease in the P content. Since these analysis include both leaf and stalk, the difference may not have been so marked if an analysis of indicator tissue was done, as in the crop log studies (Clements, 1957).

As seen from the graphs in Figures 13-21, there was a steady increase in percentage P content and a corresponding increase in yields, with increased P applications. There was a marked difference in the plant crops of kikuyu grass and Desmodium intortum in which species the percentage P content is lowest at the 500 lbs. rate of P. But yields have increased significantly in spite of it. This may be due to dilution effect and the differences in the proportion of P among the various plant tissues.

The P content of tomato increased with Si application at the 2000 lbs. rate of P. Mimosa pudica, which showed a negative response to P, had a very low concentration of Si. But Si content was high in the third crop of kikuyu grass in which there was a lack of response to P and a positive response for Si.

The application of Si resulted in a wide range of Si absorption, from an average of 1.43% (104.72 mg.) in corn to an average of 0.05% (2.13 mg.) in tomato. As evidenced by the graphs in Figures 13-21, the rate of application of Si had a very direct influence on plant Si. There is some evidence of the influence of Si rates or Si content on P uptake and no noticeable relationship between plant yield and Si content. In most species, Si absorption was very slightly increased by increments of P application.

In all plants the P:Si ratio decreased with Si application. It was increased to a very small extent by additions of P fertilizer, with the exception of corn and sedge grass in which the ratio diminished with P application. This may be due to the fact that for these species, the increase in Si solubility due to applied P more than offset the dilution effects due to increased yields. The average P:Si ratio was lowest in corn (0.208) and highest in tomato (6.192). No relationship was observed between yield and P:Si ratio.

A detailed analysis was done on the chemical composition of corn to investigate the distribution of P and Si in the various parts of the plant. The weights, chemical composition and P:Si ratios of the sheath, leaf and stalk and roots at each of the 12 treatment combinations are given in Tables 7 and 8, respectively. Averages of 12 treatments are used for the comparisons given below. In the plants harvested at 30 days, TCA soluble P was 0.02%, TCA soluble Si was 0.004%. In sheaths of the plants harvested at 40 days, 0.006% of the P and 0.003% of the Si were TCA soluble. Of the total P in the roots and plant, 34% was in the root, 47% was in the leaf and stalk, and 19% was in the sheath. Of the Si, 10% was in the root, 42% in the leaf and stalk. Forty-eight percent of the Si was concentrated in the sheath. (Figures 24 and 25)

Experiment 2

Kikuyu grass was grown in all pots with 2 rates of P (500 and 2000 lbs. per acre) and 2 rates of Si (1 and 4 tons per acre), in 3 placements in a factorial design. The three placements were (1) Si and P mixed with the whole soil, (2) Si and P mixed into one layer of soil and placed 2 cm. below the surface, and (3) Si and P applied in separate layers--P was mixed into a thin layer of soil and placed 2 cm. below the surface and Si ($CaSiO_3$) was placed 5 cm. below it.

The 3 placements were employed to investigate the nature of the Si-P interaction in the soil. The hypothesis was that if interaction was direct, placement 2 would result in higher yields than placement 1. In placement 3, the Si and P were so arranged to prevent direct interaction in the soil between the two elements. Phosphorus was placed above the Si since its mobility is known to be low. Since the extent of the root system is governed by the age of the plant, and the solubility is slow, 3 cuttings were taken at successive stages of growth.

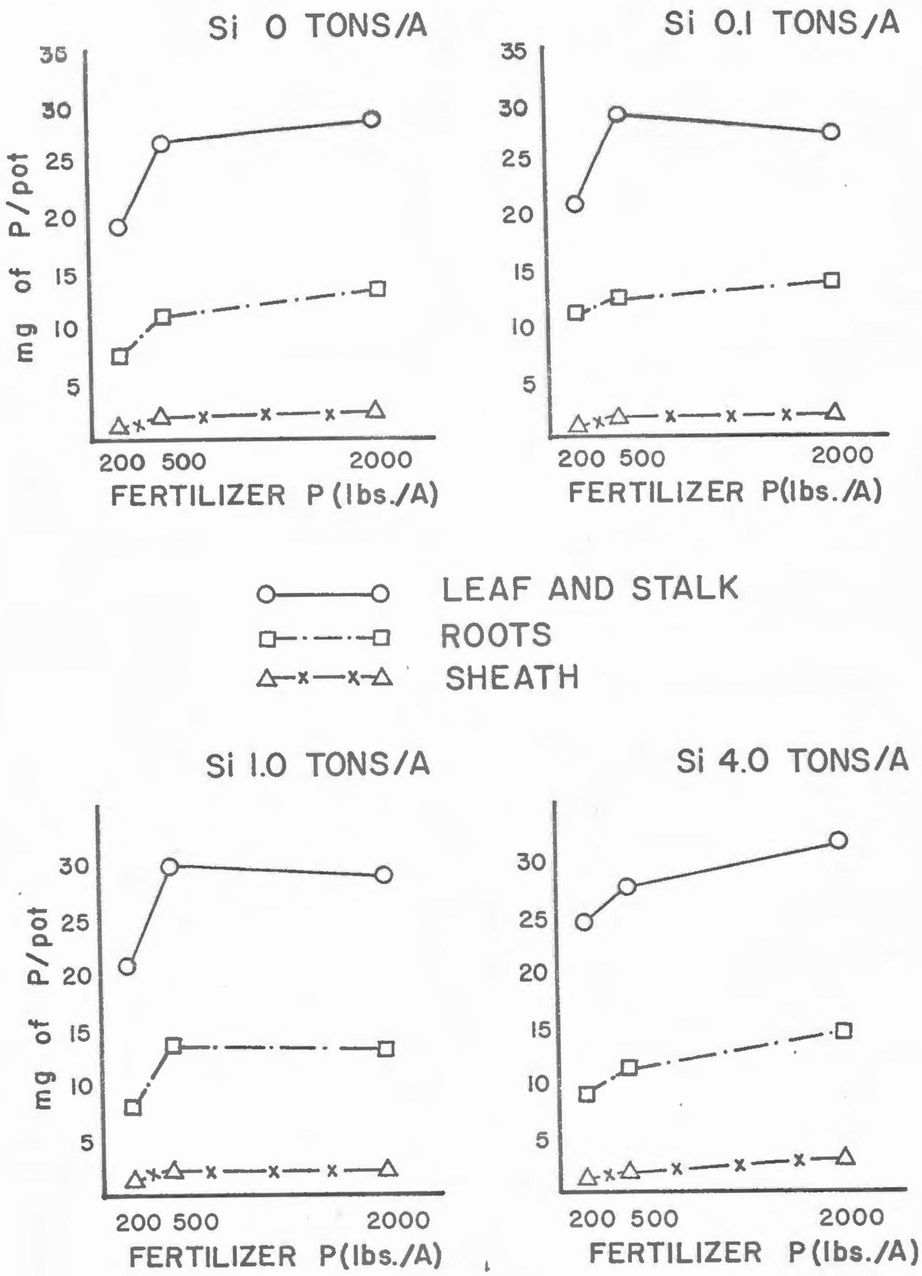

Figure 24. Effect of Calcium Silicate and Phosphorus on P Distribution in Corn

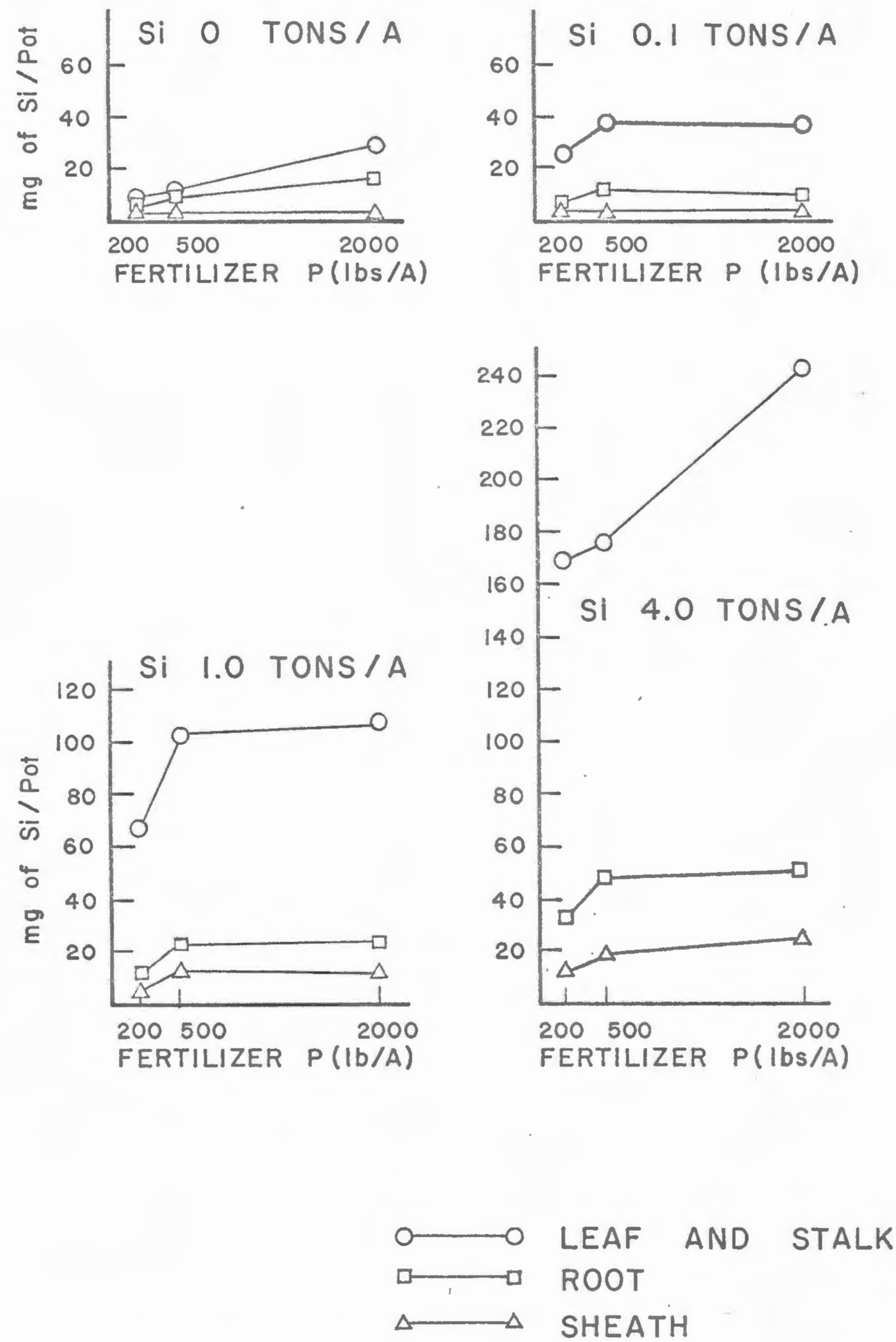

Figure 25. Effect of Calcium Silicate and Phosphorus on Si Distribution in Corn

Yield:

In the first cutting, 4 tons of Si gave higher yields than 1 ton in placement 1 at both rates of P application. In placement 2, yields of 500 lbs. and 2000 lbs. P were equal at 1 ton Si. But at 4 tons Si, 2000 lbs. of P gave a higher yield. Yields in placement 3 were generally low with the exception of 1 ton Si with 2000 lbs. P which gave the highest yield of all 12 treatments (Table 18, Figure 26).

In the second cutting, placement 2 gave the highest yields and placement 3 the lowest. At both rates of P, 4 tons of Si gave the highest yields. At the lower rate of Si, yields at 2000 lbs. P were lower than at 500 lbs. (Table 18, Figure 27).

In the third cutting, placement 2 gave higher yields than placements 1 or 3. Four tons of Si gave higher yields in placements 1 and 2. There was no difference in yield response between the two rates of P. At 1 ton Si yields were slightly lower at the higher rate of P application (Table 18, Figure 27).

Over-all yields were higher at placement 2. There was no increase in yields for P after the first cutting, but a response to Si can be observed in all three cuttings.

A summary of the analyses of variance for all the 3 cuttings is given in Table 19 and the results of Duncan's multiple range tests for treatment means are shown in Tables 20 and 21.

Table 18. Effect of Calcium Silicate and Phosphorus on the Yield, Phosphorus Content and Silicon Content of Kikuyu Grass in Relation to Placement[1/]

Treatment Si tons/A	Treatment P lbs/A	Placement	Yield g/pot	Phosphorus %	Phosphorus mg/pot	Silicon %	Silicon mg/pot	P:Si
			First Cutting					
1.0	500	L-1	4.15	0.262	10.87	0.394	16.35	0.66
		L-2	7.73	0.222	17.16	0.310	23.96	0.72
		L-3	4.57	0.214	9.78	0.180	8.23	1.19
	2000	L-1	4.99	0.428	21.36	0.400	19.96	1.07
		L-2	7.75	0.440	34.10	0.330	25.58	1.33
		L-3	9.70	0.260	25.22	0.238	23.09	1.09
4.0	500	L-1	6.38	0.260	16.59	0.820	52.32	0.32
		L-2	4.27	0.366	15.63	0.516	22.03	0.71
		L-3	5.51	0.246	13.55	0.238	13.11	1.03
	2000	L-1	7.03	0.430	30.23	0.724	50.90	0.59
		L-2	6.63	0.514	34.08	0.444	29.44	1.16
		L-3	4.88	0.392	19.13	0.316	15.42	1.24
			Second Cutting					
1.0	500	L-1	6.73	0.330	22.21	0.288	19.38	1.14
		L-2	6.11	0.294	17.96	0.518	31.65	0.57
		L-3	5.44	0.364	19.80	0.288	15.67	1.26
	2000	L-1	5.20	0.316	16.43	0.430	22.36	0.73
		L-2	5.11	0.554	28.31	0.422	21.56	1.31
		L-3	5.98	0.502	30.02	0.432	25.83	1.16
4.0	500	L-1	6.29	0.368	23.15	0.730	45.92	0.50
		L-2	7.69	0.228	17.53	0.676	51.98	0.34
		L-3	4.89	0.330	16.14	0.330	16.14	1.00
	2000	L-1	6.91	0.350	24.19	0.852	58.87	0.41
		L-2	8.21	0.538	44.17	0.538	44.17	1.00
		L-3	5.71	0.432	24.67	0.432	24.67	1.00

L-1: Si and P mixed with the whole soil
L-2: Si and P mixed into one layer
L-3: Si and P in separate layers

[1/] Mean of two replicates. For complete details see Appendix tables.

Table 18. Effect of Calcium Silicate and Phosphorus on the Yield, Phosphorus Content and Silicon Content of Kikuyu Grass in Relation to Placement[1/] (Continued)

Treatment Si tons/A	Treatment P lbs/A	Placement	Yield g/pot	Phosphorus %	Phosphorus mg/pot	Silicon %	Silicon mg/pot	P:Si
			Third Cutting					
1.0	500	L-1	9.32	0.254	23.67	0.456	42.50	0.56
		L-2	9.78	0.194	18.97	0.478	46.75	0.41
		L-3	9.50	0.218	20.71	0.220	20.90	0.99
	2000	L-1	6.39	0.332	21.22	0.554	35.40	0.60
		L-2	9.31	0.284	26.44	0.558	51.95	0.51
		L-3	8.36	0.296	24.75	0.404	33.77	0.73
4.0	500	L-1	9.57	0.248	23.73	0.840	80.39	0.30
		L-2	10.39	0.204	21.20	0.846	87.90	0.24
		L-3	8.92	0.244	21.76	0.282	25.15	0.87
	2000	L-1	9.46	0.270	25.54	1.068	101.30	0.25
		L-2	10.32	0.290	29.93	1.090	112.49	0.27
		L-3	8.93	0.270	24.11	0.382	34.11	0.71

L-1: Si and P mixed with the whole soil
L-2: Si and P mixed into one layer
L-3: Si and P in separate layers

[1/]Mean of two replicates. For complete details see Appendix tables.

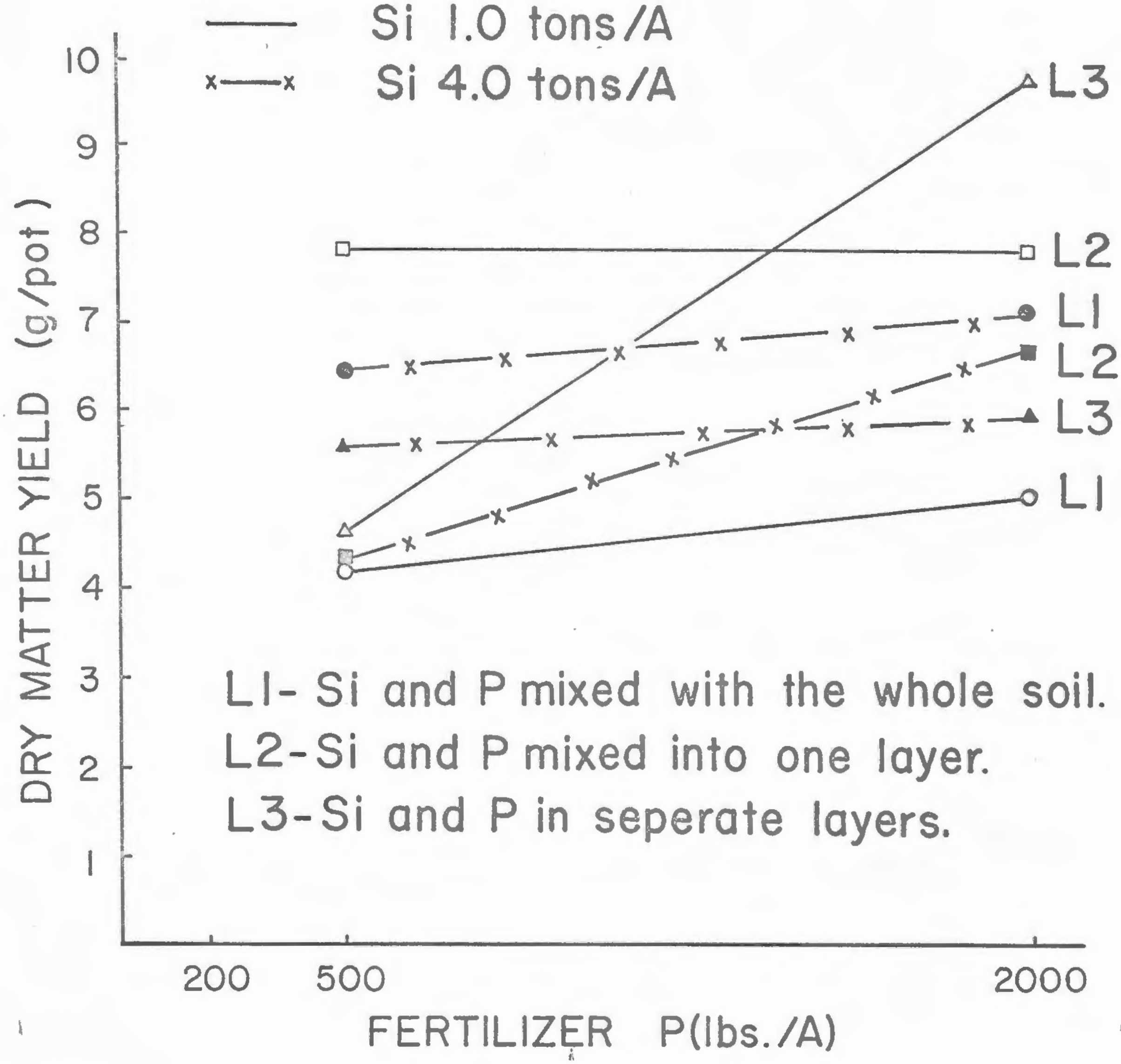

Figure 26. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of Kikuyu Grass - 1st Cutting in Relation to Placement

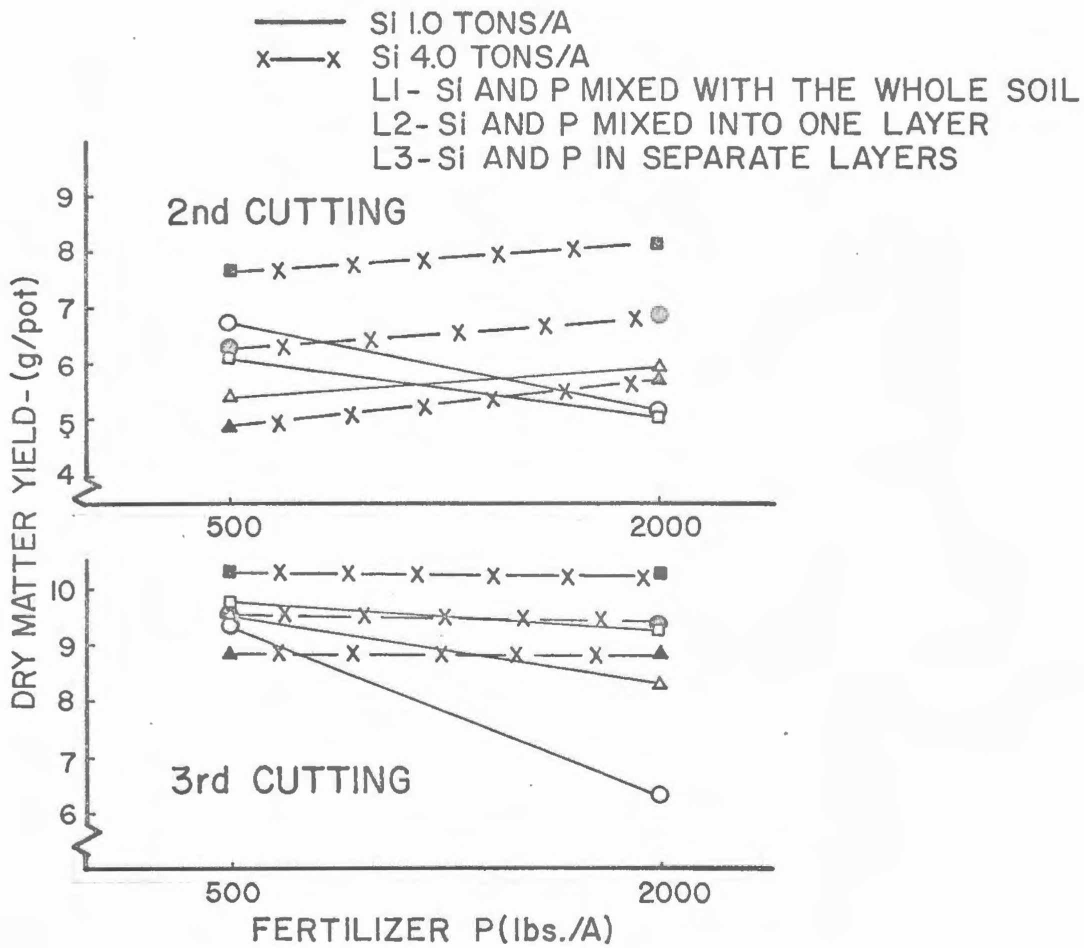

Figure 27. Effect of Calcium Silicate and Phosphorus on the Dry Matter Yield of Kikuyu Grass - 2nd and 3rd Cutting in Relation to Placement

Table 19. Experiment 2 - Summary of Analyses of Variance (F Values) for Dry Matter Yields of 3 Cuttings of Kikuyu Grass

Sources	d.f.	Cut 1	Cut 2	Cut 3
Phosphorus	1	10.03**	ns	4.68
Silicon	1	2.51	5.76*	5.17*
Placement	2	1.58	4.38*	4.58*
P x Si	1	1.87	3.40	4.02
P x Pl.	2	1.03	ns	1.07
Si x Pl.	2	10.37**	5.07*	1.78
P x Si x Pl.	2	7.34*	ns	ns

* Significant at the 5% level.
**Significant at the 1% level.

Table 20. Experiment 2 - Summary of Duncan's Multiple Range Test for Treatment Means - (Effect of P, Si and Placement on Total Yield)

		Cut 1	Cut 2	Cut 3
Phosphorus	500 lbs/A	10.87b	12.38a	19.15a
	2000 lbs/A	13.66a	12.34a	17.58a
Silicon	1 ton/A	12.96a	11.52a	19.19a
	4 tons/A	11.57a	13.19a	17.55a
Placement*	1	11.28a	8.37a	11.57a
	2	13.19a	9.01a	13.26a
	3	12.33a	7.34a	11.73a

*Placement 1: Si and P mixed with whole soil.
Placement 2: Si and P mixed into one layer.
Placement 3: Si and P in separate layers.

Table 21. Experiment 2 - Summary of Duncan's Multiple Range Test for Means of Individual Treatment Combinations

Treatment		Placement*	1st Cutting	2nd Cutting	3rd Cutting
Si tons/A	P lbs/A				
1	500	1	4.15e	6.73abc	9.32a
		2	7.73bc	6.11bc	9.78a
		3	4.57de	5.44c	9.50a
	2000	1	4.99de	5.20c	6.39b
		2	7.75ab	5.11c	9.31a
		3	9.70a	5.98bc	8.36a
4	500	1	6.38bcde	6.29abc	9.57a
		2	4.27e	7.69ab	10.39a
		3	5.51bcde	4.89c	8.92a
	2000	1	7.03bcd	6.91abc	9.46a
		2	6.63bcde	8.21a	10.32a
		3	4.88de	5.71bc	8.93a

*1 - Si and P mixed in whole soil.
2 - Si and P mixed into one layer.
3 - Si and P in separate layers.

In the first cutting, yields were significantly influenced at the 1% level of P and Si x placement interaction. An interaction of the 5% level of significance is also found between P and Si and placement (Table 19).

At the rates of 1 ton Si and 500 lbs. P, placement 2 gave significantly higher yields than placements 1 or 3 (Table 21). It is probable that at the lower rate of P, the proximity of Si may have increased P availability. In the first cutting the highest yield was obtained at the rates of 2000 lbs. of P and 1 ton Si in placement 3. This was probably due to the concentration of P in a position readily available to the roots at the early stages of growth. This yield was not significantly different from the yield in placement 2 receiving the same rates of P and Si, but was significantly higher than the yield in placement 1. At the 4 ton rate of Si, there was no difference between the 2 rates of P application (Table 21).

In the second cutting, yields were significantly influenced at the 5% level by Si, placement and an interaction between Si and placement. At the 1 ton rate of Si, there was no significant difference in yield between the two rates of P or the 3 placements. At the 4 ton rate of Si, the yield in placement 2 was significantly higher than in placement 3 at both the 500 and 2000 lbs. rates of P, but was not significantly different from the yield in placement 1. The increases in yield for additions of Si in the second cutting and the lack of response to P application is probably due to the higher P availability caused by the increased solubility of Si (Table 21).

In the third cutting there were significant yield responses to Si and placement (Table 21).

Chemical Composition:

Mean chemical composition of each cutting and placement are shown in Table 22. In all these cuttings, P content was higher in placement 2. Both P content and Si content increased with successive cuttings, but percent P increased at the second cutting and decreased at the third cutting. Si content was highest at placement 2 in the second and third cuttings. It was lowest in placement 3 in all cuttings. This may be attributed to the fact that Si was further from the active root zone in placement 3 (Figures 28 and 29).

P:Si ratio decreased with successive cuttings and increased through placements 1, 2 and 3.

In both experiments, some analyses were done to determine the Al and Ca content in plant tissue. The concentration of Al was too low to be of any significance. The Ca content could not be related to P treatments and as such have not been discussed. The results of the analyses are shown in the Appendix.

Table 22. Experiment 2 - Mean* Chemical Composition of Each Cutting of Kikuyu Grass With Respect to Placement

Cutting	Placement**	Phosphorus		Silicon		P:Si
		%	mg/pot	%	mg/pot	
1	1	0.345	19.76	0.584	34.88	0.591
	2	0.386	25.24	0.400	25.25	0.965
	3	0.278	16.92	0.243	14.96	1.144
2	1	0.341	21.49	0.575	36.63	0.593
	2	0.404	26.99	0.538	37.34	0.751
	3	0.407	22.66	0.370	20.58	1.100
3	1	0.276	23.54	0.729	64.90	0.379
	2	0.243	24.14	0.743	74.77	0.327
	3	0.257	22.83	0.322	28.48	0.798

* Mean values of four treatment combinations.

**1 - Si and P mixed with the whole soil.

2 - Si and P mixed into one layer.

3 - Si and P in separate layers.

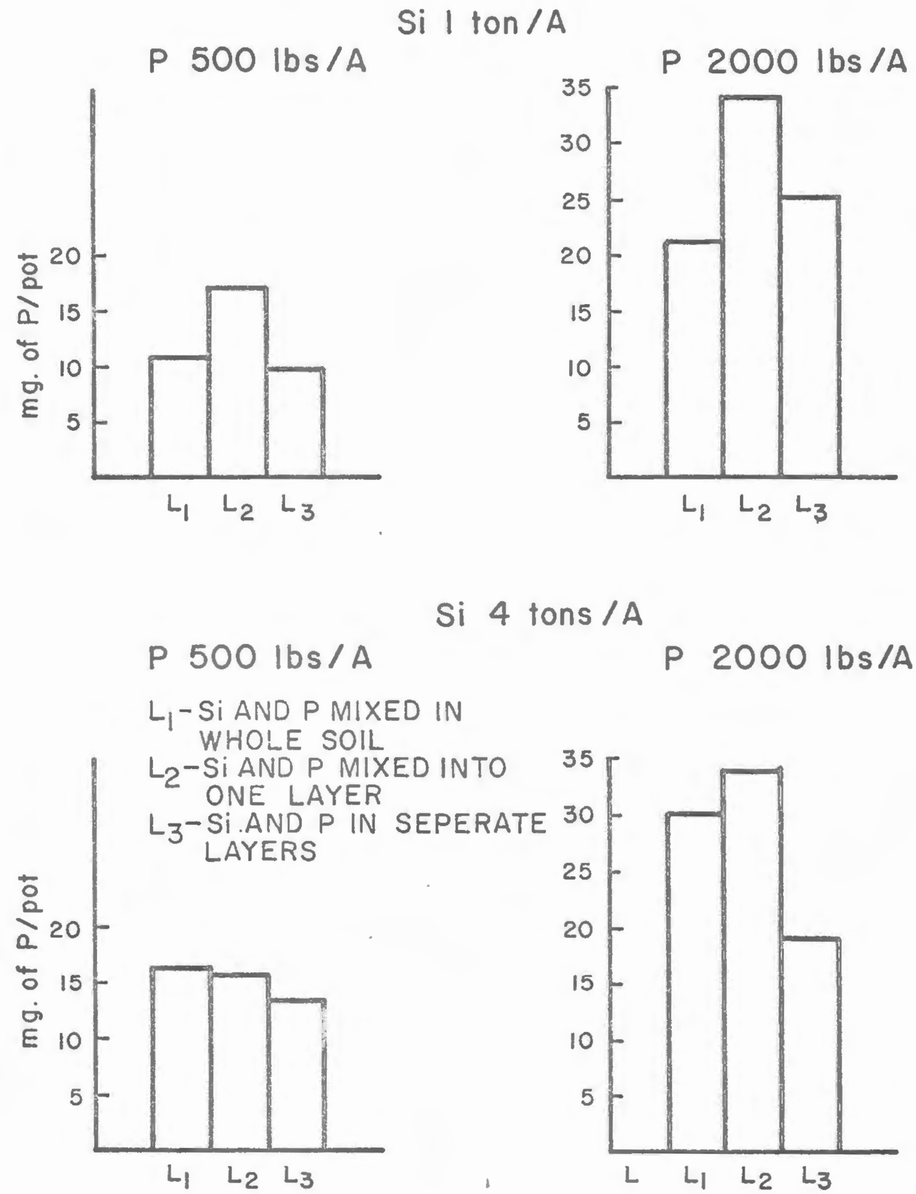

Figure 28. Influence of Calcium Silicate and Phosphorus Placement on P Uptake by Kikuyu Grass - 1st Cutting

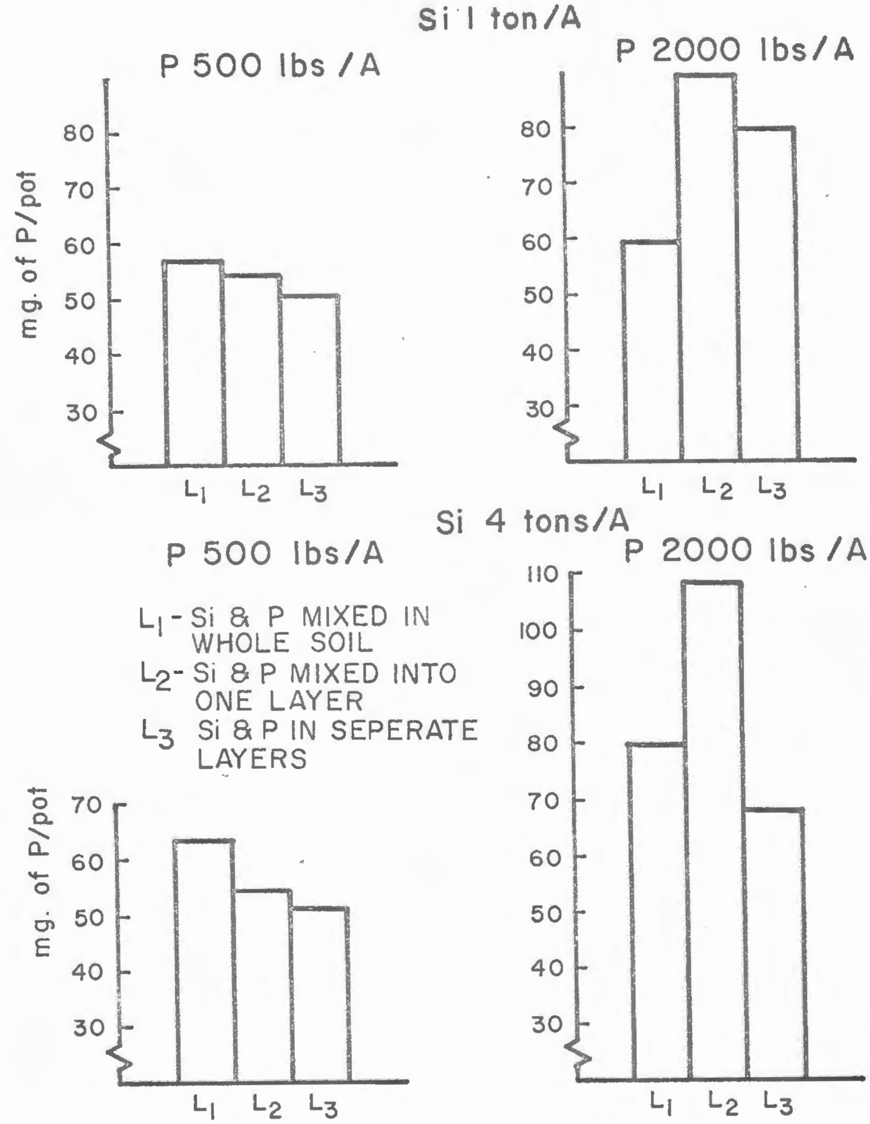

Figure 29. Effect of Calcium Silicate and Phosphorus Placement on P Uptake by Kikuyu Grass (Total of Three Cuttings)

SUMMARY AND CONCLUSION

In the two experiments conducted in the greenhouse, kikuyu grass, corn, Desmodium intortum, sedge grass, tomato and Mimosa pudica were grown in pots of virgin Kapaa soil, fertilized with 3 rates of P (200, 500 and 2000 lbs. per acre) and 4 rates of Si (0, 0.1, 1.0 and 4.0 tons per acre) in a factorial design. Placement studies were carried out by growing kikuyu grass with 2 rates of P (200 and 500 lbs. per acre) and 2 rates of Si (1 and 4 tons per acre) in 3 placements (mixed with whole soil, mixed into one layer of soil, and placed separately), also in a factorial design, and 3 successive cuttings were taken.

It was found that Si significantly increased the yield of corn and the subsequent cuttings of kikuyu grass. In corn and the second cutting of sedge, increase in yields were accompanied by a decrease in the P requirement as influenced by Si. The third cutting of kikuyu grass, Si response was developed with time, which was more or less independent of P applied.

Phosphorus increased significantly the yield of all plant crops, the response being more pronounced in tomato, Desmodium intortum and plant crop of sedge.

In placement studies yields were highest when Si and P were mixed into a thin (1 cm.) layer of soil and placed 2 cm. below the surface. In most instances the beneficial effects of Si could be attributed to increased availability of fertilizer P, especially in the latter stages of growth when fertilizer P was limiting.

The response of kikuyu grass to P applications decreased with successive cuttings, while the response to Si applications increased. Silicon probably improved yields by decreasing the P requirement of the plant and also by increasing the fertilizer P availability when P is limiting.

Percentage P content of plants decreased in the following order: tomato > kikuyu grass > corn > Desmodium intortum > sedge > Mimosa pudica. Percentage Si content decreased in the order: corn > sedge > Desmodium intortum > kikuyu grass > tomato > Mimosa pudica. Phosphorus content was lower and Si content was higher in successive cuttings. P:Si ratio was not related to yields.

It was found in a detailed analysis of the corn plant that the roots contained 34% of the total P in the plant and only 10% of the Si, while the sheaths contained 46% of the Si and only 19% of the P. Percentage of soluble P and Si was lower in older plants.

The sensitivity of plants to Si seemed to increase with increasing ability among the species to accumulate Si.

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A P P E N D I X

Appendix Table 1
Effect of Calcium Silicate and Phosphorus Levels on the Yield of Kikuyu Grass Grown on Kapaa Soil

Treatment		Yield - grams per pot		
Rate of Si tons/A	Rate of P lbs/A	R1	R2	Mean
		First Cutting		
None	200	2.25	3.20	2.73
	500	4.12	4.42	4.27
	2000	9.55	6.78	8.17
0.1	200	2.09	3.62	2.86
	500	4.20	5.29	4.75
	2000	6.40	7.10	6.75
1.0	200	2.45	1.61	2.03
	500	5.28	3.02	4.15
	2000	4.70	5.28	4.99
4.0	200	1.95	2.70	2.33
	500	6.88	5.88	6.38
	2000	5.96	8.10	7.03
		Second Cutting		
None	200	4.88	7.39	6.14
	500	4.82	6.94	5.88
	2000	5.81	7.62	6.72
0.1	200	6.82	6.88	6.85
	500	7.36	7.55	7.46
	2000	6.02	5.43	5.73
1.0	200	5.65	4.20	4.93
	500	6.98	6.47	6.73
	2000	6.25	4.15	5.20
4.0	200	4.23	7.93	6.08
	500	6.49	6.09	6.29
	2000	7.24	6.57	6.91

Appendix Table 1 (Continued)
Effect of Calcium Silicate and Phosphorus Levels
on the Yield of Kikuyu Grass Grown on Kapaa Soil

Treatment		Yield - grams per pot		
Rate of Si tons/A	Rate of P lbs/A	R1	R2	Mean
		Third Cutting		
None	200	4.16	8.00	6.08
	500	7.45	8.11	7.78
	2000	8.47	9.23	8.85
0.1	200	7.50	7.92	7.71
	500	8.41	8.71	8.56
	2000	7.57	8.34	7.96
1.0	200	7.76	6.18	6.97
	500	9.37	9.24	9.31
	2000	6.32	6.46	6.39
4.0	200	9.50	8.30	8.90
	500	9.31	9.82	9.56
	2000	9.02	9.90	9.46
		Fourth Cutting		
None	200	-	8.54	8.54
	500	6.01	7.87	6.94
	2000	8.86	8.63	8.75
0.1	200	7.83	8.22	8.03
	500	8.62	8.80	8.71
	2000	9.30	8.32	8.81
1.0	200	6.72	-	6.72
	500	8.31	9.30	8.81
	2000	6.02	-	6.02
4.0	200	8.56	8.40	8.48
	500	8.50	8.83	8.67
	2000	9.65	9.62	9.69

Appendix Table 2
Effect of Calcium Silicate and Phosphorus Levels on the Yield of Corn Grown on Kapaa Soil

Treatment		Yield - gram per pot		
Rate of Si tons/A	Rate of P lbs/A	R1	R2	Mean
		Leaf and Stalks		
None	200	10.31	8.43	9.37
	500	12.12	8.92	10.52
	2000	15.90	12.50	14.20
0.1	200	12.30	10.10	11.20
	500	14.61	12.17	13.39
	2000	13.22	13.42	13.32
1.0	200	11.35	8.65	10.00
	500	15.65	11.00	13.33
	2000	13.79	14.12	13.96
4.0	200	11.93	10.38	11.16
	500	12.59	12.35	12.97
	2000	15.08	12.32	13.70
		Sheaths		
None	200	1.33	1.96	1.65
	500	2.37	2.10	2.24
	2000	2.16	3.96	3.06
0.1	200	1.94	1.88	1.91
	500	2.43	2.95	2.69
	2000	3.04	3.03	3.04
1.0	200	1.99	2.23	2.11
	500	2.11	2.98	2.55
	2000	3.14	2.38	2.76
4.0	200	1.69	2.22	1.96
	500	2.27	3.25	2.76
	2000	3.70	3.16	3.43

Appendix Table 2 (Continued)
Effect of Calcium Silicate and Phosphorus Levels
on the Yield of Corn Grown on Kapaa Soil

Treatment		Yield - grams per pot		
Rate of Si tons/A	Rate of P lbs/A	R1	R2	Mean
		Roots		
None	200	5.63	4.60	5.12
	500	7.42	6.28	6.85
	2000	9.38	8.60	8.99
0.1	200	6.00	7.18	6.85
	500	9.43	8.02	8.73
	2000	9.35	8.57	8.96
1.0	200	5.50	5.37	5.44
	500	7.70	7.18	7.44
	2000	8.46	8.15	8.31
4.0	200	5.35	5.78	5.57
	500	7.43	8.44	7.84
	2000	9.15	9.60	9.38

Appendix Table 3
Effect of Calcium Silicate and Phosphorus Levels
on the Yield of Desmodium intortum Grown on Kapaa Soil

Treatment		Yield - grams per pot		
Rate of Si tons/A	Rate of P lbs/A	R1	R2	Mean
		First Cutting		
None	200	0.32	0.69	0.56
	500	1.38	1.05	1.22
	2000	2.29	3.09	2.69
0.1	200	0.40	0.36	0.38
	500	1.46	1.10	1.28
	2000	3.13	2.70	2.92
1.0	200	0.32	0.24	0.28
	500	1.43	1.29	1.36
	2000	2.90	2.60	2.75
4.0	200	0.17	0.43	0.30
	500	1.42	1.58	1.50
	2000	2.53	2.64	2.59
		Second Cutting		
None	200	9.45	8.22	8.84
	500	8.66	9.61	9.14
	2000	7.03	10.78	8.91
0.1	200	7.93	8.48	8.21
	500	8.66	9.33	9.00
	2000	8.45	8.39	8.42
1.0	200	8.79	8.39	8.59
	500	9.17	9.54	9.36
	2000	8.20	7.22	7.71
4.0	200	7.39	7.52	7.46
	500	9.42	9.55	9.49
	2000	6.91	7.27	7.09

Appendix Table 4
Effect of Calcium Silicate and Phosphorus Levels on the Yield of Sedge Grown on Kapaa Soil

Treatment		Yield - grams per pot		
Rate of Si tons/A	Rate of P lbs/A	R1	R2	Mean
		First Cutting		
None	200	2.98	3.42	3.20
	500	5.32	4.70	5.11
	2000	7.47	6.50	6.99
0.1	200	3.72	3.35	3.54
	500	6.01	6.32	6.17
	2000	5.90	6.70	6.30
1.0	200	4.63	3.52	4.13
	500	5.60	5.64	5.62
	2000	5.95	6.35	6.15
4.0	200	4.50	5.11	4.81
	500	5.00	5.03	5.02
	2000	7.28	6.95	7.12
		Second Cutting		
None	200	2.43	2.47	2.45
	500	4.32	3.10	3.71
	2000	4.60	4.16	4.38
0.1	200	2.43	2.80	2.62
	500	3.46	3.83	3.65
	2000	4.77	4.02	4.40
1.0	200	3.00	2.53	2.77
	500	4.55	3.90	4.23
	2000	3.83	4.10	3.97
4.0	200	3.88	5.08	4.48
	500	4.21	4.24	4.23
	2000	4.12	3.89	4.01

Appendix Table 5
Effect of Calcium Silicate and Phosphorus Levels
on the Yield of Hybrid Tomato (N-57) Grown on Kapaa Soil

Treatment		Yield - grams per pot		
Rate of Si tons/A	Rate of P lbs/A	R1	R2	Mean
None	200	2.56	2.30	2.43
	500	4.42	4.80	4.61
	2000	4.72	5.03	4.88
0.1	200	2.00	2.49	2.25
	500	4.95	4.13	4.84
	2000	4.94	5.07	5.01
1.0	200	2.64	2.90	2.77
	500	4.51	4.56	4.54
	2000	5.40	5.67	5.54
4.0	200	2.45	2.72	2.58
	500	4.73	4.46	4.60
	2000	5.72	5.38	5.55

Appendix Table 6
Effect of Calcium Silicate and Phosphorus Levels
on the Yield of *Mimosa pudica* Grown on Kapaa Soil

Treatment		Yield - grams per pot		
Rate of Si tons/A	Rate of P lbs/A	R1	R2	Mean
None	200	8.42	8.85	8.64
	500	6.54	5.68	6.11
	2000	6.33	7.40	6.87
0.1	200	10.45	8.49	9.47
	500	6.01	4.85	5.43
	2000	7.00	7.50	7.25
1.0	200	9.32	7.82	8.57
	500	5.80	6.86	6.33
	2000	7.15	7.08	7.12
4.0	200	8.20	10.25	9.23
	500	5.80	7.10	6.45
	2000	7.20	7.47	7.34

Appendix Table 7
Concentration of Phosphorus in Kikuyu Grass (1st Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	2621	2741	2681	0.268
	500	2156	2222	2189	0.218
	2000	3044	4557	3801	0.380
0.1	200	3114	2541	2828	0.282
	500	2468	2608	2538	0.254
	2000	4141	4973	4557	0.456
1.0	200	3020	2754	2887	0.288
	500	2475	2748	2612	0.262
	2000	4740	3809	4275	0.428
4.0	200	2568	2581	2575	0.258
	500	2541	2675	2608	0.260
	2000	4208	4391	4300	0.430

Appendix Table 8
Concentration of Silicon in Kikuyu Grass (First Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	645	688	667	0.066
	500	795	816	806	0.080
	2000	945	1010	978	0.098
0.1	200	1547	1547	1547	0.154
	500	1117	1440	1279	0.128
	2000	1547	1976	1762	0.176
1.0	200	4125	6167	5146	0.514
	500	4576	3309	3943	0.394
	2000	3911	4104	4008	0.400
4.0	200	8960	9110	9035	0.904
	500	8208	8186	8197	0.820
	2000	7348	7133	7241	0.724

Appendix Table 9
Concentration of Phosphorus in Kikuyu Grass (2nd Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	2393	1900	2147	0.214
	500	3589	3336	3463	0.346
	2000	3421	3303	3362	0.336
0.1	200	2103	2103	2103	0.210
	500	3101	3387	3244	0.324
	2000	3219	3438	3329	0.332
1.0	200	2339	2575	2457	0.246
	500	3387	3219	3303	0.330
	2000	2848	3455	3152	0.316
4.0	200	2528	2238	2383	0.238
	500	3640	3707	3674	0.368
	2000	3523	3471	3497	0.350

Appendix Table 10
Concentration of Silicon in Kikuyu Grass (2nd Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	435	327	381	0.038
	500	414	414	414	0.042
	2000	1132	893	1013	0.102
0.1	200	914	914	914	0.092
	500	1001	1045	1023	0.102
	2000	1567	1916	1742	0.174
1.0	200	3091	3374	3233	0.324
	500	2983	2765	2874	0.288
	2000	3505	5094	4300	0.430
4.0	200	5595	5486	5541	0.554
	500	7380	7228	7304	0.730
	2000	6422	10602	8512	0.852

Appendix Table 11
Concentration of Phosphorus in Kikuyu Grass (3rd Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	2641	1743	2192	0.220
	500	2907	2415	2661	0.266
	2000	2242	1989	2116	0.212
0.1	200	2142	1730	1936	0.194
	500	2641	2628	2635	0.264
	2000	2442	2315	2379	0.238
1.0	200	1923	2941	2432	0.244
	500	2508	2575	2542	0.254
	2000	3213	3406	3310	0.332
4.0	200	2049	1796	2923	0.292
	500	2528	2442	2485	0.248
	2000	2974	2442	2708	0.270

Appendix Table 12
Concentration of Silicon in Kikuyu Grass (3rd Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	899	957	928	0.092
	500	982	991	987	0.098
	2000	1731	1665	1648	0.164
0.1	200	2647	1740	2194	0.220
	500	1765	2081	1923	0.192
	2000	2189	2439	2314	0.232
1.0	200	4899	6188	5544	0.554
	500	4791	4340	4566	0.456
	2000	5028	6038	5533	0.554
4.0	200	7628	8337	7983	0.798
	500	8874	7907	8391	0.840
	2000	11087	10270	10679	1.068

Appendix Table 13
Concentration of TCA Soluble Phosphorus in Corn (Sheath) Grown on Kapaa Soil With Applications of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	58	41	50	0.005
	500	58	46	52	0.005
	2000	63	58	61	0.006
0.1	200	60	46	53	0.005
	500	94	46	70	0.007
	2000	87	72	80	0.008
1.0	200	51	46	49	0.005
	500	58	46	52	0.005
	2000	60	56	58	0.006
4.0	200	58	56	57	0.006
	500	46	48	47	0.005
	2000	94	82	88	0.009

Appendix Table 14
Concentration of TCA Soluble Silicon in Corn (Sheath) Grown on Kapaa Soil With Applications of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	12	15	14	0.001
	500	11	11	11	0.001
	2000	19	18	19	0.002
0.1	200	20	11	16	0.002
	500	14	17	16	0.002
	2000	20	19	20	0.002
1.0	200	23	28	26	0.003
	500	30	38	34	0.003
	2000	36	34	35	0.004
4.0	200	33	52	43	0.004
	500	45	40	43	0.004
	2000	48	38	43	0.004

Appendix Table 15
Concentration of Phosphorus in Corn (Sheath)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	779	973	876	0.088
	500	1064	1038	1051	0.105
	2000	908	921	915	0.092
0.1	200	662	714	688	0.068
	500	753	740	747	0.074
	2000	753	843	798	0.080
1.0	200	779	908	844	0.084
	500	701	1103	902	0.090
	2000	869	869	869	0.086
4.0	200	740	753	747	0.074
	500	740	792	766	0.076
	2000	882	1038	960	0.096

Appendix Table 16
Concentration of Silicon in Corn (Sheath)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	1849	1387	1618	0.162
	500	2049	1494	1772	0.178
	2000	3522	2774	3148	0.314
0.1	200	2881	3095	2988	0.298
	500	3159	3884	3522	0.352
	2000	4269	4269	4269	0.426
1.0	200	8858	6617	7738	0.774
	500	9434	8923	9179	0.918
	2000	8324	9007	8666	0.866
4.0	200	19423	15368	17396	1.740
	500	20106	13874	16990	1.700
	2000	14945	13127	14036	1.404

Appendix Table 17
Concentration of Phosphorus in Corn (Leaf & Stalk) at 40 Days
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	1977	2211	2094	0.210
	500	2465	2702	2584	0.258
	2000	2188	1898	2043	0.204
0.1	200	1792	1990	1891	0.190
	500	2188	2194	2191	0.220
	2000	1957	2175	2066	0.206
1.0	200	1891	2254	2073	0.208
	500	1911	2583	2247	0.224
	2000	1924	2188	2056	0.206
4.0	200	2122	2254	2188	0.218
	500	2129	2109	2119	0.212
	2000	2287	2122	2205	0.220

Appendix Table 18
Concentration of Silicon in Corn (Leaf & Stalk) at 40 Days
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	885	1152	1019	0.102
	500	1132	1132	1132	0.114
	2000	2162	1853	2008	0.200
0.1	200	2471	1956	2214	0.222
	500	2779	2841	2810	0.282
	2000	2758	2697	2728	0.272
1.0	200	7205	6588	6897	0.690
	500	5744	9058	7402	0.740
	2000	7823	7617	7720	0.772
4.0	200	13238	17088	15163	1.516
	500	13279	13897	13588	1.358
	2000	20094	15441	17768	1.776

Appendix Table 19
Concentration of Phosphorus in Corn (Root)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	1614	1435	1525	0.152
	500	1626	1595	1611	0.162
	2000	1467	1563	1515	0.152
0.1	200	1448	1499	1474	0.148
	500	1467	1435	1451	0.146
	2000	1595	1575	1585	0.158
1.0	200	1339	1531	1435	0.144
	500	1754	1882	1818	0.182
	2000	1595	1595	1585	0.158
4.0	200	1697	1563	1630	0.164
	500	1371	1499	1435	0.144
	2000	1524	1563	1544	0.154

Appendix Table 20
Concentration of Silicon in Corn (Root)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	519	757	638	0.064
	500	1470	1686	1578	0.158
	2000	2291	1318	1805	0.180
0.1	200	735	1102	919	0.092
	500	1362	1254	1308	0.130
	2000	994	1318	1156	0.116
1.0	200	1016	994	1005	0.100
	500	1427	2183	1805	0.180
	2000	1643	1146	1395	0.140
4.0	200	1794	2723	2259	0.226
	500	1967	2723	2345	0.234
	2000	3047	1967	2705	0.270

Appendix Table 21
Concentration of Phosphorus in Desmodium intortum (1st Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	2792	3324	3058	0.306
	500	2779	2580	2680	0.268
	2000	3245	2912	3079	0.308
0.1	200	2593	2593	2593	0.260
	500	2726	2646	2686	0.268
	2000	3112	3285	3199	0.320
1.0	200	2593	2460	2527	0.252
	500	2739	2513	2626	0.262
	2000	3245	3497	3371	0.338
4.0	200	-	2992	2992	0.300
	500	2407	3045	2726	0.272
	2000	3444	4202	2823	0.282

Appendix Table 22
Concentration of Silicon in Desmodium intortum (1st Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	707	663	685	0.068
	500	729	685	707	0.070
	2000	840	1083	962	0.096
0.1	200	1238	1238	1238	0.124
	500	1503	1503	1503	0.150
	2000	1967	2343	2155	0.216
1.0	200	6233	7604	6919	0.692
	500	7537	8090	7814	0.782
	2000	8333	8775	8554	0.856
4.0	200	-	9328	9328	0.932
	500	10941	9968	10455	1.046
	2000	12953	14987	13970	1.398

Appendix Table 23
Concentration of Phosphorus in Desmodium intortum (2nd Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	1432	1613	1528	0.152
	500	1974	1924	1949	0.194
	2000	2534	2503	2519	0.252
0.1	200	2086	1918	2002	0.200
	500	2111	2098	2105	0.210
	2000	2596	2783	2690	0.270
1.0	200	2011	2024	2018	0.202
	500	2304	2279	2292	0.230
	2000	2702	2808	2750	0.276
4.0	200	2129	2042	2086	0.208
	500	2490	2223	2357	0.236
	2000	-	2515	2515	0.252

Appendix Table 24
Concentration of Silicon in Desmodium intortum (2nd Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	973	828	901	0.090
	500	828	952	890	0.090
	2000	1201	1387	1294	0.130
0.1	200	1822	1842	1832	0.184
	500	2255	1822	2029	0.202
	2000	2380	2712	2546	0.254
1.0	200	7534	7038	7286	0.728
	500	5278	6292	5785	0.578
	2000	8404	9170	8787	0.878
4.0	200	11985	12295	12140	1.214
	500	9915	10494	10205	1.020
	2000	-	13330	13330	1.334

Appendix Table 25
Concentration of Phosphorus in Sedge (1st Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	2064	1932	1998	0.200
	500	2183	2296	2240	0.224
	2000	3931	3748	3840	0.384
0.1	200	2032	1957	1995	0.200
	500	2271	2328	2300	0.230
	2000	4097	4246	4172	0.418
1.0	200	1938	1768	1853	0.186
	500	2271	2315	2293	0.230
	2000	3682	4428	4055	0.406
4.0	200	2108	2297	2203	0.220
	500	2322	2422	2372	0.238
	2000	3798	4528	4163	0.416

Appendix Table 26
Concentration of Silicon in Sedge (1st Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	1169	898	1034	0.104
	500	898	1002	950	0.096
	2000	1733	1524	1629	0.162
0.1	200	2359	2025	2192	0.220
	500	1524	1670	1597	0.160
	2000	2129	2422	2276	0.228
1.0	200	6743	7578	7161	0.716
	500	6326	5052	5689	0.568
	2000	5177	6117	5647	0.564
4.0	200	13466	13466	13466	1.346
	500	13006	11983	12495	1.250
	2000	11649	11649	11649	1.165

Appendix Table 27
Concentration of Phosphorus in Sedge (2nd Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	1921	1871	1896	0.190
	500	2139	2097	2118	0.212
	2000	2606	2824	2715	0.272
0.1	200	1772	1758	1765	0.176
	500	2238	2323	2281	0.228
	2000	3213	2874	3044	0.304
1.0	200	1801	1765	1783	0.178
	500	2175	2295	2235	0.224
	2000	2733	2789	2761	0.276
4.0	200	1758	2118	1938	0.194
	500	2224	2464	2344	0.234
	2000	2846	3072	2959	0.296

Appendix Table 28
Concentration of Silicon in Sedge (2nd Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	2030	1665	1848	0.184
	500	1345	1551	1448	0.144
	2000	1893	1802	1848	0.184
0.1	200	3649	3580	3615	0.362
	500	2805	2714	2760	0.276
	2000	3877	3033	3455	0.346
1.0	200	11197	12155	11676	1.168
	500	8552	8392	8472	0.848
	2000	8574	8050	8312	0.832
4.0	200	14777	14891	14834	1.484
	500	15917	13477	14697	1.470
	2000	15461	14617	15039	1.504

Appendix Table 29
Concentration of Phosphorus in Tomato Grown on Kapaa Soil With Applications of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	1843	1895	1879	0.188
	500	2299	2248	2274	0.228
	2000	5519	5418	5469	0.546
0.1	200	1959	1965	1962	0.196
	500	2184	2280	2232	0.224
	2000	5147	4859	5003	0.500
1.0	200	1876	1734	1805	0.180
	500	2550	2743	2647	0.264
	2000	5536	5299	5418	0.542
4.0	200	1972	1837	1905	0.190
	500	2711	2781	2746	0.274
	2000	5536	5231	5384	0.538

Appendix Table 30
Concentration of Silicon in Tomato Grown on Kapaa Soil With Applications of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	373	282	283	0.028
	500	273	248	261	0.026
	2000	316	299	308	0.030
0.1	200	359	427	393	0.040
	500	307	282	295	0.030
	2000	359	256	308	0.030
1.0	200	709	675	692	0.070
	500	675	572	624	0.062
	2000	675	632	654	0.066
4.0	200	957	828	893	0.090
	500	769	683	726	0.072
	2000	828	769	799	0.080

Appendix Table 31
Concentration of Phosphorus in *Mimosa pudica*
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Phosphorus in ppm			% of P
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	1884	1985	1933	0.194
	500	2351	2842	2597	0.260
	2000	2850	2850	2850	0.286
0.1	200	1457	1651	1554	0.156
	500	2609	2512	2562	0.256
	2000	2770	2810	2790	0.280
1.0	200	1650	2351	2001	0.200
	500	2536	2399	2468	0.246
	2000	2753	3019	2886	0.288
4.0	200	2069	1973	2021	0.202
	500	2753	2592	2673	0.268
	2000	3100	2834	2964	0.296

Appendix Table 32
Concentration of Silicon in *Mimosa pudica*
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus

Treatment		Silicon in ppm			% of Si
Si tons/A	P lbs/A	R1	R2	Mean	
None	200	257	274	266	0.026
	500	214	317	266	0.026
	2000	257	368	313	0.032
0.1	200	308	291	300	0.030
	500	317	326	322	0.032
	2000	480	377	429	0.042
1.0	200	463	488	476	0.048
	500	471	462	467	0.046
	2000	702	711	707	0.070
4.0	200	617	848	733	0.074
	500	617	531	574	0.058
	2000	702	788	745	0.074

Appendix Table 33
Effect of Calcium Silicate and Phosphorus
on Ca Uptake by Kikuyu Grass

Treatment			Calcium	
Si tons/A	P lbs/A	Yield g	%	mg/pot
		1st Cutting		
None	200	2.73	0.096	2.62
	500	4.27	0.259	11.06
	2000	8.17	0.224	18.30
0.1	200	2.86	0.111	3.17
	500	4.75	0.120	5.70
	2000	6.75	0.087	5.87
1.0	200	2.03	0.121	2.46
	500	4.15	0.061	2.53
	2000	4.99	0.050	2.49
4.0	200	2.33	0.068	1.58
	500	6.38	0.052	3.32
	2000	7.03	0.037	2.60
		2nd Cutting		
None	200	6.14	0.197	12.09
	500	5.88	0.147	8.64
	2000	6.72	0.164	11.02
0.1	200	6.85	0.212	14.52
	500	7.46	0.259	19.32
	2000	5.73	0.289	16.56
1.0	200	4.93	0.131	6.46
	500	6.73	0.194	13.06
	2000	5.20	0.301	15.65
4.0	200	6.08	0.102	6.20
	500	6.29	0.223	14.03
	2000	6.91	0.245	16.93

Appendix Table 34
Effect of Calcium Silicate and Phosphorus
on Ca Uptake by Corn

Treatment			Calcium	
Si tons/A	P lbs/A	Yield g	%	mg/pot
		Sheath		
None	200	1.65	0.271	4.47
	500	2.24	0.263	5.89
	2000	3.06	0.214	6.55
0.1	200	1.91	0.252	4.81
	500	2.69	0.203	5.46
	2000	3.04	0.150	4.56
1.0	200	2.11	0.277	5.84
	500	2.55	0.216	5.51
	2000	2.76	0.101	2.79
4.0	200	1.96	0.275	5.39
	500	2.76	0.195	5.38
	2000	3.43	0.179	6.14
		Leaf and Stalk		
None	200	9.37	0.095	8.90
	500	10.52	0.023	2.42
	2000	14.20	0.047	6.67
0.1	200	11.20	0.094	10.53
	500	13.39	0.015	2.00
	2000	13.32	0.128	17.05
1.0	200	10.00	0.067	6.70
	500	13.33	0.052	6.93
	2000	13.96	0.056	7.82
4.0	200	11.16	0.107	11.94
	500	12.97	0.054	7.00
	2000	13.70	0.039	5.34

Appendix Table 34 (Continued)
Effect of Calcium Silicate and Phosphorus
on Ca Uptake by Corn

Treatment		Yield	Calcium	
Si tons/A	P lbs/A	g	%	mg/pot
		Plant at 30 Day		
None	200	1.73	0.216	3.74
	500	3.09	0.197	6.09
	2000	5.62	0.103	5.79
0.1	200	1.80	0.172	3.10
	500	2.63	0.077	2.03
	2000	4.64	0.035	1.62
1.0	200	1.97	0.260	5.12
	500	2.84	0.119	3.38
	2000	5.53	0.098	5.42
4.0	200	1.56	0.168	2.62
	500	1.97	0.129	2.54
	2000	5.00	0.034	1.70

Appendix Table 35
Effect of Calcium Silicate and Phosphorus
on Ca Uptake by *Desmodium intortum*

Treatment		Yield	Calcium	
Si tons/A	P lbs/A	g	%	mg/pot
		1st Cutting		
None	200	0.56	1.171	6.56
	500	1.22	0.469	5.72
	2000	2.69	0.620	16.66
0.1	200	0.38	0.989	3.76
	500	1.28	0.650	8.32
	2000	2.92	0.637	18.60
1.0	200	0.28	0.753	2.11
	500	1.36	0.476	6.47
	2000	2.75	0.620	17.05
4.0	200	0.30	1.118	3.35
	500	1.50	0.710	10.65
	2000	2.59	0.874	22.64
		2nd Cutting		
None	200	8.84	1.576	139.32
	500	9.14	0.975	89.12
	2000	8.91	0.912	81.26
0.1	200	0.21	0.851	69.86
	500	9.00	0.739	66.51
	2000	8.42	0.746	62.81
1.0	200	8.59	0.856	73.53
	500	9.36	1.167	109.23
	2000	7.71	0.738	56.90
4.0	200	7.46	1.030	76.84
	500	9.49	1.157	109.80
	2000	7.09	0.955	67.71

Appendix Table 36
Effect of Calcium Silicate and Phosphorus
on Ca Uptake by Sedge

Treatment			Calcium	
Si tons/A	P lbs/A	Yield g	%	mg/pot
		1st Cutting		
None	200	3.20	0.153	4.89
	500	5.11	0.141	7.20
	2000	6.99	0.129	9.02
0.1	200	3.54	0.140	4.96
	500	6.17	0.081	0.50
	2000	6.30	0.044	2.77
1.0	200	4.13	0.050	2.07
	500	5.62	0.029	1.63
	2000	6.15	0.039	2.40
4.0	200	4.81	0.131	6.30
	500	5.02	0.078	3.92
	2000	7.12	0.047	3.35

Appendix Table 37
Effect of Calcium Silicate and Phosphorus
on Ca Uptake by Tomato

Treatment			Calcium	
Si tons/A	P lbs/A	Yield g	%	mg/pot
None	200	2.43	1.383	33.60
	500	4.61	1.251	57.67
	2000	4.88	0.923	45.04
0.1	200	2.25	1.250	28.13
	500	4.54	1.171	53.16
	2000	5.01	0.525	26.30
1.0	200	2.77	1.214	33.63
	500	4.54	1.020	46.31
	2000	5.54	0.501	27.76
4.0	200	2.58	1.787	46.10
	500	4.60	1.409	64.81
	2000	5.55	0.808	44.84

Appendix Table 38
Effect of Calcium Silicate and Phosphorus
of Ca Uptake by *Mimosa pudica*

Treatment			Calcium	
Si tons/A	P lbs/A	Yield g	%	mg/pot
None	200	8.64	1.339	115.69
	500	6.11	1.209	73.87
	2000	6.87	1.134	77.91
0.1	200	9.47	1.135	107.48
	500	5.43	0.966	52.45
	2000	7.25	0.971	70.40
1.0	200	8.57	1.020	87.41
	500	6.33	1.023	64.76
	2000	7.12	0.941	67.00
4.0	200	9.23	1.093	100.88
	500	6.45	0.983	63.40
	2000	7.34	0.802	58.87

Appendix Table 39
Experiment 2 - Effect of Calcium Silicate and Phosphorus Levels on the Yield of Kikuyu Grass Grown on Kapaa Soil in Relation to Placement

Treatment			Yield-grams per pot		
Rate of Si tons/A	Rate of P lbs/A	Placement	R1	R2	Mean
		1st Cutting			
1.0	500	mixed in whole soil	5.28	3.02	4.15
		mixed in top layer	8.30	7.16	7.73
		in separate layers	4.78	4.35	4.57
	2000	mixed in whole soil	4.70	5.28	4.99
		mixed in top layer	9.40	6.10	7.75
		in separate layers	9.91	9.50	9.70
4.0	500	mixed in whole soil	6.88	5.88	6.38
		mixed in top layer	4.11	4.43	4.27
		in separate layers	4.92	6.10	5.51
	2000	mixed in whole soil	5.96	8.10	7.03
		mixed in top layer	6.58	6.68	6.63
		in separate layers	5.23	4.53	4.88
		2nd Cutting			
1.0	500	mixed in whole soil	6.98	6.47	6.73
		mixed in top layer	5.04	7.18	6.11
		in separate layers	6.23	4.65	5.44
	2000	mixed in whole soil	6.25	4.15	5.20
		mixed in top layer	5.04	5.18	5.11
		in separate layers	6.00	5.95	5.98
4.0	500	mixed in whole soil	6.49	6.09	6.29
		mixed in top layer	7.17	8.20	7.69
		in separate layers	4.75	5.02	4.89
	2000	mixed in whole soil	7.24	6.57	6.91
		mixed in top layer	7.58	8.65	8.12
		in separate layers	5.72	5.70	5.71

Appendix Table 39 (Continued)
Experiment 2 - Effect of Calcium Silicate and Phosphorus Levels on the Yield of Kikuyu Grass Grown on Kapaa Soil in Relation to Placement

Treatment			Yield-grams per pot		
Rate of Si tons/A	Rate of P lbs/A	Placement	R1	R2	Mean
		3rd Cutting			
1.0	500	mixed in whole soil	9.37	9.24	9.32
		mixed in top layer	9.72	9.83	9.78
		in separate layers	10.38	8.62	9.50
	2000	mixed in whole soil	6.32	6.46	6.39
		mixed in top layer	8.59	10.02	9.31
		in separate layers	8.19	8.53	8.36
4.0	500	mixed in whole soil	9.31	9.82	9.57
		mixed in top layer	8.86	11.91	10.39
		in separate layers	8.58	9.26	8.92
	2000	mixed in whole soil	9.02	9.90	9.46
		mixed in top layer	10.80	9.83	10.32
		in separate layers	9.03	8.82	8.93
		4th Cutting			
1.0	500	mixed in whole soil	8.31	9.30	8.81
		mixed in top layer	8.57	9.45	9.01
		in separate layers	8.63	9.38	9.01
	2000	mixed in whole soil	6.02	-	6.02
		mixed in top layer	9.40	8.60	9.00
		in separate layers	-	9.11	9.11
4.0	500	mixed in whole soil	8.50	8.83	8.67
		mixed in top layer	9.36	9.22	9.29
		in separate layers	9.51	8.38	8.95
	2000	mixed in whole soil	9.65	9.62	9.64
		mixed in top layer	9.32	9.47	9.40
		in separate layers	8.98	8.20	8.59

Appendix Table 40
Concentration of Phosphorus in Kikuyu Grass (First Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus - In Relation to Placement

Treatment		Placement	Phosphorus in ppm			% of P
Si tons/A	P lbs/A		R1	R2	Mean	
1.0	500	L1	2475	2748	2612	0.262
		L2	2129	2295	2212	0.222
		L3	2029	2262	2146	0.214
	2000	L1	4740	3809	4275	0.428
		L2	4108	4757	4433	0.444
		L3	-	2595	2595	0.260
4.0	500	L1	2541	2675	2608	0.260
		L2	3759	3559	3659	0.366
		L3	2641	2295	2468	0.246
	2000	L1	4208	4391	4300	0.430
		L2	5173	5106	5140	0.514
		L3	3975	3859	3917	0.392

NOTE: Placement: L1 - Mixed in whole soil
L2 - Mixed in top layer
L3 - In separate layers

Appendix Table 41
Concentration of Silicon in Kikuyu Grass (First Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus - in Relation to Placement

Treatment		Placement	Silicon in ppm			% of Si
Si tons/A	P lbs/A		R1	R2	Mean	
1.0	500	L1	4576	3309	3943	0.394
		L2	3696	3502	3099	0.310
		L3	1805	1805	1805	0.180
	2000	L1	3911	4104	4008	0.400
		L2	3287	3309	3298	0.330
		L3	-	2385	2385	0.238
4.0	500	L1	8208	8186	8197	0.820
		L2	5157	5157	5157	0.516
		L3	2234	2514	2374	0.238
	2000	L1	7348	7133	7241	0.724
		L2	4512	4383	4448	0.444
		L3	3051	3266	3159	0.316

NOTE: Placement: L1 - Mixed in whole soil
L2 - Mixed in top layer
L3 - In separate layers

Appendix Table 42
Concentration of Phosphorus in Kikuyu Grass (Second Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus - in Relation to Placement

Treatment		Placement	Phosphorus in ppm			% of P
Si tons/A	P lbs/A		R1	R2	Mean	
1.0	500	L1	3387	3219	3303	0.330
		L2	3235	2662	2949	0.294
		L3	3640	3640	3640	0.364
	2000	L1	2848	3455	3152	0.316
		L2	5746	5325	5536	0.554
		L3	-	5022	5022	0.502
4.0	500	L1	3640	3707	3674	0.368
		L2	2393	2157	2275	0.228
		L3	2874	3744	3309	0.330
	2000	L1	3522	3471	3497	0.350
		L2	4245	6531	5388	0.538
		L3	4071	4550	4311	0.432

NOTE: Placement: L1 - Mixed in whole soil
L2 - Mixed in top layer
L3 - In separate layers

Appendix Table 43
Concentration of Silicon in Kikuyu Grass (Second Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus - in Relation to Placement

Treatment		Placement	Silicon in ppm			% of Si
Si tons/A	P lbs/A		R1	R2	Mean	
1.0	500	L1	2983	2765	2874	0.288
		L2	5247	5094	5171	0.518
		L3	2612	3135	2874	0.288
	2000	L1	3505	5094	4300	0.430
		L2	4898	3527	4213	0.422
		L3	-	4310	4310	0.432
4.0	500	L1	7380	7228	7304	0.730
		L2	6400	7119	6760	0.676
		L3	2874	3744	3309	0.330
	2000	L1	6422	10602	8512	0.852
		L2	4245	6531	5388	0.538
		L3	4071	4550	4311	0.432

NOTE: Placement: L1 - Mixed in whole soil
L2 - Mixed in top layer
L3 - In separate layers

Appendix Table 44
Concentration of Phosphorus in Kikuyu Grass (Third Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus - in Relation to Placement

Treatment		Placement	Phosphorus in ppm			% of P
Si tons/A	P lbs/A		R1	R2	Mean	
1.0	500	L1	2508	2575	2542	0.254
		L2	1989	1909	1949	0.194
		L3	2242	2136	2189	0.218
	2000	L1	3213	3406	3310	0.332
		L2	2941	2754	2848	0.284
		L3	-	2954	2954	0.296
4.0	500	L1	2528	2442	2485	0.248
		L2	2162	1909	2036	0.204
		L3	2408	2455	2432	0.244
	2000	L1	2974	2442	2708	0.270
		L2	3140	2641	2891	0.290
		L3	2707	2707	2707	0.270

NOTE: Placement: L-1 - Mixed in whole soil
L-2 - Mixed in top layer
L-3 - In separate layers

Appendix Table 45
Concentration of Silicon in Kikuyu Grass (Third Cutting)
Grown on Kapaa Soil With Applications
of Calcium Silicate and Phosphorus - in Relation to Placement

Treatment		Placement	Silicon in ppm			% of Si
Si tons/A	P lbs/A		R1	R2	Mean	
1.0	500	L1	4791	4340	4566	0.456
		L2	4748	4813	4781	0.478
		L3	2192	2192	2192	0.220
	2000	L1	5048	6038	5533	0.554
		L2	6596	4577	5587	0.558
		L3	-	4039	4039	0.404
4.0	500	L1	8874	7907	8391	0.840
		L2	7499	9411	8455	0.846
		L3	2643	3008	2826	0.282
	2000	L1	11087	10270	10679	1.068
		L2	11172	10614	10893	1.090
		L3	3610	4039	3825	0.382

NOTE: Placement: L-1 - Mixed in whole soil
L-2 - Mixed in top layer
L-3 - In separate layers

Appendix Table 46
Analysis of Variance in the Yield of Kikuyu Grass

Source	d.f.	ss	ms	F
		First Cutting		
Replication	1	0.0571		
Treatment	(11)	(90.2154)		
Phosphorus	2	72.6607	36.3303	77.745**
Silicon	3	8.2962	2.7654	5.918*
Si x P	6	9.2585	1.5431	3.302*
Error	11			
TOTAL:	23			
		Second Cutting		
Replication	1	0.9087		
Treatment	(11)	(11.9923)		
Phosphorus	2	1.5226	0.7613	
Silicon	3	3.6807	1.2269	
Si x P	6	6.7890	1.1315	
Error	11	16.8563	1.5323	
TOTAL:	23			
		Third Cutting		
Replication	1	1.2015		
Treatment	(11)	(30.8201)		
Phosphorus	2	7.7168	3.8584	4.416*
Silicon	3	12.2141	4.0713	4.659*
Si x P	6	10.8892	1.8148	2.077
Error	11	9.6113	0.8737	
TOTAL:	23			

**Significant at P = 0.01
*Significant at P = 0.05

Appendix Table 47
Analysis of Variance in the Yield of Corn

Source	d.f.	ss	ms	F
Replication	1	19.3680		
Treatment	(11)	(105.3194)		
Phosphorus	2	83.4154	41.7077	48.866**
Silicon	3	10.1249	3.3749	3.954*
Si x P	6	11.7792	1.9632	2.300
Error	11	9.3892	0.8535	
TOTAL:	23			

**Significant at P = 0.01
*Significant at P = 0.05

Appendix Table 48
Analysis of Variance in the Yield of Desmodium intortum

Source	d.f.	ss	ms	F
		First Cutting		
Replication	1	0		
Treatment	(11)	(22.9506)		
Phosphorus	2	22.6833	11.3416	175.5**
Silicon	3	0.0164	0.0054	
P x Si	6	0.2509	0.0418	
Error	11	0.7116	0.0646	
TOTAL:	23			
		Second Cutting		
Replication	1			
Treatment	(11)	(12.8576)		
Phosphorus	2	6.5814	3.2907	3.836
Silicon	3	2.7212	0.9070	
P x Si	6	3.5550	0.5841	
Error[a/]	10	8.5777	0.8577	
TOTAL:	23			

**Significant at P = 0.01
*Significant at P = 0.05
[a/] Corrected for missing data.

Appendix Table 49
Analysis of Variance in the Yield of Sedge Grass

Source	d.f.	ss	ms	F
		First Cutting		
Replication	1	0.0392	0.0392	
Treatment	(11)	(36.1519		
Phosphorus	2	30.1218	15.0609	89.065**
Silicon	3	0.9298	0.2099	1.832
P x Si	6	5.1003	0.8500	5.026**
Error	11	1.9608	0.1691	
TOTAL:	23			
		Second Cutting		
Replication	1	0.0913		
Treatment	(11)	(11.6443)		
Phosphorus	2	5.3701	2.6850	12.488**
Silicon	3	1.9567	0.6522	3.033
P x Si	6	4.3175	0.7196	3.346
Error	11	2.3650	0.2150	
TOTAL:	23			

**Significant at P = 0.01
*Significant at P = 0.05

Appendix Table 50
Analysis of Variance in the Yield of Tomato

Source	d.f.	ss	ms	F
Replication	1	0.0092		
Treatment	(11)	(33.5258)		
Phosphorus	2	32.4744	16.2372	220.016**
Silicon	3	0.5690	0.1896	2.569
Si x P	6	0.4824	0.0804	1.089
Error	11	0.8118	0.0738	
TOTAL:	23			

Appendix Table 51
Analysis of Variance in the Yield of *Mimosa pudica*

Source	d.f.	ss	ms	F
Replication	1	0.0532		
Treatment	(11)	(36.9924)		
Phosphorus	2	34.3198	17.1599	22.546**
Silicon	3	0.6939	0.2313	
Si x P	6	1.9787	0.3298	
Error	11	8.3721	0.7611	
TOTAL:	23			

**Significant at P = 0.01
*Significant at P = 0.05

Appendix Table 52
Analysis of Variance on the Yield of Kikuyu Grass in Relation to Placement

Source	d.f.	ss	ms	F
		First Cutting		
Replication	1	1.0086		
Treatment	(11)	(64.3264)		
Phosphorus	1	11.7041	11.7041	10.028**
Silicon	1	2.9261	2.9261	2.507
Placement	2	3.6799	1.8399	1.576
P x Si	1	2.1840	2.1840	1.871
P x Pl	2	2.4082	1.2041	1.032
Si x Pl	2	24.2054	12.1029	10.370**
P x Si x Pl	2	17.1383	8.5691	7.342*
Error[a/]	10	11.6719	1.1671	
TOTAL:	22			
		Second Cutting		
Replication	1	0.0193		
Treatment	(11)	(22.8835)		
Silicon	1	4.2168	4.2168	5.769*
Phosphorus	1	0.0024	0.0024	
Placement	2	6.3970	3.1985	4.376*
P x Si	1	2.4833	2.4833	3.398
Si x Pl	2	7.4141	3.7075	5.073*
P x Pl	2	1.4989	0.7494	
P x Si x Pl	2	0.8710	0.4355	
Error[a/]	10	7.3088	0.7309	
TOTAL:	22			
		Third Cutting		
Replication	1	0.6902		
Treatment	(11)	(24.0870)		
Silicon	1	4.0590	4.0590	5.167*
Phosphorus	1	3.6739	3.6739	4.676
Placement	2	7.1966	3.5983	4.581*
P x Si	1	3.1610	3.1610	4.023
Si x Pl	2	2.7978	1.3989	1.781
P x Pl	2	1.6762	0.8381	1.061
P x Si x Pl	2	1.5225	0.7612	
Error[a/]	10	7.8554	0.7855	
TOTAL:	22			

**Significant at P = 0.01
*Significant at P = 0.05
[a/] Corrected for missing data