

Lime, Gypsum, and Basaltic Dust Effects on the Calcium Nutrition and Fruit Quality of Pineapple

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Abstract

Pineapples grown in acid soils containing high levels of manganese (Mn) can exhibit iron deficiency because Mn interferes with iron bio-functioning. This situation is commonly corrected with regular iron sprays. Soil Mn concentration can be reduced by liming, but pineapple growers keep the soil pH below 5.0 because it helps reduce the incidence of rots caused by *Phytophthora* sp. This study was conducted in Hawaii on an acid soil high in Mn to evaluate the effects of calcium source (lime, gypsum, and basaltic dust, a quarry by-product), on soil pH, plant iron utilization, and plant calcium nutrition of a low-acid hybrid pineapple. The effects of calcium source and amount on fruit translucency, acidity and sugars were also examined. Without iron sprays, no calcium source prevented severe iron deficiency in this acid soil. When pineapple was sprayed with iron, all calcium sources increased calcium levels in the soil and in D-leaf and fruit tissues. Basal-white leaf calcium in the treatments ranged from 0.19 to 0.55% and all levels were at or above those considered adequate; green tissue levels ranged from 0.11 to 0.20%. There were no significant effects of treatments on plant growth, fruit weight, fruit size distribution or most indices of fruit quality. Further analysis showed that the fruit translucency index (TI) decreased as the amount of calcium applied was increased and 64% of the decrease in TI was accounted for by applied calcium. There was also a significant negative correlation between TI and extractable soil calcium, basal white and green D-leaf calcium, and fruit calcium. Lime can raise soil pH to levels that can increase the incidence of root and heart rot while gypsum and basaltic dust will supply calcium without increasing soil pH. Basaltic dust could provide calcium as well as other nutrients in organic farming.

INTRODUCTION:

Pineapples are well adapted to acid soils and tolerate relatively high levels of soluble aluminum and manganese. In soils containing large amounts of soluble iron and manganese, pineapple plants can absorb relatively large amounts of both elements but apparently are unable to effectively utilize absorbed iron, resulting in severe iron deficiency. Manganese-induced iron deficiency in pineapple is corrected by regular sprays of iron, usually as iron sulphate. Soils with low pH's also tend to have low concentrations of soil calcium and liming such soils increases soil pH, soil calcium supply, and reduces soluble levels of manganese and aluminum. However, pineapple growers are cautioned to lime carefully because the incidence of root rot problems caused by *Phytophthora* sp. increases as pH rises (Swete Kelly, 1993), and the problem is more severe above pH 5.5 (Frossard, 1976).

Low soil calcium can induce calcium deficiency symptoms in the plant and fruit (Malezieux and Bartholomew, 2003), but calcium levels above those found to be sufficient for normal plant and fruit development can still provide benefits. Liming raises soil pH and

reduces manganese solubility. Increasing the calcium supply with gypsum could also reduce manganese availability while leaving soil pH unchanged or even lowered. If moderate amounts of lime or lime plus gypsum could reduce manganese availability without raising soil pH above about 5.0, it was hypothesized that there would be no need for foliar iron sprays. High calcium would also reduce manganese uptake (Hue and Mai, 2002). Further, fertilization with calcium increased fruit calcium levels and improved fruit storage life by reducing the incidence of internal browning associated with refrigerated storage (Herath et al., 2000). High fruit translucency caused by cell sap leakage into the apoplast is a problem in fresh fruit production in some months of the year in Hawaii. High translucency causes losses because it is associated with increased bruising injury, fruit leakage and potential carton rejection due to the perception of disease. The physiological roles of calcium in plants include maintenance of cell membrane functioning and cell wall integrity, both of which could be important in fruit translucency. No studies on the effects of calcium or other plant nutrients on fruit translucency of pineapple were found.

We report the results of a study to evaluate the effects of calcium sulfate, agricultural lime (calcium carbonate) and basaltic dust, a by-product of the rock quarrying industry, on soil pH, plant calcium supply, iron uptake and plant calcium nutrition and also to determine the effect of calcium source and amount on fruit quality, particularly flesh translucency, titratable acidity and total soluble solids content of pineapple.

MATERIALS AND METHODS:

The experiment was installed in a pineapple field on a soil of the Wahiawa series (very-fine clayey, kaolinitic, isohyperthermic, Rhodic Haplustox) from central Oahu, Hawaii. The soil is acidic (pH of 1:1 soil-water paste, 4.5) with high Mehlich 3 extractable manganese (305 ug g⁻¹), low iron (65 ug g⁻¹), and low calcium (162 ug g⁻¹) concentration. The experimental design was a split-plot with iron sprays as the main plots and calcium sources and basaltic dust (BD) treatments as the subplots. The treatments were as follows:

Main-plot treatments: With and Without iron sulfate sprays.

Sub-plot treatments:

1. Check	Plantation practice	(0 added Ca)
2. Basaltic Dust (BD)	50 Mg ha ⁻¹	(3,360 kg total Ca ha ⁻¹) (216 kg extractable Ca ha ⁻¹)
3. Gypsum (CaSO ₄ .2H ₂ O)	9.0 Mg ha ⁻¹	(2061 kg total Ca ha ⁻¹)
4. Gypsum	18.0 Mg ha ⁻¹	(4122 kg total Ca ha ⁻¹)
5. Lime + Gypsum	3.4 + 4.5 Mg ha ⁻¹	(2352 kg total Ca ha ⁻¹)
6. Lime (CaCO ₃)	6.7 Mg ha ⁻¹	(2688 kg total Ca ha ⁻¹)

The rates of lime (ground coral) and basaltic dust were selected to raise soil pH to 5.0 while the gypsum and gypsum plus lime treatments were selected to provide additional amounts and forms of calcium that would not greatly increase soil pH. All treatments were replicated three times. Plots were four two-row beds separated by an additional two-row bed and measured 5.12 m wide by 8.84 m long. All plots received standard plantation practice of cow manure, pre-plant fumigation and post-planting application of nematicides to help control nematodes, pre-plant fertilizer, and drip irrigation. The calcium and BD treatments were applied before planting and incorporated into the soil in each plot with a rototiller. Plots were planted on November 13, 2001 with selected crowns of a low-acid hybrid pineapple (*Ananas comosus* L. (Merr.)) cultivar D10 weighing 113 to 170 g. Foliar

fertilizers containing iron sulfate were applied monthly starting at about 2 months after planting following standard plantation practices. The minus-iron plots received foliar fertilizer that did not include iron sulfate. The experiment was forced with ethephon to induce reproductive development approximately one year after planting.

Data were collected from 7.62 m of the center two beds. Approximately 100 fruit were harvested from each plot. The collected data included soil samples from each plot at three months after planting, tissue nutrient levels of 'D' leaves (most recently matured leaf, the tallest leaf) (Py et al., 1987) collected at six months after planting and at the time of forcing, and estimated plant weights at the time of forcing. Ten D-leaves were collected from each plot, the leaves were washed with tap and deionized water to remove soil and fertilizer residue, and tissue samples were taken from the basal white and middle one-third of the green tissue of each leaf and the samples were composited and oven dried. Soil samples collected at depths of 0-15 and 15-30 cm from each plot were analyzed using the soil paste method for pH, N ammonium acetate, pH 7.0 for cations, modified Truog extractant for phosphorus and Mehlich 3 extraction for micronutrients (Hue, et al., 2000). At harvest, data on fruit size distribution, total fruit weight per plot, and fruit characteristics were collected. Fruit size distribution was based on boxed fresh fruit classes (8, 10, 12, and 14 fruit per 18 kg box), and rejects. Fruits were harvested at shell color 2 (yellowing visible at the base of the fruit) or higher beginning on June 3, 2003 and weekly thereafter until all fruit were harvested (July 1, 2003), classified by size, weighed, and subsampled for fruit characteristics, which included total soluble solids (TSS), refractometer method, titratable acidity (TA), tissue calcium, and fruit flesh translucency. Subsample size for fruit characteristics at each harvest was six fruit per plot at the same stage of maturity with representation where possible from the four larger size classes. Translucency was measured after the fruit was cut, based on the percentage of flesh that was translucent (0%: opaque flesh, not translucent; to 100%: fully translucent) (Paull and Reyes, 1996). This was converted to an index in which 1 = opaque flesh and 6 = fully translucent flesh. Fruit calcium was measured by homogenizing 50 g of fruit flesh in 100 ml deionized water, then taking a 20 ml aliquot of the mixture and adding 20 ml of 12 M HCl. The solution was heated at 60 C for 30 minutes and filtered through Whatman #42 filter paper into a 50 ml volumetric flask. The solution was made to volume with deionized water and the calcium concentration determined with an inductively coupled plasma analyzer (Qiu, et al., 1995). The results were analyzed by analysis of variance using SAS/STAT, SAS Institute Inc. Cary, NC . 1988; and Statistix software (Analytical Software, Tallahassee FL) and means were compared with the Duncan's Multiple Range test.

RESULTS AND DISCUSSION

Yields, Fruit Quality and Plant Nutrients

Manganese-induced iron deficiency was not corrected by amending the soil with lime, gypsum or basaltic dust. Foliar iron nutrition is essential if growers are to obtain acceptable yields on Hawaii's high-manganese soils; therefore, growers regularly apply foliar iron sprays. Only the results of the Plus Iron treatments are presented here because plant growth and fruit yields of the Minus Iron treatments were low, quite variable, and some plants bore no fruit.

There were no statistically significant differences in number of fruit and weight of fruit for any of the treatments in any of the fruit classes. There also was no significant difference between treatments in the total weight of fruit produced or fruit quality parameters

(Table 1). Calcium concentrations in the fruit were significantly higher where the soil was amended with calcium than in fruit from the check (Table 1). Fruit from the Lime and Gypsum 9 and Gypsum 18 treatments had higher concentrations of Ca than the other treatments while Basaltic dust had significantly lower Ca concentrations than the other amendment treatments. This reflects the low solubility of basaltic dust.

The nutrient concentrations in the basal white and green D-leaf samples collected before forcing did not show any significant differences due to treatments except in the calcium and zinc concentrations (Tables 3 & 4). In the basal white tissue (Table 2), calcium in the Check treatment was lower than in the amendment treatments but this difference was significant only for the Gypsum 9, Gypsum 18, and the Lime-gypsum treatments. In the green tissue (Table 3), calcium in the Check treatment was also lower than in the amendment treatments but this difference was significant only in the Gypsum 18 and Lime-gypsum treatments. Zinc in the Check treatment was significantly lower in both tissues than the zinc levels in the amendment treatments. The reason for this is not apparent. However, stem apical tissue is considered to provide the best indication of zinc sufficiency (W.G. Sanford, personal communication).

The D-leaf Fe/Mn ratio (weight:weight) is considered to be more important than tissue concentrations of iron in the utilization of iron in the plant (Py et al., 1987). The Fe/Mn ratios of the soil amendment treatments in the basal white tissue varied from 0.083 to 0.099 and are similar to that of the Check, i.e., 0.089, (Table 2). Thus the soil amendments did not appear to affect the concentrations of Fe or Mn in the tissue. The Fe/Mn ratios in the green tissue ranged from 0.328 to 0.454 and were not different from that of the Check, i.e., 0.342, (Table 3). These Fe/Mn ratios in the green tissue are similar to those reported by Marchal, 1971. He suggested that iron deficiency exists when the Fe/Mn ratio is less than 0.4 and the Mn content of the green tissue of the D leaf is above 200 ppm. The plants in the present experiment met these conditions for iron deficiency but received regular iron sulfate sprays and had no visual symptoms or other indications of iron deficiency. There is no obvious explanation of why the low Fe/Mn ratios did not result in iron deficiency or for the lack of agreement with the results of Marchal (1971) in the present experiment.

The basal white D-leaf tissue is traditionally used for monitoring the nutrient status of pineapple in Hawaii and Australia (Malezieux and Bartholomew, 2003). In other pineapple growing areas the entire D-leaf is used to monitor the nutrient status of pineapple. In this study both basal white and green D-leaf tissues were sampled. The relationships between the nutrients in the two tissues (Tables 2 and 3) were examined by correlation analysis for the macronutrients and also the micronutrients (Table 4). The basal white P, K, and Ca were highly correlated with the green P, K, and Ca, while the N and Mg were not significantly correlated. For the micronutrients, the basal white Fe, Zn and the Fe/Mn ratio were significantly correlated with the green leaf Fe, Zn and Fe/Mn ratio, while the Mn, Cu and B were not significantly correlated. Although the magnitudes of the nutrient concentrations in the two tissues differ, the two tissues respond in similar ways to changes in P, K, Ca, Fe, Zn and the Fe/Mn ratio.

Soil Nutrients

Soil calcium in the 0-15 cm layer was increased significantly over the calcium concentration in the Check by all soil amendments except Basaltic dust (Table 5). Soil pH was increased significantly over the pH of the Check by only the Lime and Lime-gypsum treatments and these treatments had the lowest concentrations of soil manganese. However,

only the soil manganese concentration of the Lime treatment was significantly lower than that of the Check. The Mehlich 3 extractant is relatively inefficient in extracting soil manganese so the true effects of the treatments on soil manganese may not have been measured (Hue and Mai, 2002). The iron concentration in the 0-15 cm layer of soil was relatively unaffected by the soil amendments, except for the Basaltic dust treatment, which had a significantly higher concentration of iron than the other treatments (Table 5). However, this higher concentration of iron in the soil from the Basaltic dust treatment did not result in a corresponding increase in iron in the leaf tissue. The Basaltic dust treatment also had a significantly higher concentration of soil P than the other treatments.

The concentrations of most nutrients in the 15-30 cm layer were lower than those in the 0-15 cm layer except for the concentrations of K and Mn, which were about the same as those in the 0-15 cm layer. Soil calcium and iron concentrations in the 15-30 cm layer followed similar patterns of response to the treatments as did those in the 0-15 cm layer.

The relationships among applied calcium, extractable soil calcium and calcium in various plant parts and fruit translucency index were studied with correlation analysis. The correlation coefficients for the relationships between the fruit translucency index with applied calcium, extractable soil calcium, basal white and green leaf calcium were negative and significant at $P < 0.05$ (Table 6). The correlation coefficient for the relationship between the fruit translucency index with fruit calcium was also negative and highly significant, $P < 0.01$. There is a nearly linear relationship between applied total calcium and extractable soil calcium (Fig. 1), with one point much lower than the other points. This point is the extractable soil calcium from the Basaltic dust treatment and reflects the relatively low solubility of calcium in basaltic dust. The regression equation for the relationship between applied total calcium (X) and extractable soil calcium (Y) is $Y = 93.9858 + 0.5616 X$ with adjusted $r^2 = 0.82$ and $N = 6$ with the value for Basaltic dust omitted from the regression analysis.

The fruit translucency index decreased as the amount of applied total calcium increased (Fig. 1). The relationship between applied total calcium (X) and fruit translucency index (Y) is quantified in the following regression equation: $Y = 4.1346 - 0.000258 X$ with adjusted $r^2 = 0.638$ and $N = 6$. Thus it appeared that 64% of the variation (decrease) in the fruit translucency index was accounted for by applied total calcium. The lowest fruit translucency index occurs when extractable soil calcium is 1500 mg/kg or higher. An analysis of variance indicated that the effect of applied calcium on the fruit translucency index was significant at $P < 0.05$. The fruit translucency index also decreased as extractable soil calcium increased while green leaf calcium increased with increasing extractable soil calcium (Fig. 2). The relationship between extractable soil calcium (X) and fruit translucency (Y) is described by the following regression equation: $Y = 4.677 + 0.000304X - 0.0471X^{1/2}$; adjusted $r^2 = 0.613$, $N = 6$ and the relationship between extractable soil calcium (X) and green leaf calcium (Y) is quantified by the equation $Y = 0.0502 - 0.000047X + 0.00532X^{1/2}$; adjusted $r^2 = 0.958$, $N = 6$. The lowest fruit translucency index occurred when green leaf calcium is 0.17% or higher and extractable soil calcium is 1200 mg/kg or higher. There is a negative relationship between calcium in the fruit and fruit translucency index with $r = -0.92$ (Fig. 3). Thus it appears that calcium plays a role in the severity of fruit translucency which might be expected from the function of calcium in plants, i.e., maintenance of membrane integrity and middle lamella and cell wall rigidity. The effect of calcium on the fruit translucency index was shown to be significant in the analysis of variance and regression analyses suggest that increasing soil calcium is associated with reduced fruit translucency

index.

CONCLUSIONS

None of the soil amendments reduced the effects of manganese on iron utilization in soil with high manganese concentrations. Regular iron sprays on pineapple are required to prevent severe iron chlorosis and stunting. When pineapple was sprayed with iron, application of basaltic dust, gypsum and lime increased calcium levels in the basal white, green leaf, and fruit tissue, which was associated with a decrease in the severity of fruit translucency. Large amounts of lime can raise soil pH to levels that can increase the incidence of root and heart rot while large applications of gypsum and basaltic dust will not increase soil pH and thus will not affect root health. Basaltic dust, a by-product of quarry operations, is a new soil amendment that is readily available in Hawaii and would be an acceptable source of calcium for organic agriculture production.

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Tables

Table 1. Average weight and characteristics of pineapple fruit from plots treated with soil amendments¹.

Treatment	Weight, kg	TSS ² , %	Acidity, meq/100 ml	Translucency ³ Index	Calcium (mg/100g flesh)
Check	1.42	13.9	0.38	4.01	1.96 d
Basalt Dust	1.58	13.3	0.42	3.49	2.94 c
Gypsum 9	1.55	13.6	0.39	3.28	3.97 ab
Gypsum 18	1.45	13.7	0.42	3.03	4.44 a
Lime-Gypsum	1.40	13.5	0.40	3.79	3.44 bc
Lime	1.46	13.7	0.43	3.25	4.25 a

¹Means in the same column followed by the same letter or no letter are not significantly different at P<0.05 by Duncan's Multiple Range Test.

² Fruit Total Soluble Solids.

³Translucency Index ranged from 1 (opaque) to 6 (completely translucent).

Table 2. Mean nutrient concentrations in pineapple basal white D-leaf tissue sampled from the plus iron treatments before forcing.¹

Treatment	-----%-----					-----ppm-----					
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	Fe/Mn
Check	2.38	0.32	3.71	0.19 b	0.27	65	752	17 b	11.3	14.3	0.089
Basalt Dust	2.65	0.37	3.90	0.39 ab	0.37	62	692	25 a	15.3	15.3	0.089
Gypsum 9	2.68	0.34	3.65	0.48 a	0.33	70	833	26 a	14.3	14.3	0.085
Gypsum 18	2.50	0.30	3.75	0.55 a	0.30	78	790	25 a	11.7	15.7	0.099
Lime-Gyp.	2.59	0.31	3.73	0.51 a	0.31	59	702	23 a	14.3	14.0	0.085
Lime	2.26	0.33	3.97	0.42 ab	0.31	65	801	23 a	14.3	16.0	0.083

¹Means in the same column followed by the same letter or no letter are not significantly different at P<0.05 by the Duncan's Multiple Range Test.

Table 3. Mean nutrient concentrations in the middle one-third of pineapple green D-leaf tissue sampled from the plus iron treatments before forcing.¹

Treatment	-----%-----					-----ppm-----					
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	Fe/Mn
Check	1.67	0.097	1.57	0.11 b	0.14	125	393	11 b	9.0	9.0	0.342
Basalt Dust	1.66	0.103	1.64	0.15 ab	0.14	154	346	16 a	10.3	10.3	0.454
Gypsum 9	1.63	0.097	1.59	0.19 ab	0.14	178	435	19 a	10.0	10.7	0.410
Gypsum 18	1.73	0.093	1.56	0.20 a	0.13	168	392	18 a	9.3	10.3	0.437
Lime-Gyp.	1.62	0.093	1.58	0.18 a	0.13	129	349	18 a	10.0	10.7	0.370
Lime	1.45	0.097	1.79	0.17 ab	0.13	115	368	18 a	10.7	9.0	0.328

¹Means in the same column followed by the same letter or no letter are not significantly different at P<0.05 by the Duncan's Multiple Range Test.

Table 4. Correlation coefficients for the relationships between nutrients in pineapple green (G) and basal white (W) D-leaf tissue sampled before forcing from the plus iron treatments.

	GN	GP	GK	GCa	GMg		
WN	<u>0.438</u>	0.023	-0.583	0.183	-0.057		
WP	-0.266	<u>0.728</u>	0.378	0.070	0.532		
WK	-0.048	0.132	<u>0.601</u>	-0.234	-0.152		
WCa	0.060	0.126	-0.068	<u>0.897</u>	0.150		
WMg	-0.063	0.493	0.231	0.305	<u>0.423</u>		
	GFe	GMn	GCu	GZn	GB	GFe/Mn	
WFe	<u>0.583</u>	-0.341	0.256	-0.015	-0.286	0.823	
WMn	0.092	<u>0.298</u>	0.296	0.113	-0.341	-0.016	
WCu	-0.028	-0.047	<u>0.111</u>	0.305	0.014	-0.002	
WZn	0.494	-0.044	0.455	<u>0.826</u>	0.529	0.255	
WB	0.198	-0.483	0.309	0.003	<u>0.384</u>	0.374	
WFe/Mn	0.503	-0.460	0.074	-0.116	-0.099	<u>0.578</u>	

$r > 0.4683$ $P < 0.05$ for $df = 16$; $r > 0.5897$ $P < 0.01$ for $df = 16$

Table 5. Means of soil analyses at 3 months after planting from the pineapple calcium Experiment¹.

Treatment	pH	<----- ppm ----->					
		P	K	Ca	Mg	Mn ²	Fe ²
0-15 cm depth							
Check	4.5 cd	38 b	144 a	169 d	47 b	305 a	347 b
Basalt Dust	4.9 bc	58 a	131 a	523 cd	71 ab	310 a	511 a
Gypsum 9	4.5 d	31 b	162 a	1631 b	63 ab	295 ab	350 b
Gypsum 18	4.4 d	29 b	138 a	2638a	72 a	301 ab	333 b
Lime-Gyp.	4.9 b	29 b	154 a	1084 bc	54 ab	276 ab	345 b
Lime	5.6 a	34 b	153 a	1251 bc	61 ab	264 b	349 b
15-30 cm							
Check	4.5ab	43 a	149 ab	171 c	48 a	296 a	339 b
Basalt Dust	4.6a	30 ab	135 b	231 bc	46 a	311 a	375 a
Gypsum 9	4.4 bc	20 b	180 a	446 b	59 a	322 a	342 ab
Gypsum 18	4.3 c	24 b	151 ab	749 a	65 a	353 a	345 ab
Lime-Gyp.	4.5 b	23 b	155 ab	418 b	52 a	324 a	346 ab
Lime	4.6a	26 b	158 ab	321 bc	50 a	303 a	352 ab

¹Means in the same column in the same soil depth followed by the same letter are not significantly different at $P < 0.05$ by the Duncan's Multiple Range Test.

²Extracted with Mehlich 3 extractant.

Table 6. Correlation Coefficients for the relationships between applied Ca, soil and plant Ca and fruit translucency index (TI)¹

Variable	Applied Ca	Soil Ca	Basal White Ca	Green Leaf Ca	Fruit Ca	TI
Applied Ca	1.000					
Soil Ca	0.683	1.000				
Basal White Ca	0.802	0.8226	1.0000			
Green Leaf Ca	0.741	0.8886	0.9767	1.0000		
Fruit Ca	0.737	0.8807	0.8597	0.9215	1.0000	
Translucency Index	-0.843	-0.8266	-0.7681	-0.8258	-0.9180	1.0000

¹Probability of obtaining a value as large or larger for 4 df: P<0.05 = 0.8114; P<0.01 = 0.9172.

Figures

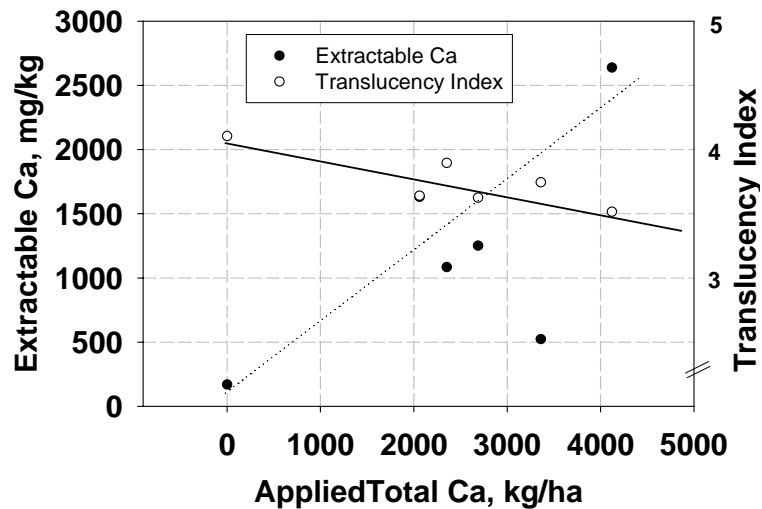


Fig. 1. Effect of applied total calcium on extractable soil calcium and fruit translucency index. Regression equation for Applied Total Calcium (X) and Extractable Soil Calcium (Y) (dotted line): $Y = 93.986 + 0.5616 X$. Adjusted $r^2 = 0.82$, $N = 6$. Regression Equation for Applied Total Calcium (X) and Fruit Translucency Index (Y) (solid line): $Y = 4.1346 - 0.0003 X$. Adjusted $r^2 = 0.64$, $N = 6$.

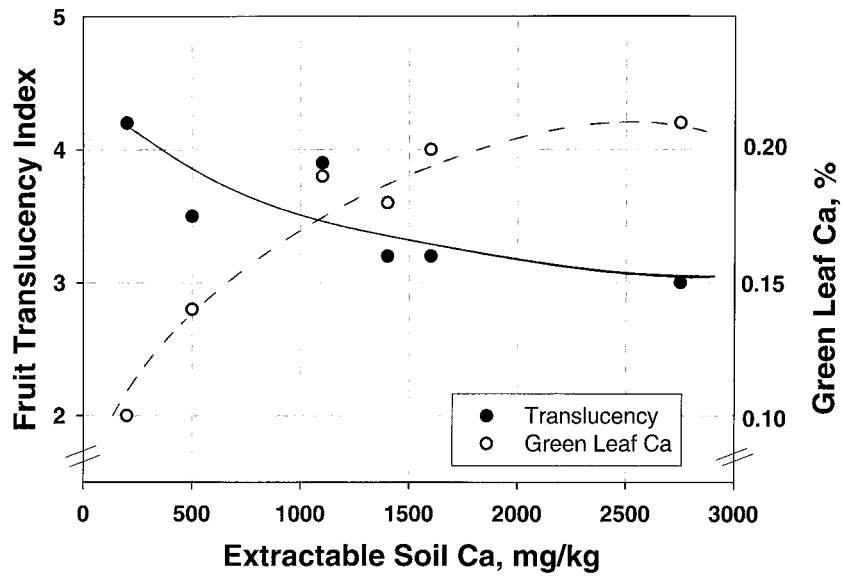


Fig. 2. Effect of Extractable Soil Calcium on Fruit Translucency Index and Green Leaf Calcium. Regression equation for Extractable Soil Calcium (X) and Fruit Translucency Index (Y) (solid line): $Y=4.6766+0.000304X-0.04711X^{1/2}$; Adjusted $r^2=0.61$, $N=6$. Regression equation for Extractable Soil Calcium (X) and Green leaf Calcium (Y) (dotted line); $Y=0.05018-0.000047X+0.005316X^{1/2}$; Adjusted $r^2=0.96$, $N=6$.

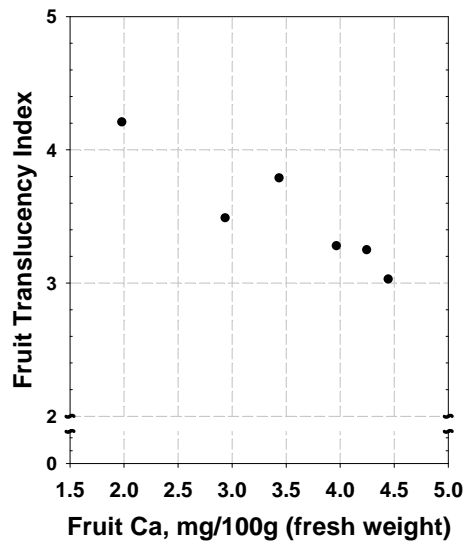


Fig. 3. Relationship between Fruit Calcium and Fruit Translucency Index.