# ハワイのラトゾール土壌においてカリおよびカルシウムの施用が落花生の増収量と養分吸収に及ぼす影響

# Response and nutrient uptake of peanut on Hawaiian latosols treated with potassium and calcium

By

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## Introduction

The peanut (*Arachis hypogaea*), one of the economic leguminous crops, has been thoroughly studied elsewhere while only briefly in Hawaii. Recently it has been reported that calcium has a striking effect on peanut yield[4,5,11,24].

Hawaiian latosols are highly weathered and contain relatively low levels of plant nutrients[9,17]. It is highly necessary to give effctive fertilization to grow satisfactory crops on these soils.

Inspite of its importance for crops, potassium is often supplied insufficient amounts for economic production. Consequently, in growing the peanut, which has the potential of supplying at least all of the Islands' needs, growers should be expected to supply potassium along with other nutrient elements.

It is now well known that among plant nutrients there is an antagonistic relationship between potassium and calcium, or between potassium and calcium plus magnesium[31,32].

In view of these difficulties, there is a need for studying the proper level of potassium and calcium in the production of peanuts on Hawaiian latosols. The objectives of the present thesis are (a) to study the effect of varying levels of potassium and calcium on peanut yields and fruit filling on three Hawaiian latosols, and (b) to study the nutrient uptake of the peanut plant with regard to potassium, calcium, and magnesium. To this end experiments were conducted using the Paaloa soil belonging to the Humic Latosol great soil group, and the Wahiawa and Waimanalo soils of the Low Humic Latosol great soil group.

## Literature Review

### NUTRITIONAL REQUIREMENT AND HABIT OF THE PEANUT

It is fundamental knowledge recorded in many textbooks of soil science that plants need the ten major and several other minor nutrient elements. This is also true for the peanut. In fact, obvious deficiency symptoms have been established with the peanut in the absence of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, boron, and zinc[6,30]. Growth reduction has also been observed in the absence of copper and molybdenum respectively, although specific deficiency symptoms were not recognized[30].

The peanut takes up all nutrient elements through the root of the vegetative stage, but after the pegs reach the growing medium, the plant takes up nutrients throgh both the root and pegs or shells of the fruit[2,4,6,28]. The fruit filling of the peanut strikingly is mainly influenced by the nutrient uptake especially of calcium through the pegs or shells[3,4,5,6,10,23]. Consequently, the degree of nutrient uptake by the pegs or shells becomes an important factor to fruit filling. This seems to be the result of sluggish movement or near immobility of calcium in plant tissue[2,4], coupled with its specific role in the synthesis of protein[29].

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## NUTRIENT UPTAKE OF THE PEANUT

As mentioned above, calcium is an important nutrient element for the peanut. It has been found that in some instances a depressive effect of one ion on the uptake of other ions occurs in various species of plants[1,15,20,21,25,31,32]. This interaction, specifically referring to potassium, calium, and magnesium, is not exceptional for the peanut[3,6,7], but may also occur in other plants.

Concerning the peanut, excellent studies by Burkhart and Page[7] and Burkhart and Collins[6] vividly showed the uptake of potassium, calcium, and magnesium in the peanut plant, and the interaction among these elements. Burkhart and Page analized blades, petioles, and stems of the peanut for several nutrient elements extracted by hot water. They found among the plant fractions that the leaf blades were the most suitable for estimating the nutrient status of the plant. The fresh tissue of the blades contained about 7,000 ppm of $K_2O$, 5,000 ppm of CaO, and 3,000 ppm of MgO in the vegetative stage; and about 10,000 ppm of $K_2O$, 6,400 ppm of CaO, and 2,700 ppm of MgO at maturity. The content of each element varied according to the stage of plant development; viz., the vegetative stage, early fruiting stage, maturity, etc., although the dominancy of potassium content over calcium and of calcium content over magnesium was retained.

Burkhart and Collins showed that potassium application increased the potassium uptake of the peanut but depressed the uptake of calcium and magnesium; and calcium application increased the uptake of calcium and magnesium but depressed the potassium uptake. They also clarified the interaction among potassium, calcium, and magnesium in plant tissue, by studying mineral composition of peanut leaves that showed nutrient deficiency symptoms of calcium, potassium, magnesium, phosphorus, nitrogen and boron. The content of potassium, calcium, and magnesium in the peanut leaves varied noticeably when one of them was absent in the culture solution, while their content was relatively constant in the absence of only such elements as phosphorus, nitrogen, and boron. In the absence of potassium, a remarkable increase of calcium and magnesium was observed. On the other hand, in the absence of calcium, a striking increase of potassium and a slight increase of magnesium was recognized, and in the absence of magnesium a striking increase of potassium and a fair depression of calcium occurred compared to that of complete nutrient solutions.

Another comprehensive study on peanut nutrition was conducted by Bledsoe[3]. He grew the peanuts on quartz sand, separating the rooting medium from fruiting medium, and analyzed the peanut leaves. The increase of the potassium or calcium content in the plant tissue at the deficiency level of calcium or potassium in the rooting medium, when complete nutrient solution was given to the fruiting medium, confirmed the interrelationship of these mineral elements as reported by Burkhart and Collins[6]. Furthermore, it was also shown by Bledsoe that there is a different relationship of these three nutrients in shells of the fruit from that in the leaves. Calcium and magnesium content in shells were less influenced by the nutrient status of the rooting medium as long as complete nutrient solution was supplied to the fruiting medium; whereas the content of potassium in the shells increased when no calcium added to the rooting medium.

## RESPONSE OF THE PEANUT TO POTASSIUM AND CALCIUM

The strong antagonistic relationship between potassium and calcium in the growing medium poses fertilization problems in peanut production. In addition to the effect of ion antagonism, the effect of petassium and calcium on the peanut is influenced by (a) the original level of the elements in the soil, (b) the placement of the elements, (c) the time of the application, (d) the character of the growing medium, and (e) the peanut variety.

Two reports state that reaponse of the peanut to calcium application depends on the original level of calcium in the soil. Colwell and Brady[11] obtained markedly increased peanut yield by gypsum treatment of soils which contained 0.21 to 1.39 me. of calcium per 100 gram.

Rogers[24], in growing Spanish and runner peanuts on southern Alabama soils, found that the critical level of exchangeable calcium for peanut yield was in the range of 600 to 800 pounds of calcium per acre. The soils containing less than 600 pounds of exchangeable calcium per acre produced significantly increased yields of peanuts on the addition of calcium.

Several investigators report also, that the peanut responds to potassium and calcium according to whether these nutrient elements are applied to the root zone or to the fruit zone. Burkhart and Collins[6] grew the peanut on sand culture separating the fauiting medium from the rooting medium. They added varying rates of potassium and calcium to the nutrient solution and found that: (a) the presence of calcium in the fruiting medium had a definite favorable effect on the fruit quality irrespective of the nature of the rooting medium, (b) the presence of potassium in the fruiting medium had a definite unfavorable effect on the fruit quality irrespective of the nature of the rooting medium, and (c) the most favorable rate of potassium to calcium was medium potassium and high calcium in the root zone. Colwell and Brady[11] obtained greater yield of the poanut following the addition of gypsum to the fruit zone, but found no increase for the addition of gypsum to the root zone. Brady *et al.*[5] also obtained increased fruit filling from the addition of calcium to fruiting medium, but slightly depressed fruit filling by the addition of potassium to the fruiting or rooting medium in the absence of calcium, although the depression did not occur in the presence of added calcium.

The time of application of potassium and calcium seems to have bearing in peanut production. Prevot[27] reported that potassium, as well as phosphorus, is very important for the peanut at the early stages of growth, but lime becomes increasingly important towards the end of the vegetative period. Colwell and Brady[11] found that the peanut responded to the addition of gypsum when it was added to the fruit zone at the early blooming stage but did not respond when added to the root zone at planting. Brady[4] reported that calcium should be applied to the fruit zone 15 days after the gynophores reach the growing medium as this is the critical period. The study by Mizuno[23] somewhat agrees with Brady's, since he states that the best period for calcium application is 10 to 30 days after the gynopheres enter the growing medium.

The character of growing medium or type of soil influences the effect of calcium on fruit filling and the yield of the peanut. Mehlich and Reed[15] showed that in kaolinitic medium, the fruit filled well even at a low rate of calcium saturation in the fruiting medium; whereas a high rate of calcium saturation was necessary for a high level of fruit filling in montomorillonitic and organic media. In a pot culture test, Eastman[13], using the Kapaa soil with a cation exchange capacity value of 30.9 me., obtained higher peanut yields in the pots with calcium treatment than in the pots without calcium treatment. However, he did not obtain any difference in yield between the two treatments when using the Lualualei soil of which the cation exchange capacity was 77.3 me. per 100 gram.

Yield response of the peanut to calcium and potassium have been reported for varieties of Jumbor runner[4,5], Virginia bunch[10,11], Spanish type[24], and North Carolina runner[10], but all varieties do not necessarily respond to the addition of calcium in the same way. Middleton *et al.*[19] reported that the most striking effect of gypsum treatment was obtained on the varieties of Virginia bunch and North Carolina runner, but there was only a slight effect on Spanish 2B and White Spanish. The Spanish 2B and White Spanish, even in the check plot, yielded as much as the Virginia bunch and North Carolina did in the plot of gypsum treatment. The addition of potassium with gypsum increased plant size as a whole.

These striking effects of calcium on peanut yield are mainly reported in the United States. However, remarkable effect of potassium in combination with calcium on peanut yield has also been reported from Africa. Piggott[22], on an infertile soil of Sierra Leone, obtained only 500 pounds of peanuts per acre in the control, but in contrast obtained 915 pounds of peanut for a treatment with 200 kg of potassium phosphate and 200 kg of hydrated lime per acre. Furthermore he obtained 1,495 pounds of peanuts with 200 kg of potassium phosphate, 200 kg of hydrated lime, and 200 kg of magnesium sulfate per acre. Comber[12] found that the best ratio of K:Ca:Mg for the production of peanuts in an infertile soil of Gambia was 20:40:40 or 30:40:30 expressed in milli-equivalents.

## Material and Method

### THE VARIETY OF THE PEANUT

The peanut variety Valencia was chosen for the present experiment. The growth characteristic of Valencia is as follows[30]. The period of growth to early muturity requires about 120 days. The plant habit is erect and forms a small semi-bunch growth. Peanut varieties are usually classified into four types, namely: (a) the large-seeded Virginia with both bunch- and runner-types; (b) the true runner; (c) the Spanish; and (d) the unclassified. Valencia is grouped with the unclassified but sometimes grouped with the Spanish, because of its similarity to the Spanish in appearance.

### SOILS

Three soils from Paaloa, Wahiawa, and Waimanalo series were used in this experiment. Uncultivated surface soils were collected from a depth of about 0 to 7 inches.

*Paaloa soil:* This soil belongs to the Honolua family of the Humic Latosol. The soil of the Paaloa series is mainly planted to pineapple, which in general produces good yields. The characteristics of the Paaloa soil, according to Cline[9], are that the soil is derived from weathered rock in place, has a dark grayish brown color, is of silty clay in texture, is very friable, and possesses a well developed strong, medium structure. This soil receives 70 to 100 inches of rainfall annually. It is rich in iron oxide and kaolinite. The soil used in the experiment was collected from an uncultivated area at Helemano, Oahu, where native grasses grew in moderate profusion. Some chemical properties of the soil are shown in Table 1.

*Wahiawa soil:* The soil belongs to the Wahiawa family of the Low Humic Latosol. The soils of this series are mainly cultivated for sugar cane and pineapple, which show good production. According to Cline[9], this series is derived from basalt, dark red in color, friable silty clay in texture, contains high concentration of manganese, possesses good drainage, and receives annually 30 to 60 inches of rainfall. The soil is dominantly kaolinitic and iron oxide in mineralogy. The soil used in the experiment was collected from an uncultivated nearly flat area of the Poamoho Experiment Station, where native grasses were growing in moderate denseness. Some chemical properties of the soil are shown in Table 1.

*Waimanalo soil:* This soil belongs to the Waimanalo family, a mono-series family of the Low Humic Latosol. The site is now maily cultivated for vegetables, though it was once planted to sugar cane. According to the description of Cline[9], the top soil is dark grayish-brown in color; the origin is alluvium; it is characteristically high in exchangeable magnesium; and is of moderate stickiness and plasticity. It is said that this soil is transitional to the Dark Magnesium Clay great soil group and is believed to contain some 2:1 type clay minerals. The area receives 50 to 60 inches of rainfall annually. The soil used in the experiment was collected from an uncultivated area near the drainage ditch in the Block Y of the Waimanalo

Table 1. Chemical properties of the experimental soils*

| Soil | pH | Cation ex. capacity | Exchangeable Ca | Exchangeable Mg | Exchangeable K | Exchangeable Na | P | Base saturation | N | O.m. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Me./100g | | | | ppm | % | | |
| Paaloa | 4.8 | 18.5 | 1.1 | 1.1 | 0.48 | 0.27 | 28 | 16.1 | 0.27 | 5.7 |
| Wahiawa | 5.4 | 14.9 | 3.0 | 2.0 | 0.72 | 0.39 | 40 | 40.7 | 0.24 | 5.0 |
| Waimanalo | 6.7 | 41.6 | 22.9 | 12.6 | 4.06 | 1.74 | 177 | 99.4 | 0.25 | 5.3 |

* Each value is a mean of two soil samples.

Experiment Station. The sampling area on a 5 percent slope was covered with grass of moderate stand. Some chemical properties of the soil are shown in Table 1.

### PREPARATION OF THE SOIL AND ADDITION OF NUTRIENTS

The test soil was sieved through a quarter inch mesh screen in order to remove large clods, stones, and remains of plant root. It was then placed in 5 gallon iron sheet metal cans. The basic nutrient elements, shown in Table 2, were added and mixed thoroughly with the soil to a depth of 7 inches. The amounts of the nutrient elements were calculated on the basis of surface area of the can and reported on an acreage basis. Hydrated lime was added to the Paaloa soil in order to raise its pH from 4.8 to 5.4, because the original pH of the soil was considered to be rather low for peanut growth. Potassium and calcium were applied in various combination as shown in Table 3. The carriers for potassium and calcium were KCl and $CaSO_4$, respectively. Both were mixed with the soil at the time the basic nutrient elements were added. For each soil the treatments were replicated three times.

Table 2. Basic nutrient elements added to the soils in the peanut pot experiment

| Nutrient element | Material | Paaloa soil | Wahiawa soil | Waimanalo soil |
|---|---|---|---|---|
| | | (Pounds of element per acre) | | |
| Ca | $Ca(OH)_2$ | 882* | — | — |
| P | Treble phos. | 1,000 | 1,000 | 1,000 |
| Mg | $MgSO_4 \cdot 7H_2O$ | 100 | 100 | —** |
| B | $Na_2B_4O_7 \cdot 10H_2O$ | 5 | 5 | 5 |
| Mo | $(NH_4)_2Mo_7O_{24} \cdot 4H_2O$ | 2.5 | 2.5 | 2.5 |
| Zn | $ZnSO_4 \cdot H_2O$ | 5 | 5 | 5 |
| Cu | $CuSO_4 \cdot 5H_2O$ | 20 | 20 | 20 |

* Hydrated lime was added to the Paaloa soil in order to raise the pH from 4.5 to 5.4. The amount of calcium was equivalent to 1 ton of lime. The estimation of calcium for the pH raise was made according to Foster and Matsusaka[14].

** Magnesium was not added to the Waimanalo soil, since the soil was rich in magnesium.

Table 3. Treatment combinations of K and Ca added to the experimental soils

| Ca* (in $CaSO_4$) pounds per acre | K (in KCl) pounds per acre | | | |
|---|---|---|---|---|
| 0 | 0 | 200 | 400 | 800 |
| 800 | 0 | 200 | 400 | 800 |
| 1,600 | 0 | 200 | 400 | 800 |
| 3,200 | 0 | 200 | 400 | 800 |

* For the Paaloa soil which received $Ca(OH)_2$ to raise the pH from 4.8 to 5.4, additional series receiving no $Ca(OH)_2$ was included.

### POT ARRANGEMENT AND PLANTING

Five gallon sheet metal cans were used as the pot for containing the test soils. The pots were filled with the treated soil and arranged in a Randomized Complete Block design. One weak after the pots were filled, treated and watered, eight to ten peanut seeds were planted 1 inch deep in each pot. After the peanut seedlings were well established, they were thinned to two plants per pot. The pots were watered daily to near field moisture capacity or as often as required to maintain normal growth of the peanuts.

### ANALYSIS OF THE SOIL AND PEANUT LEAVES

Two soil samples from each soil were analyzed for pH, cation exchange capacity, nitrogen, phosphorus, potassium, calcium, magnesium, and sodium prior to the nutrient treatment, Table 1. The soil pH was measured with a Beckman pH meter, using a 1:1 soil-water mixture after allowing it to stand overnight with occasional stirring. Cation exchange capacity, total nitrogen, and readily available phosphorus were determined by the method given by Kanehiro[16]. The soil was extracted with neutral *N* ammonium acetate and then washed with alcohol to make it free of excess ammonium acetate. Being released by replacement with potassium chloride and distillation, the ammonium retained by the soil after alcohol washing was measured as an estimate of the cation exchange capacity. Total nitrogen was determined by digesting the soil with concentrated sulfuric acid and a salt mixture, followed by distillation with alkali into 4% boric acid, and by titration with sulfuric acid. Readily available phosphorus was determined colorimetrically as the phosphomolybdate blue complex after extraction with 0.02 *N* $H_2SO_4$. Calcium and magnesium were determined by titration with EDTA (ethylene-diaminetetraacetate) after treating the leachate, obtained in the determination of the cation exchange capacity, with aqua regia to remove ammonium acetate and organic matter according to the procedures suggested by Chapman and Pratt[3]. Assuming the C/N ratio of the soil to be 12.5 and the carbon content of organic matter to be 58%, organic matter content was estimated by multiplying the nitrogen by a factor of 21.

Peanut leaves were analyzed for potassium, calcium, and magnesium. For the tissue analysis, one sample from each replication was collected from the fourth and fifth leaves from the apex of the peanut plant a week before harvest. Leaf samples were dried overnight at 65°C and ground in a Willey mill. The ground sample was ashed for several hours at 550°C in a muffle furnace and extracted with 6 *N* hydrochloric acid. The diluted solution of the dissolved ash was used for the analysis. Potassium was determined by a Coleman flame photometer. Calcium and magnesium were measured by titration with EDTA. The analytical procedures of the tissue analysis were mostly those of Chapman and Pratt[3].

Since the analysis was carried out on tissue samples dried at 65°C, separate samples were dried overnight at 105°C. The tabulated values are calculated on the 105°C dry-matter basis.

### Harvest

The peanut was harvested when it reached maturity which was indicated by drying and yellowing of the lower leaves. Soil particles were removed from the plant root and shells. The peanuts were oven dried for 48 hours at 65°C and then weighed. The above-ground portion plus the underground portion including the fruit is reported as the whole plant. The yleid of both the whole plant and the shelled peanuts is expressed as the oven-dry weight at 65°C. Shelling percent is expressed by the weight of shelled peanuts to that of the fruit with shells.

## Result and Discussion I

### Growth Performance of the Peanut

The peanuts were planted on February 20 and harvested on June 15, 1963. Germination of the seed began 7 days after sowing and emergence was completed in the following 10 days. During germination, care was taken to protect the peanut seedlings from ants by spraying with malathion. Water was supplied as needed during the plant growth. Towards the end of the flowering stage, a very slight appearance of chlorosis was observed on the leaf margin in all three soils, disappearing after each rainfall. This symptom was absent at maturity. The chlorosis did not seem to have a serious effect on the peanut growth, although the cause itself was not identified. The plants were generally larger on the Wahiawa and Waimanalo soils than on the Paaloa soil.

### Yield of the Whole Peanut Plant, Shelled Peanuts, and Shelling Percent

1. *Results on Paaloa soil.*

The yield of the whole plant, shelled peanuts, and the shelling percent on the Paaloa soil are shown in Figures 1, 2, and 4.

It was shown by analysis of variance that there was no significant difference of the yield of the whole plant resulting from the calcium treatment. However, the yield of the whole plant was influenced significantly by the potassium treatment. Subsequent comparisons indicated, as shown in Table 4, that the yield of the whole plant was higher for the K-400 level than for the K-0 level. The yields in the other levels of potassium, K-200 and K-800, were not significantly higher than that of the K-0 level.

For the yield of the shelled peanuts, there was no significant difference in the yield resulting either from the potassium or calcium treatment; however, a slight increase in yield was obtained for the K-400 level. A significant correlation between the whole plant and shelled peanut yield was obtained (Fig. 3). This suggests that a nutritional factor other than potassium and calcium, for example nitrogen, may have limited the peanut yield in this experiment. The low peanut yield in proportion to the whole plant yield seems to be mostly a result of a low shelling percent. A determination was made to see if the peanut yield was affected by soil

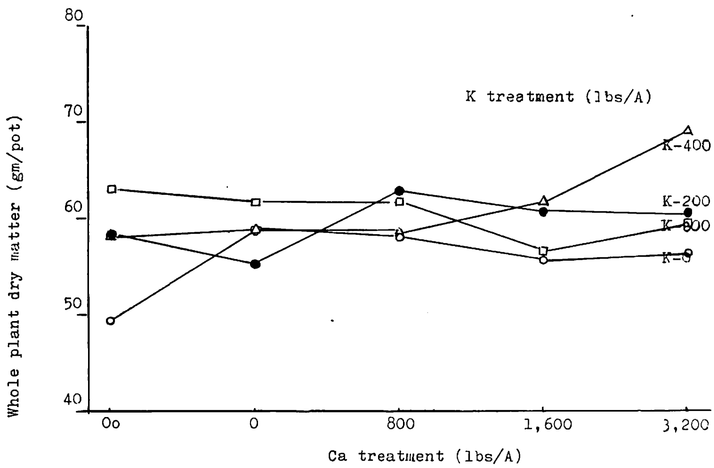



Fig. 1 Yield of the whole plant of the peanut on Paaloa soil treated with varying rates of K and Ca.

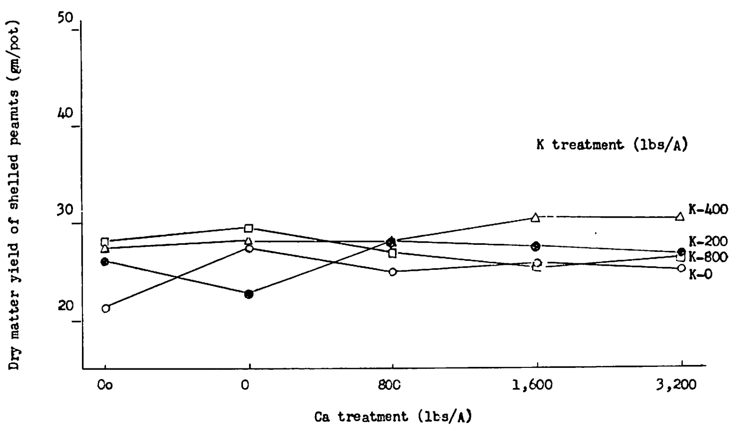
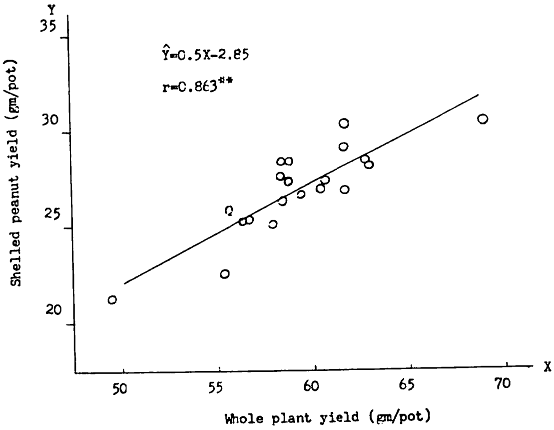



Fig. 2 Yield of the shelled peanuts on Paaloa soil treated with varying rates of K and Ca.




** Indicates correlation coefficient at the 1% level of significance.

Fig. 3 Relationship between the whole plant and shelled peanut yield on Paaloa soil.

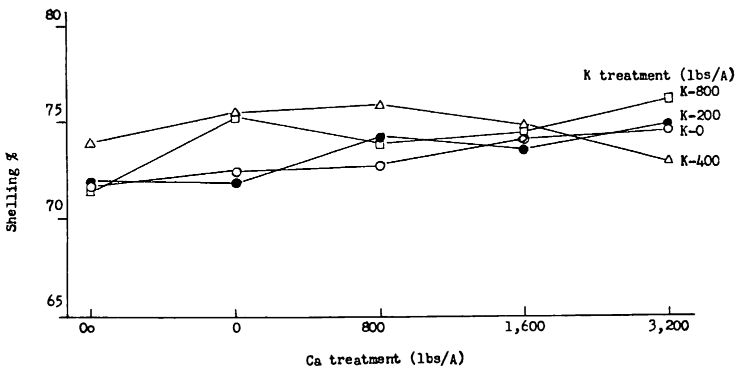



Fig. 4 Shelling percent of the peanut on Paaloa soil treated with varying rates of K and Ca.

Table 4. Differences in whole plant yields among K treated plots, Paaloa soil.*

| K-level | $\bar{x}$ | $\bar{x}$-55.7 | $\bar{x}$-59.7 | $\bar{x}$-60.5 |
|---|---|---|---|---|
| K-400 | 62.6 | 6.9* | 2.9 | 2.0 |
| K-800 | 60.5 | 4.8 | 0.9 | |
| K-200 | 59.7 | 4.0 | | |
| K- 0 | 55.7 | | | |
| D=4.86 | | | | |

* indicates significant difference at the 5% level.

** The treatment means were compared using Tukey's method as defined on p. 251 of the *Statistical Methods* by Snedecor[26].

pH by supplying the Paaloa soil with $Ca(OH)_2$ in addition to the 4 levels of $CaSO_4$. No significant differences, however, could be demonstrated between the peanut yields in the check ($Ca\text{-}0_0$) and the pH raised treatment (Ca-0). This result seems to be in accordance with that of Colwell and Brady[11], who reported a correlation coefficient as low as 0.182 without significance between peanut yield and soil pH ranging from 4.9 to 6.1.

Shelling percentage was nearly constant for the varying levels of calcium at each potassium level. No significant difference was detected as a result of either the potassium or calcium treatments.

*2. Results on Wahiawa soil.*

The yield of the whole plant, shelled peanuts, and shelling percent on the Wahiawa soil are shown in Figures 5, 6, and 8.

Differences in yields of the whole plant among calcium and potassium levels were not significant. However, the whole plant yield trend suggests that an increasing addition of calcium in the K-200 level had a favorable effect, but additions exceeding Ca-1,600 resulted in decreased yields. For the K-400 level, the yields increased with increased additions of calcium.

Statistically, it was found that there were no differences in the shelled peanut yields either among potassium levels or among calcium levels. There was a significant correlation between the whole plant and shelled peanut yields (Fig. 7). The shelled peanut yield decreased as the calcium increased in the K-0 and K-800 levels. Only a small variation in the shelled peanut yield occurred with the increased addition of calcium for the K-200 level. For the K-400 level,

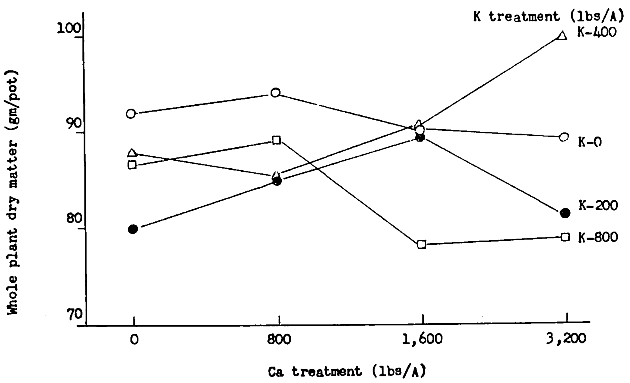



Fig. 5 Yield of the whole plant of the peanut on Wahiawa soil treated with varying rates of K and Ca.

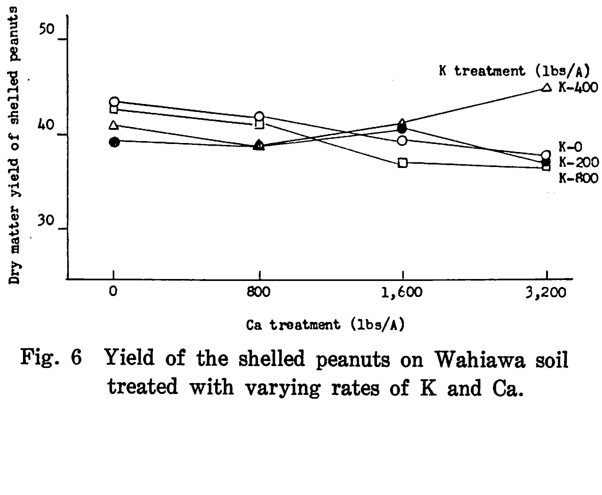
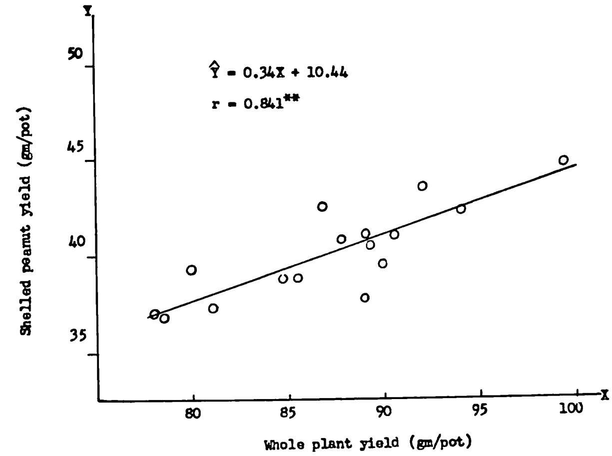



Fig. 6 Yield of the shelled peanuts on Wahiawa soil treated with varying rates of K and Ca.




** Indicates correlation coefficient at the 1% level of significance.

Fig. 7 Relationship between the whole plant and shelled peanut yield on Wahiawa soil.

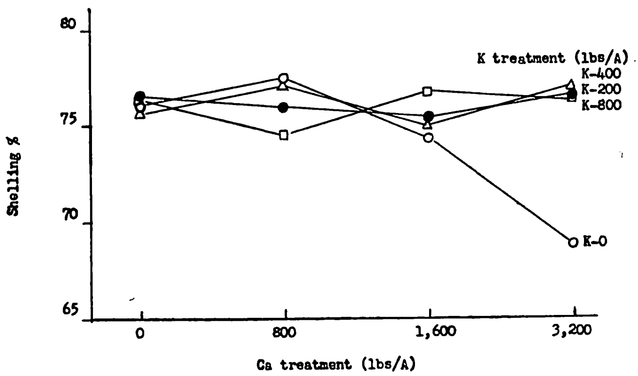



Fig. 8 Shelling percent of the peanut on Wahiawa soil treated with varying rates of K and Ca.

the increased calcium addition seemed to result in a higher yield of the shelled peanuts. Among the various potassium levels, the K-400 level seemed to be slight higher in yield than others.

There were no significant differences in shelling percent either among potassium levels. The shelling percent varied in a narrow range except for that of the K-0 level. For the K-0 level, the shelling percent was depressed with the increased addition of calcium. The result on shelling percent agrees with the data on shelled peanut yield in which no significant yield increase was obtained for either the calcium or potassium treatment.

*3. Results on Waimanalo soil.*

The yields of whole plant, shelled peanuts, and shelling percent on the Waimanalo soil are shown in Figures 9, 10, and 12.

The analysis of variance showed no significant difference of the whole plant yield among calcium and potassium levels. The following trends were observed: for the K-0 level, the highest yield was obtained at Ca-1,600; for the K-200 level, the highest yield was shown at Ca-3,200; for the K-400 level, the highest yield was shown at Ca-0. The addition of 400

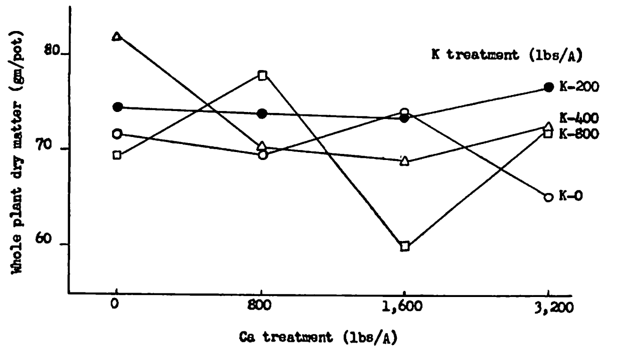



Fig. 9 Yield of the whole plant of the peanut on Waimanalo soil treated with varying rates of K and Ca.

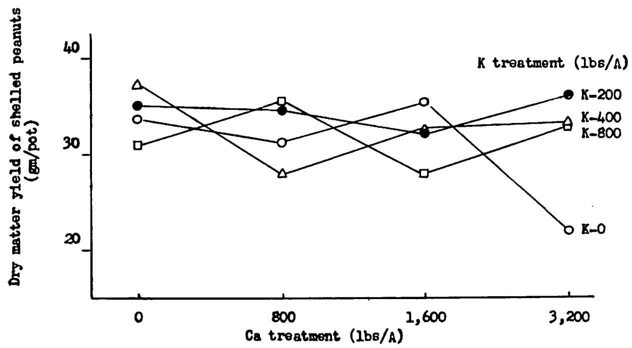
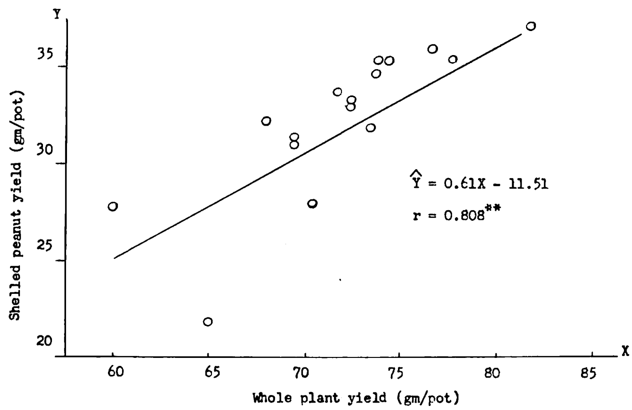



Fig. 10 Yield of the shelled peanuts on Waimanalo soil treated with varying rates of K and Ca.




** Indicates correlation coefficient at the 1% level of significance.

Fig. 11 Relationship between the whole plant and shelled peanut yield on Waimanalo soil.

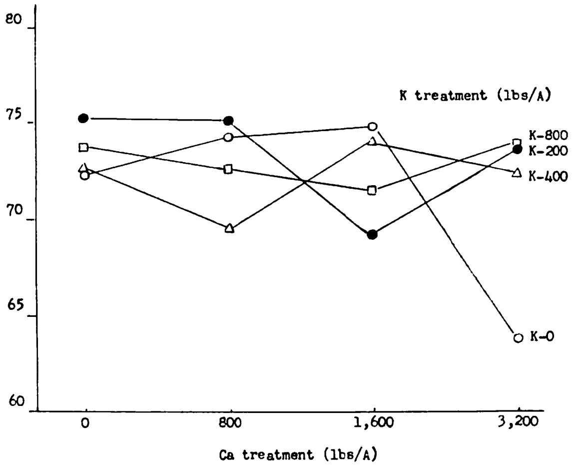
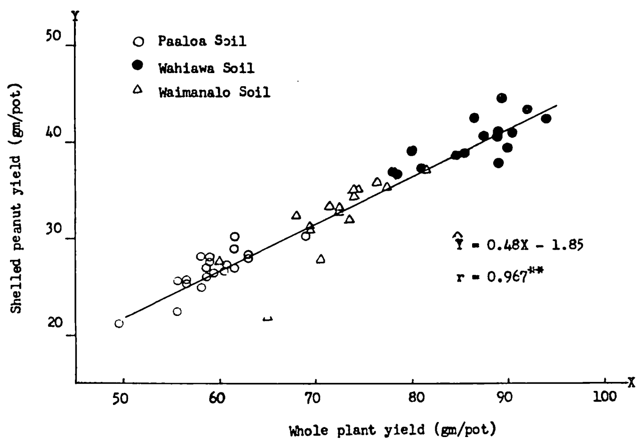



Fig. 12 Shelling percent of the peanut on Waimanalo soil treated with varying rates of K and Ca.

pounds of potassium per acre seemed to produce a good yield response without any addition of calcium. For the K-800 level, the highest yield was obtained at Ca-800.

The analysis of variance showed that there were no significant differences in the shelled peanut yields among potassium and calcium levels. Although no significant differences were detected in the effect of potassium and calcium on shelled peanut yields, a significant calcium x potassium interaction was found. This interaction appeared to be depressive in that the shelled peanut yield decreased slightly when both the calcium and potassium supply was increased. It was found that the shelled peanut yield correlated significantly to that of the whole plant yield (Fig. 11), as shown on the Paaloa and Wahiawa soils.

The analysis of variance showed that there was no significant difference in the shelling percent among potassium and calcium levels. Shelling percent for the Waimanalo soil in general remained relatively constant except for the K-0 level, which showed a marked depression by the addition of 3,200 pounds of calcium per acre. No significant interaction on the shelling




** Indicates correlation coefficient at the 1% level of significance.

Fig. 13 Relationship between the whole plant and shelled peanut yield on three Soils.

percent between potassium and calcium treatment was detected. However, it would be correct to consider that the marked depression at Ca-3,200 in the K-0 level implied some problems of soil management and fertility; that is, the heavy application of calcium at the low potassium level resulted in rather poor fruit filling of the peanut.

*4. Relationship between the whole peanut plant and shelled peanut yield on the three soils.*

As it was found in the proceding section that there was a significant correlation between the whole peanut plant yield and shelled peanut yield in each soil. A subsequent statistical analysis was computed to study the relationship between the yields on all three soils. A significant correlation coefficient was obtained between the whole peanut plant and shelled peanut yield (Fig. 13).

*5. Relationship between the shelled peanut yield and nutrient elements of the soil and plant tissue.*

Correlation between the shelled peanut yield and nutrient elements of the soils and plant tissue of the peanut was studied. There was no statistically significant correlation between the shelled peanut yield and nutrient elements either of the soils or of the plant tissue, except for the ratio of $K/\sqrt{(Ca+Mg)/2}$ of the plant tissue from the Paaloa soil and plant calcium from the Wahiawa soil (Table 5). The two significant correlation coefficients were probably obtained by chance, because any such definite tendency was not shown on the other soils. However, it was detected that the correlation between the shelled peanut yield and $K/\sqrt{(Ca+Mg)/2}$ of the plant tissue was generally higher than that of the soils. This would indicate that the ratio of $K/\sqrt{(Ca+Mg)/2}$ of the plant tissue is the more sensitive indicator of the shelled peanut yield.

Table 5. Relationship between the shelled peanut yield and nutrient elements of soils and plant tissue

| Soil | | Yield vs. Soil | | | |
|---|---|---|---|---|---|
| | | K | Ca | | $K/\sqrt{(Ca+Mg)/2}$ |
| Paaloa | r | 0.394 | 0.192 | | 0.312 |
| Wahiawa | r | 0.121 | 0.357 | | 0.086 |
| Waimanalo | r | 0.019 | 0.004 | | 0.120 |
| **Soil** | | **Yield vs. Plant** | | | |
| | | K | Ca | Mg | $K/\sqrt{(Ca+Mg)/2}$ |
| Paaloa | r | 0.034 | 0.167 | 0.307 | 0.459* |
| Wahiawa | r | 0.057 | 0.638* | 0.096 | 0.260 |
| Waimanalo | r | 0.162 | 0.337 | 0.237 | 0.136 |

* Indicates correlation coefficient at the 5% level of significance.

## Result and Discussion II

### NUTRIENT UPTAKE OF THE PEANUT

Peanut leaves were analyzed for potassium, calcium, and magnesium to study how the uptake of these nutrients was affected by the varying rates of potassium and calcium.

*1. Results on Paaloa soil.*

The result of leaf analysis of the peanut plant grown on Paaloa soil is shown in Figures 14a, 14b. Analyses of variance showed that the potassium, calcium, and magnesium uptake of peanut plants was significantly affected by both potassium and calcium treatments.

The potassium content ranged from 1.15 to 3.54% and calcium from 1.86 to 3.29%. Differences of the potassium contents were compared among various potassium and calcium

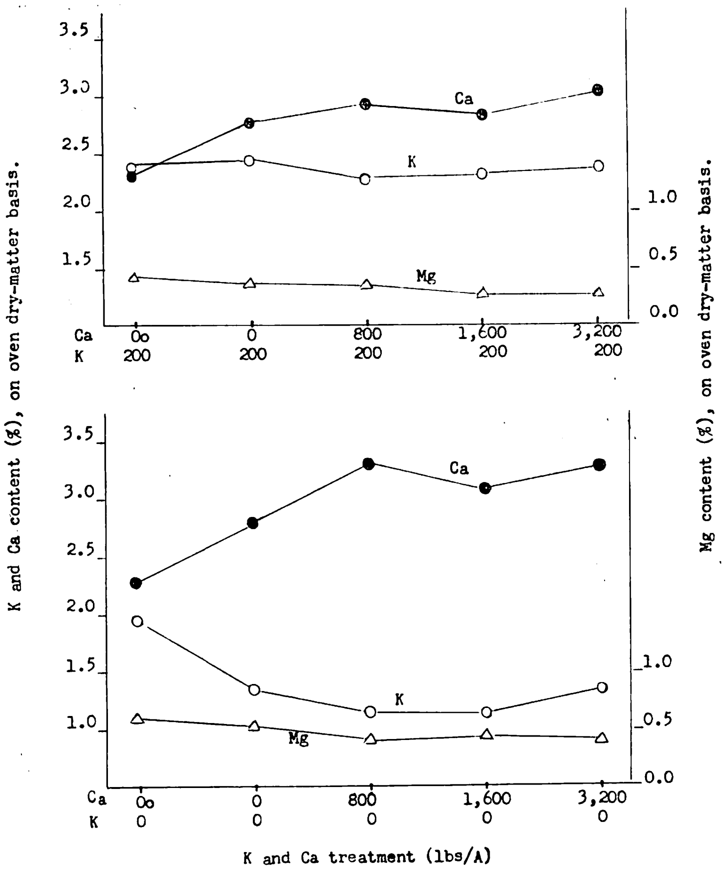



Fig. 14a K, Ca, and Mg content of peanut plants grown on Paaloa soil as affected by K and Ca treatment.

Table 6. Percent K content of peanut plants as affected by varying rates of K and Ca treatment

| K level | K treatment | | | Ca level | Ca treatment | | |
|---|---|---|---|---|---|---|---|
| | Paaloa | Wahiawa | Waimanalo | | Paaloa | Wahiawa | Waimanalo |
| | | | | $0_0$ | 2.85 | — | — |
| 0 | 1.41* | 2.58 | 2.87 | 0 | 2.86 | 2.47 | 2.83 |
| 200 | 2.36 | 2.73 | 2.87 | 800 | 2.48 | 2.55 | 3.16 |
| 400 | 3.03 | 2.79 | 2.94 | 1,600 | 2.37 | 2.69 | 2.81 |
| 800 | 3.49 | 3.08 | 2.90 | 3,200 | 2.31 | 2.95 | 2.76 |
| D= | 0.97 | 0.30 | n.s.** | | 0.46 | n.s. | 0.27 |

* The side lined values indicate that there is no significant difference larger than the D value.
** n.s. stands for no significant difference among treatments as found in analyses of variance.

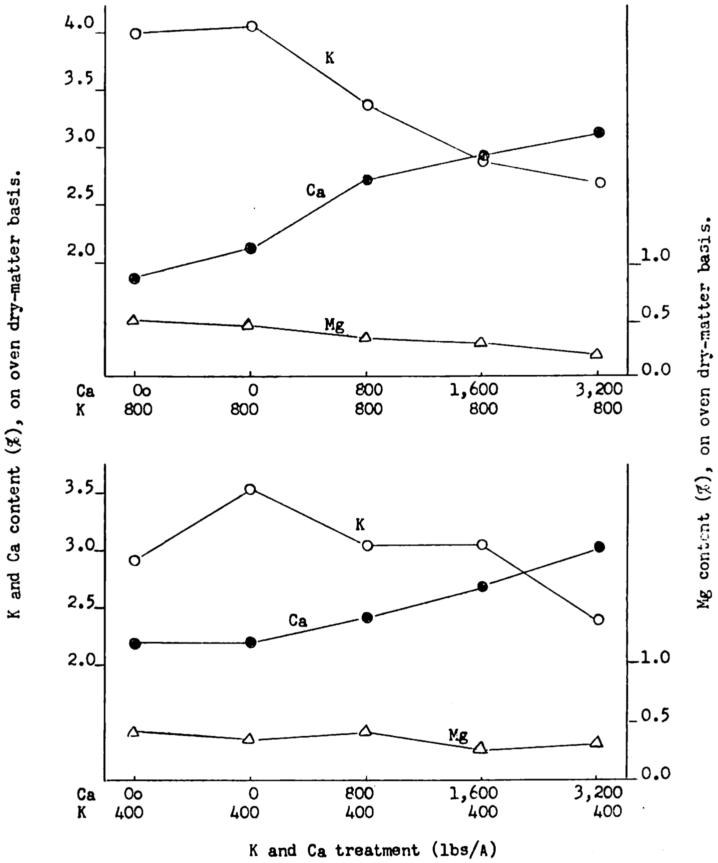



Fig. 14b K, Ca, and Mg content of oeanut plants grown on Paaloa soil as affected by K and Ca treatment.

Table 7. Percent Ca content of peanut plants as affected by varying rates of K and Ca treatment

| K level | K treatment | | | Ca level | Ca treatment | | |
|---|---|---|---|---|---|---|---|
| | Paaloa | Wahiawa | Waimanalo | | Paaloa | Wahiawa | Waimanalo |
| | | | | $0_0$ | 2.17 | — | — |
| 0 | 2.96 | 2.66 | 3.12 | 0 | 2.48 | 2.47 | 3.20 |
| 200 | 2.78 | 2.69 | 3.11 | 800 | 2.81 | 2.55 | 3.04 |
| 400 | 2.50 | 2.54 | 3.24 | 1,600 | 2.88 | 2.69 | 2.14 |
| 800 | 2.53 | 2.76 | 3.14 | 3,200 | 3.13 | 2.93 | 3.24 |
| D= | 0.41 | n.s. | n.s. | | 0.57 | 0.46 | n.s. |

Table 8. Percent Mg content of peanut plants as affected by varying rates of K and Ca treatment

| K level | K treatment | | | Ca level | Ca treatment | | |
|---|---|---|---|---|---|---|---|
| | Paaloa | Wahiawa | Waimanalo | | Paaloa | Wahiawa | Waimanalo |
| | | | | $0_0$ | 0.52 | — | — |
| 0 | 0.50 | 0.42 | 0.54 | 0 | 0.45 | 0.53 | 0.54 |
| 200 | 0.37 | 0.47 | 0.51 | 800 | 0.40 | 0.52 | 0.51 |
| 400 | 0.38 | 0.54 | 0.46 | 1,600 | 0.34 | 0.45 | 0.46 |
| 800 | 0.36 | 0.44 | 0.49 | 3,200 | 0.31 | 0.38 | 0.49 |
| D= | 0.14 | 0.12 | n.s. | | 0.18 | 0.14 | n.s. |

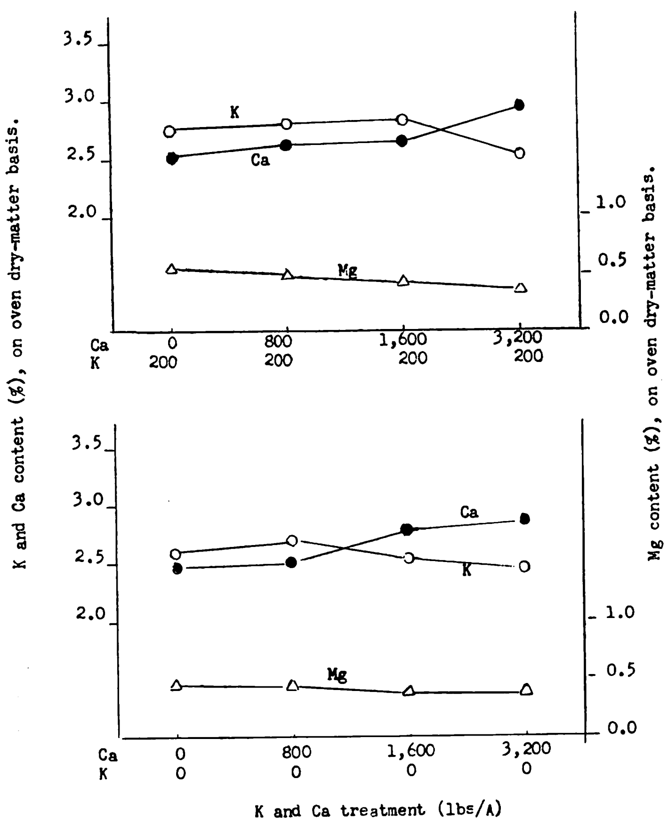



Fig. 15a K, Ca, and Mg content of peanut plants grown on Wahiawa soil as affected by K and Ca treatment.

levels (Table 6). Subsequent comparisons of the calcium content in peanut plants among potassium and calcium treatments were shown in Table 7. The lowest levels of potassium were obtained at the K-0 level, and the lowest calcium content occurred in the Ca-$O_0$ treatment. On the other hand, the highest potassium content was obtained in K-800, and the highest calcium content at Ca-3,2000. This may imply that the addition of potassium and calcium is reflected immediately in the plant because of the low content of potassium and calcium in the Paaloa soil (Table 1). The magnesium content ranged from 0.18 to 0.62%. Differences of the magnesium content among various potassium and calcium levels were compared (Table 8). It is noteworthy that the depression of magnesium from 0.50 to 0.18% took place with an increasing supply of calcium for the K-800 level.

As a whole, there was an antagonistic relationship in the content of potassium and calcium. The potassium content increased with an increasing supply of potassium but decreased when the calcium supply was increased and vice versa in calcium content. In the K-800 level, the relationship of potassium and calcium content seemed to agree with that of Burkhart and Collins[6]. The magnesium content tended to decrease with an increased supply of calcium. However, since the variation of magnesium content was relatively small, it would be reasonable to consider that there is an antagonistic relationship between potassium and calcium plus magnesium as shown in other plant species[31].

2. *Results on Wahiawa soil.*

The results of the leaf analyses for the peanut plants grown on Wahiawa soil are shown

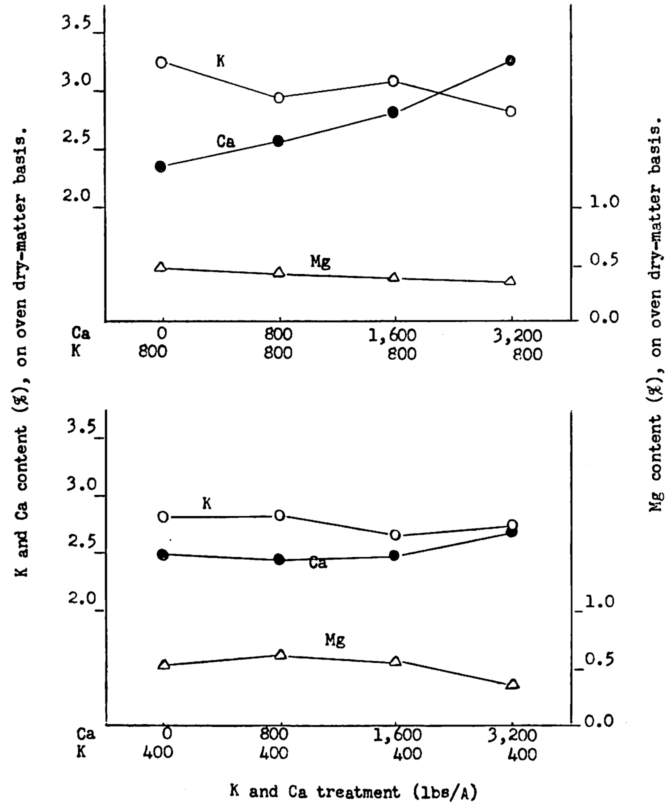



Fig. 15b K, Ca, and Mg content of peanut plants grown on Wahiawa soil as affected by K and Ca treatment.

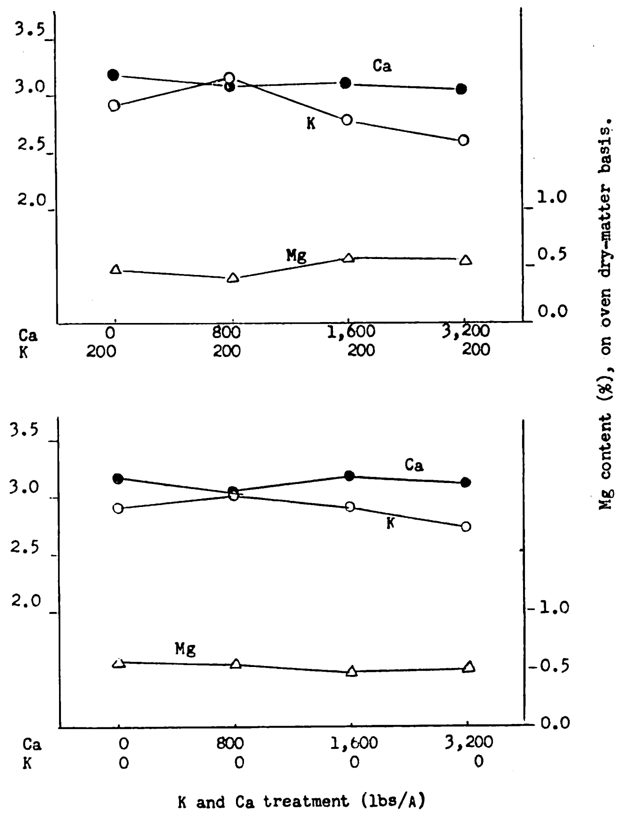



Fig. 16a K, Ca, and Mg content of peanut plants grown on Waimanalo soil as affected by K and Ca treatment.

in Figs. 15a and 15b. Analyses of variance showed that the potassium uptake was significantly affected by the potassium treatment. The calcium uptake was significantly affected by the calcium treatment, and the uptake of magnesium was significantly affected by both potassium and calcium treatments.

The potassium content ranged from 2.53 to 3.28% and calcium content from 2.45 to 3.38%. Comparisons of the potassium and calcium content in peanut plants for the respective potassium and calcium treatments were shown in Tables 6 and 7. The lowest content of potassium was obtained at Ca-3,200 in K-0, and the lowest content of calcium was at Ca-0 in K-300. The highest content of potassium was obtained at Ca-0 in K-800 and the highest content of calcium was at Ca-3,200 in K-800.

The magnesium content ranged from 0.38 to 0.64%. The magnesium content did not shift much with potassium supply but it decreased with increasing additions of calcium. Difference of the magnesium content in peanut plants for potassium and calcium levels was compared in Table 8.

As a whole, on Wahiawa soil, the antagonistic relationship between potassium and calcium was not as evident as that on Paaloa soil. However, there was a trend of antagonism shown by the depression of potassium content associated with the increase of calcium content from Ca-1,600 to Ca-3,200 at the following levels of potassium, K-0, K-200 and K-800.

*3. Results on Waimanalo soil.*

The results of leaf analysis for potassium, calcium, and magnesium in the peanut plant

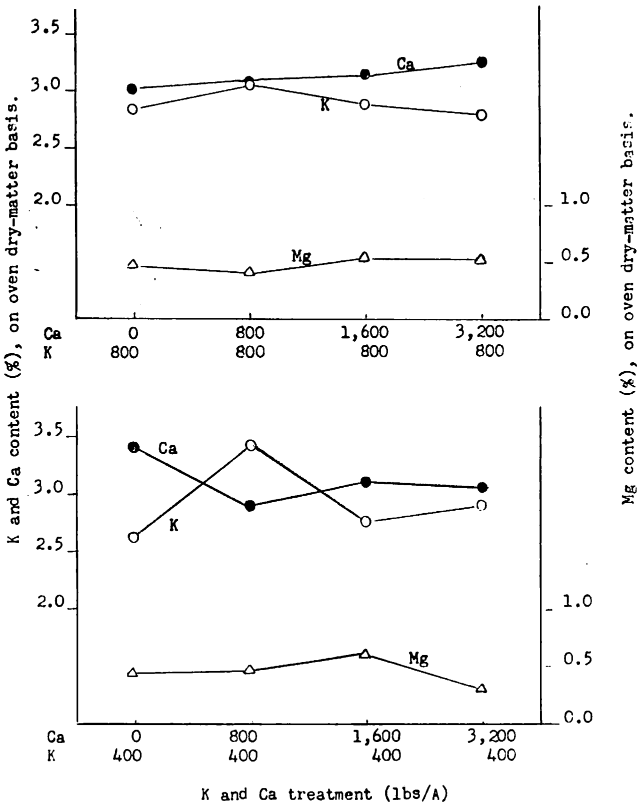



Fig. 16b K, Ca, and Mg content of peanut plants grown on Waimanalo soil as affected by K and Ca treatment.

grown on Waimanalo soil are shown in Figs. 16a and 16b. Analyses of variance showed that only the uptake of potassium was significantly affectd by the calcium treatment, while neither uptake of calcium nor magnesium was significantly affected by the treatments of potassium and calcium.

The potassium content ranged from 2.64 to 3.15% and calcium content 2.91 to 3.55%. Difference of potassium content in peanut plants among calcium levels was shown in Table 6. Magnesium content was in a range of 0.31 to 0.59%. No definite trend was observed in the change of the magnesium content either to the level of potassium or to the supply of calcium.

As a whole, a slight tendency of potassium content to decrease with increasing addition of calcium was shown, but this was not as appreciable as that of the Paaloa and Wahiawa soils. The tendency of the calcium content to increase with the added increments of calcium was rather negligible. Consequently, it may be concluded that the antagonistic relationship between potassium and calcium for the peanut in Waimanalo soil was not noteworthy.

## Summary

The effects of varying potassium and calcium rates on the peanut yield was studied using three Hawaiian Latosols in a pot experiment. Total vegetative yields (whole plant), shelled peanuts and shelling percentages as related to soil treatment were analyzed statistically.

Total vegetative yield increased significantly with potassium treatment in the Paaloa soil. On the Wahiawa soil response to soil treatment as measured by any form of peanut yield failed to give significant results. A significant interaction was found in total vegetative yield as a resut of soil treatment in the Waimanalo soil. When no potassium was added to the soil, increasing calcium levels seriously depressed the shelled peanut yield and shelling percentage.

A significant correlation was established between shelled peanut and total vegetative yield for all soils. The scatter diagram (Fig. 13) indicates that the limiting factor or factors, for the peanut yields may have been a variable or variables, other than those for which the experiment was designed. It was presumed that the ratio of $K/\sqrt{(Ca+Mg)/2}$ of the plant was a sensitive indicator of the shelled peanut yield.

The potassium and calcium treatments significantly affected the potassium, calcium, and magnesium uptake of the peanut plant as shown by tissue analyses. An antagonistic trend between potassium and calcium uptake was evident on the Paaloa and Wahiawa soils. On the Waimanalo soil, the calcium treatment significantly affected the potassium uptake.

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# ハワイのラトゾール土壌においてカリ及びカルシゥムの施用が落花生の増収量と養分吸収に及ぼす影響（要約）

大屋一弘

ハワイのラトゾール土壌においてカリ及びカルシゥムを種々の割合で落花生に施用した場合，落花生の収量にどのような効果があるかと云うことをポットを用いて試験を行なった。

そして落花生の全植物体，剝実重及び剝実率がカリとカルシゥムの施用によってどのように影響されたかについて統計的に検討して見た。

パアロア土壌では，カリ施用によって落花生の全植物体重が有為に増加した。ワヒアワ土壌では全植物体，剝実重及び剝実率何れについてもカリとカルシゥムの施用が有為な影響を与えなかった。ワイマナロ土壌においては，落花生の全植物体の収量についてカリとカルシゥムの相互阻害作用がはっきりと見られた。またワイマナロ土壌では無カリの場合にカルシゥムを増加して与えるとかえって剝実重及び剝実率が著しく低下した。

パアロア，ワヒアワ及びワイマナロの土壌においていずれも剝実重と全植物重との間に有為な相関々係が見られた。第 13 図の結果から，この試験においてはカリやカルシゥム以外の養分が落花生の生育制限因子であろうと推測された。剝実重については植物体中の $K/\sqrt{(Ca+Mg)/2}$ 割合がより敏感な指標となるものと思われた。

カリ及びカルシゥムの施用はそれぞれ，カリ，カルシゥム，マグネシゥムの吸収に影響することが落花生葉の分析によって示された。