Relationships of Tuber Yield, Starch Content and Starch Yield of Cassava with Potassium Status of Fertilizer, Soil and Leaf

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Abstract

Significant correlations were obtained between applied K and water-soluble soil K, and between applied K and leaf K. However, leaf K was a better indicator of starch yield than water-soluble soil K. The optimum leaf K for maximum starch yield was 2.11%. The rate of K fertilization to obtain this optimum level might depend on its methods of application. In this trial where K was broadcast one month before planting, it was predicted to be 180 kg/ha of K_2O.

Introduction

The importance of K to the productivity of cassava is well known, and reports of increased yields with its application are many (Doop, 1937, Chadha 1958; Sheng, 1963; Chew, 1970; Kumar *et al*, 1971; Ofori 1973; Ngongi *et al*, 1977. Obigbesan (1973) showed that the application of K at optimum level maximized starch content on dry matter yield of tubers, but excessive K could reduce it.

In spite of the fact that yield response to K application depends on available K in the soil, the relationship of K in the soil with the productivity of cassava is little known. Ng (1965) stated that apart from the marine clay, the rest of the cultivated soils in Peninsular Malaysia were not naturally endowed with plant nutrients and that application of fertilizer was essential for high level crop production.

The nutrient levels of plant tissue reflect the yielding ability of cassava (Cours *et al*, 1961). Fox *et al* (1975) reported that the N contents of the 4th and 5th fully expanded leaves were highly correlated with the final yield of tubers.

The tubers are mainly used as a source of energy in the form of starch, which is the biggest component in the dry matter of tubers. As K is generally more important than N in influencing not only the tuber yield but also the starch and dry matter yields in root crops, the objective of the present study was to establish relationships of soil K and leaf K with the yield of starch.

Materials and Methods

The trial was sited on an oxisol (Orthoxic Tropudult) at MARDI Station, Serdang, Selangor. The soil is classified as Serdang Series and was formerly planted to rubber.

It has been described as a Red and Yellow Latosol/Red and Yellow Podzolic soil derived from quartzites, sandstone and conglomerates (Leamy and Panton, 1966). Chemical analyses of the soil after the land was cleared of old rubber are presented in Table 1 (Tham, 1976). Prior to this cassava experiment, the site had been used for corn experiments and, later, pasture growing. The area is 45 m above sea level.

(a) Experimental – The experiment tested 8 levels of K in a randomized complete block design with four replications. Plot size was 4 m x 10 m including border rows of plants, and harvested plot size was 2 m x 3 m, which gave six plants per harvested plot.

The plots were broadcast with different rates of K one month before planting to create different levels of K in the soil. The rates of application in kg/ha of K_2O as muriate of potash were 0, 40, 60, 80, 120, 160, 200, 240 and 300.

The levels of water-soluble K were determined by taking soil samples at depth of 0-23cm from every plot just before planting, and analyzing them following a method described by Magistad, *et al* (1945). Air-dried soil weighing 20 g was mixed with 20 ml of distilled water and the solution was tested for K with a flame photometer. This simpler method was used instead of the one requiring NH_4OAc as the extractant because the latter method had been found previously to give very variable results. The pH values of soil samples were determined using 10 gm of soil in 50 ml of water.

At planting, triple superphosphate was applied as a sidedressing at the rate of 30 kg/ha of P_2O_5. The cuttings of 23 cm length were obtained from stems of the cv. Black Twig. They were placed horizontally in shallow holes at a spacing of 1 m x 1 m, and buried about 3 cm with soil. Three weeks later, sulphate of ammonia was applied as a sidedressing at the rate of 50 kg/ha of N.

Weeds were kept under control by handweeding. At three months after planting, a leaf sample was taken from each plot for the determination of K and N levels. It consisted of six leaves, each of which was the sixth fully expanded leaf of a plant at this age.

After twelve months in the field, two central rows of six plants from each plot were harvested. Tubers were weighed and sub-samples taken for determining their specific gravity values. The starch content for each sample was estimated, using the linear relationship of starch content y and specific gravity x, i.e. $y = -1.47.0 + 159.1\ x$ (Wholey and Booth, 1977). Total yield of starch from each plot was estimated by multiplying the fresh weight yield of tubers by the starch content.

(b) Statistical – For the purpose of correlating the variables and curve-fitting, the number of observations for each of the variables were reduced to eight by using the average of four readings at each level of fertilizer K applied. Simple correlations between the dependent variables, i.e., tuber yield, starch content, starch yield, K content and water-soluble soil K content, were examined by calculating their coefficients of correlation and testing their significance at 5% and 1% levels. The relationships of starch content and starch yield with K fertilizer, water-soluble soil K and leaf K were examined by fitting linear, quadratic and asymptotic regressions.

Results and Discussion

Compared to earlier pH readings given in Table 1, the present pH values had increased to 4.68, possibly as a result of applying limestone to previous crops of maize and pasture. Germination of the cuttings was excellent. However, the growth of plants in the control plots (no K applied) appeared stunted with semi-prostrate stems. The K-fertilized plants grew normally and had upright stems. Among the K-fertilized plants, differences in growth at varying rates of K application were not apparent. Sufficient N for the plants was indicated by the average leaf N level, which was 5.44% at three months after planting. The critical value of leaf N had been suggested to be 5.0% (Fox *et al,* 1975).

The average values for the dependent variables at the various levels of fertilizer K applied are shown in Appendix 1. The coefficients of correlation between the dependent variables are summarized in Table 2. The results show that correlations between the yield factors were highly significant. This implies that generally a high tuber yield would result in high starch yield and high starch content. The results in Table 2 also show that leaf K had a higher correlation with each of the yield factors than water-soluble soil K.

Linear, quadratic and asymptotic regressions were fitted to the data with fertilizer K as the independent variable. The regression of tuber yield on applied K was asymptotic. Where regressions of starch yield and starch content were concerned, the second degree polynomial regression gave a better fit than the asymptotic regression, as judged by the squared deviations from the fitted line. The results presented here do not include asymptotic equations since these are concerned mainly with starch yield and starch content and not tuber yield.

The effect of K fertilizer on the water-soluble soil K was linear, as shown in Fig. 1. With each 10 kg/ha of K_2O applied, an increase of 2.63 ppm water-soluble K in the soil was predicted. The effect of K fertilizer on leaf K was quadratic, as shown in Fig. 2. A maximum of 2.17% leaf K was predicted at 254 kg/ha of K_2O.

Starch content and starch yield as quadratic functions of applied K are shown in Figs. 3 and 4, respectively. Maximum starch content was expected to be 36.85% at 177 kg/ha of K_2O. The starch yield was predicted to be maximal at 6.53 kg/plot with an application of 207 mg of K_2O per ha.

Similarly, the relationships of water-soluble soil K and leaf K with starch yield are represented by quadratic curves given in Figs. 5 and 6. The optimum level of water-soluble soil K was 65 ppm, which was expected to give a maximum starch yield of 6.46 kg/plot. The K fertilizer required to achieve this optimum value would be 202 kg/ha of K_2O, as estimated from the equation relating these two factors. This was close to 207 kg/ha predicted from the direct relationship between starch yield and K applied.

The optimum leaf K for a maximum starch yield of 6.29 kg/plot was 2.11%. To attain this value of leaf K would require 180 kg/ha of K_2O, as estimated from the equation relating these two variables.

Thus, compared to the prediction based on leaf K, the prediction of maximum starch yield, or the rate of K application to achieve this maximum on the basis of water-soluble soil K, was closer to the result obtained from the direct relationship between starch yield and fertilizer K applied. However, the quadratic regressions of starch yield on fertilizer K and soil K had smaller values of R^2 than the quadratic regressions of starch yield on leaf K. Therefore, leaf K was a better indicator of starch yield than water-soluble soil K and fertilizer K. This was because the K available in graded amounts from either fertilizer K or water-soluble soil K was not necessarily absorbed in proportionate amounts reflected in leaf K; only the K actually absorbed mattered to the plant with regard to production of starch.

Exceeding a critical level of K, starch content or starch yield showed a downward trend. This might have been caused by K-induced deficiency of magnesium (Spear *et al,* 1978). From the equation relating starch content y with leaf K content x, where $y = 4.687 + 42.315x - 10.870x^2$ with $R^2 = 0.88$, the optimum level of leaf K for maximum starch content was 1.95%.

It should be noted that the K fertilizer was broadcast one month before planting. This might have led to some losses of K due to leaching. The predicted rate of fertilizer application to achieve maximum starch yield might be less than 180 kg/ha of K_2O if K was placed near the plants after their shoots had just emerged from the soil. Nevertheless, whether cassava received sufficient K for high yield of starch or not, it could be judged by leaf K content, which was optimal at 2.11%.

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Table.1 Soil chemical properties on an old rubber land of the Serdang Series (Tham, 1976)

Horizons	% N	Available P (ppm)	Total P (ppm)	pH 1:2.5 (H_2O)	Exchangeable cations (me/100g) Ca	Mg	Na	K	Al
0–15 cm	0.13	14	258	4.2–4.4	0.15	0.11	0.05	0.10	0.91
15–30 cm	0.10	6	212	–	0.08	0.09	0.05	0.08	0.71

Table 2. Coefficients of correlation between the dependent variables

	Starch content	Starch yield	Water-Soluble Soil K	Leaf K
Tuber yield	0.88**	0.98**	0.63	0.84**
Starch content	–	0.89**	0.44	0.74*
Starch yield	–	–	0.68	0.90**
Water soluble Soil K	–	–	–	0.84**

*denotes significance at 5% level (DF = 6)

**denotes significance at 1% level (DF = 6)

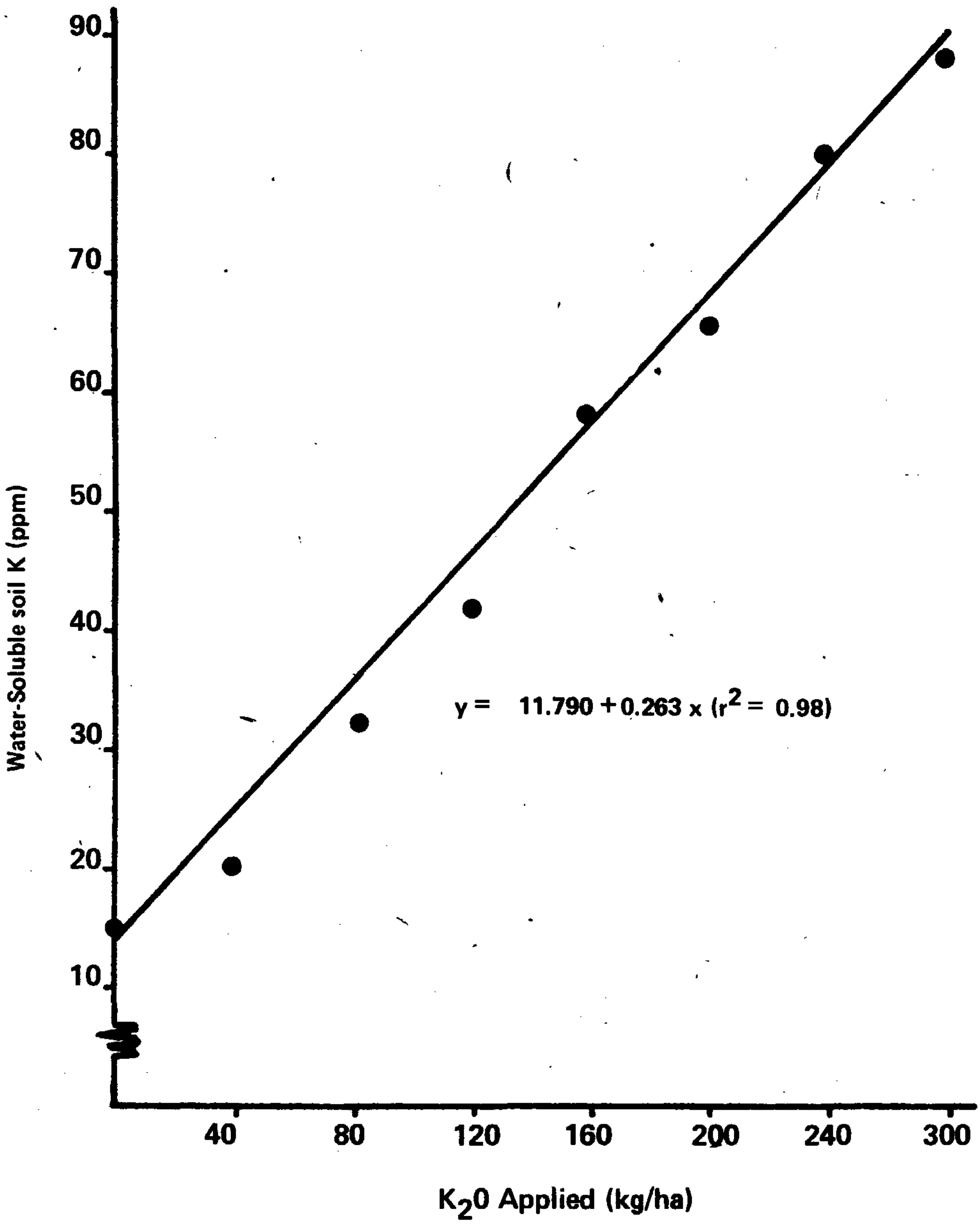

Fig. 1. Water-soluble K content of soil as a function of fertilizer K applied.

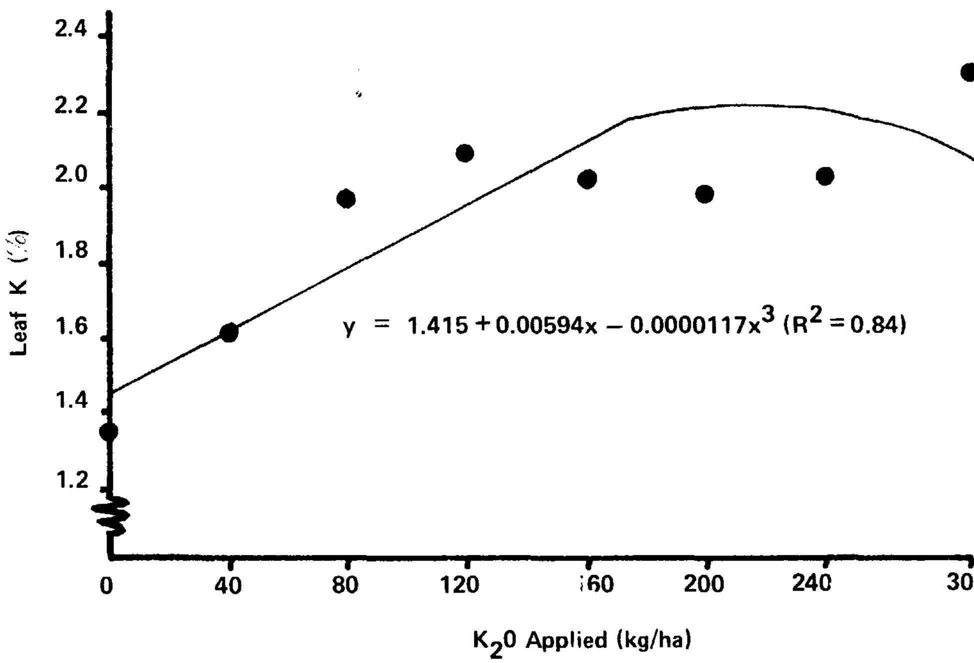

Fig. 2. Cassava leaf K content as a function of fertilizer K applied

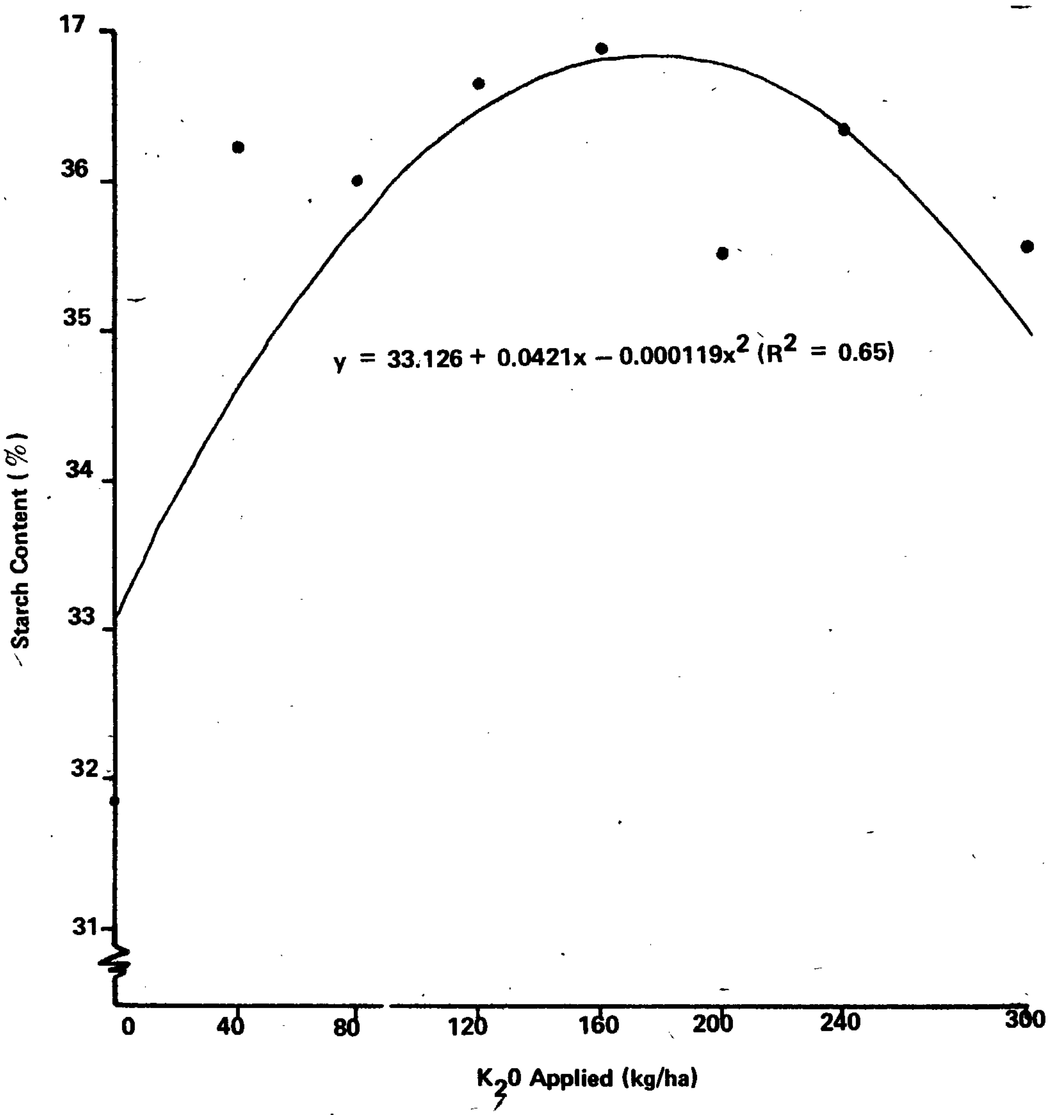

Fig. 3. Starch content of cassava tubers as a function of fertilizer K applied

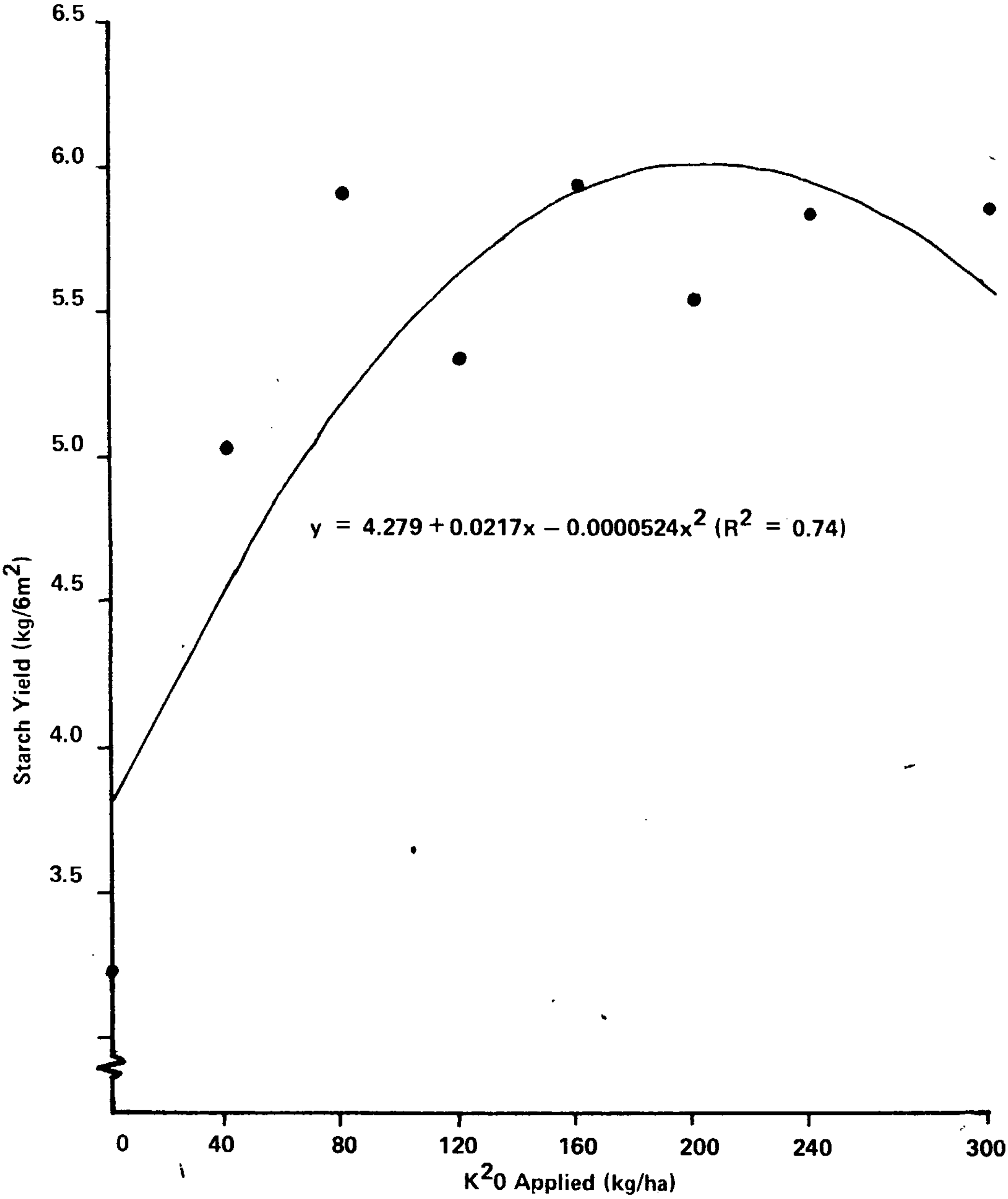

Fig. 4. Starch yield of cassava tubers as a function of fertilizer K applied

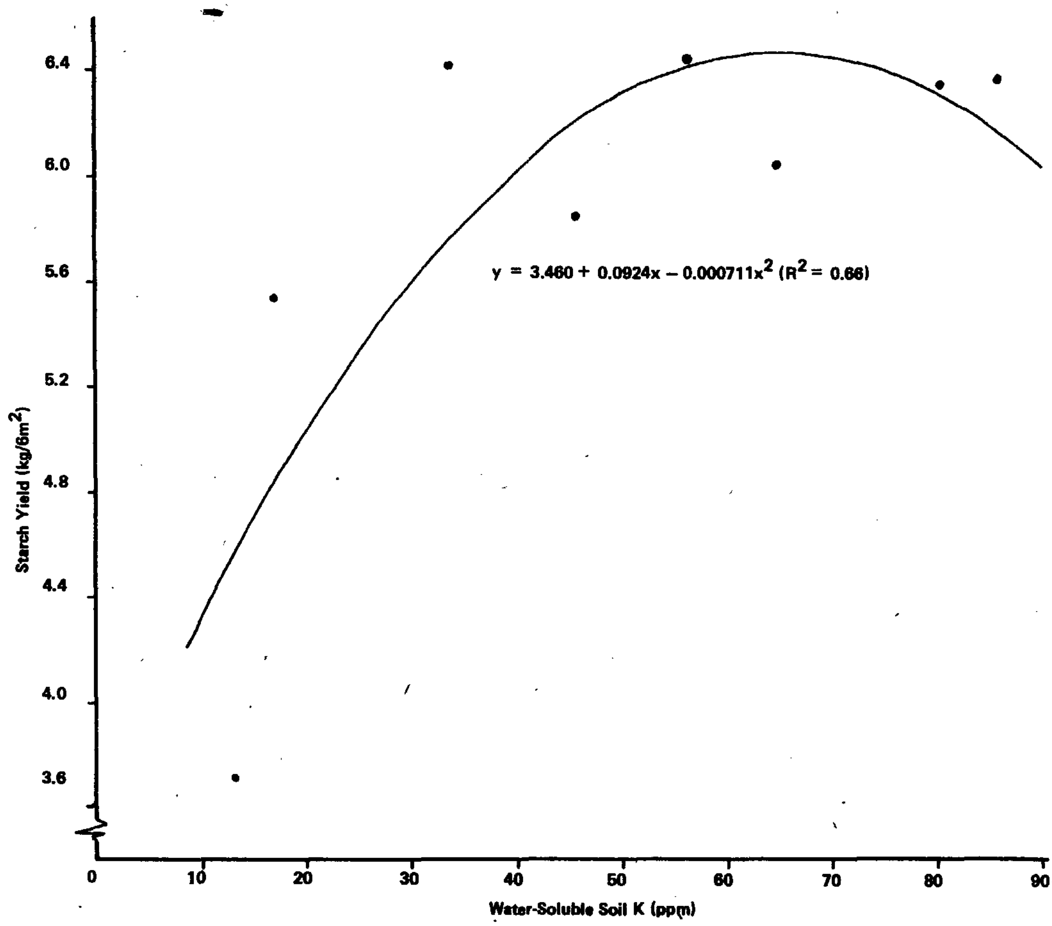

Figure 5. Starch yield of cassava tubers as a function of water-soluble K content of soil

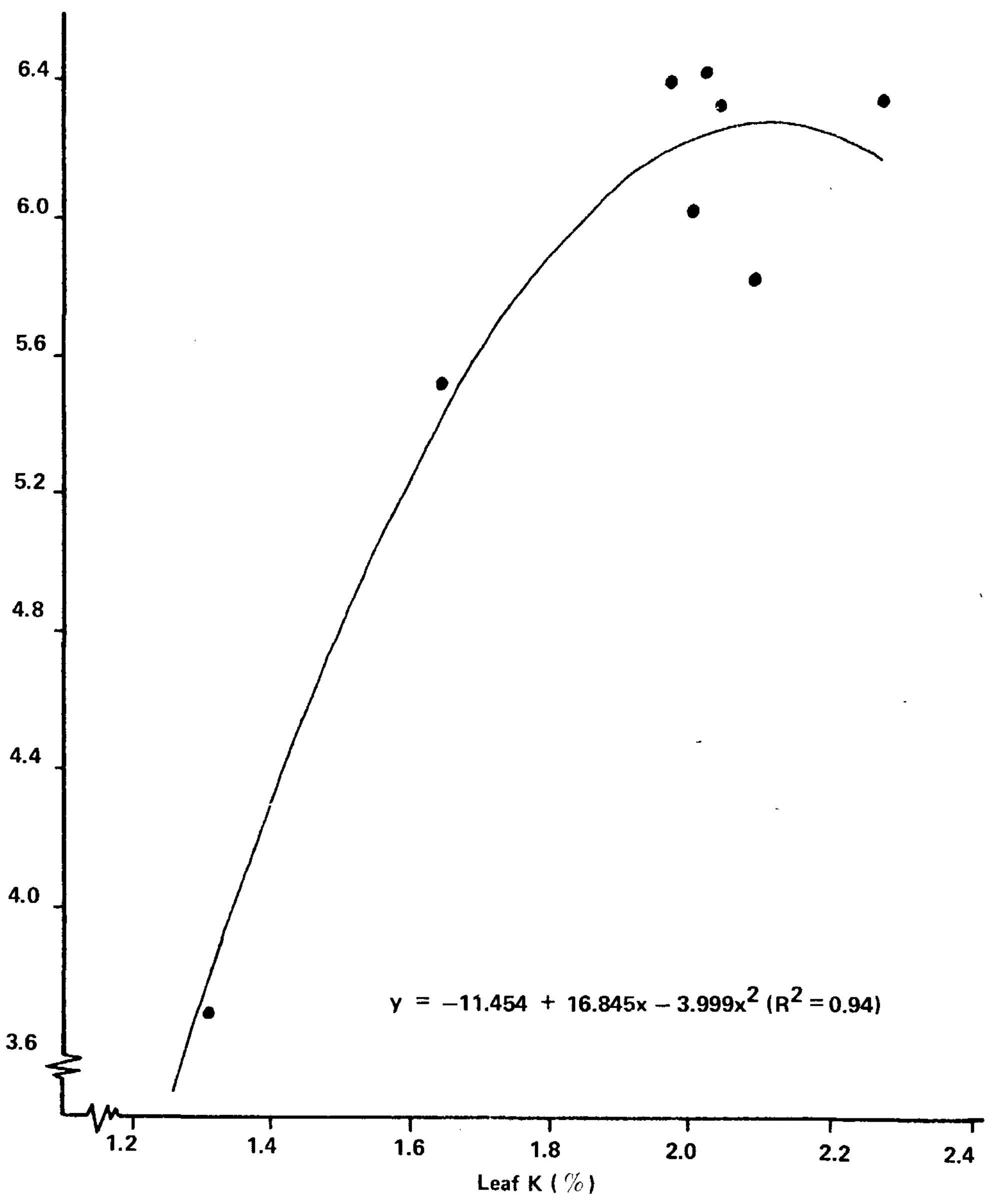

Fig. 6. Starch yield of cassava tubers as a function of leaf K content

Appendix 1. Tuber yield, starch content, starch yield, water-soluble soil K content and leaf K content at different rates of fertilizer K (Each value is an average of four readings)

Kg/ha of K_2O	Fresh-weight tuber yield per plot (kg)	Starch content of tubers on fresh weight basis (%)	Starch yield per plot (kg)	Water-soluble soil K content (ppm)	K content of leaf on dry weight basis (%)
0	11.45	31.95	3.70	13.1	1.31
40	16.65	36.23	5.53	16.8	1.64
80	17.60	36.00	6.40	33.3	1.97
120	15.90	36.63	5.83	45.4	2.09
160	17.35	36.88	6.43	55.9	2.02
200	16.95	35.50	6.03	64.5	2.00
240	17.40	36.33	6.33	80.0	2.04
300	17.85	35.55	6.35	85.5	2.27