POTASSIUM NUTRITION OF ABACA

AND A SURVEY

OF THE AVAILABLE POTASSIUM OF AN ABACA PLANTATION IN COSTA RICA

by

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THESIS

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To MY PARENTS AND BROTHERS

To BLANCA MARIA

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BIOGRAPHY

The writer was born on March 28th, 1927 in Amatitlán, Guatemala. After finishing High School in Guatemala City, he entered Southwestern Louisiana Institute, Lafayette, Louisiana, U. S. A. in September 1947 where he was awarded the degree of Bachelor of Science in Agriculture, with a major in Agronomy, in May 1952.

He enrolled in the Graduate School of the Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica, in June 1953, where he was appointed to a Field Assistanship by the Abacá Project of the U. S. Department of Agriculture to conduct investigations of the soils of the Good Hope plantations in Bataán, Costa Rica.

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I. INTRODUCTION

Information concerning the role of potassium in the nutritive complex of the abaca plant, *Musa textilis Nee*, has been very limited.[1/] For this reason it was considered highly desirable to determine whether or not potassium was one of the limiting factors in abaca production in Costa Rican plantations.

Abaca is a monocotyledoneous plant that belongs to the Musaceae family. It is a plant usually propagated vegetatively by suckers or by division of the corm,usually referred to as root heads, but also may be propagated by seed. Abaca grows best in a warm and humid climate where the rainfall is well distributed throughout the year with no long periods of dry weather. In the Philippines all of the great abaca regions of Albay, Ambos Camerines, eastern coast of Samar,Leyte and Mindanao, and the northern coast of Mindanao, have an average annual rainfall of 108.89 inches a year, a humidity range from 78 per cent to 88 per cent and an average temperature of less than 80.6°F. This type of climate is considered by Rojales (33) as optimum for the growth and development of abacá in the Philippines. The climate of the Good Hope plantation according to Glenn Robinson and M. Striker (30) is of the humid tropical low land type with a temperature range from 61°F to 92°F (1949-1940). The average annual rainfall for the years 1944-1953 was 134 inches distributed over the twelve months fairly evenly.

1/ Abacá is grown for its fiber content which is used in the manufacture of Manila rope. The plant was introduced into Central América in 1925 from the Philippines and plantations of abacá are now in operation.

The fact that abacá is a perennial crop and is grown in the same land for a long period, might be expected to cause a heavy drain of minerals from the soils as has been found to occur by Sherman (41) in the Philippines. This removal of nutrients from the soil might result in decreased yields. Results from fertilizer experiments carried on in Central América given by Robinson and Royer (29) indicated that fertilization with nitrogen and potassium may be necessary for good production from old abacá plantations in Costa Rica. To establish the extent and importance of this depletion it was essential to conduct first a survey of the available soil potassium of the Good Hope plantation, Bataán, Costa Rica. The plantation is approximately nine years old, and in many areas the yields are considered to be relatively low. Approximately half of the area has soil with medium to fine texture and suitable drainage conditions.

This investigation was conducted during the period June 1953-December 1954 as part of the program of the Abacá Project of the U. S. Department of Agriculture in cooperation with the Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica. Field work was carried on at the Good Hope plantation, Bataán, Costa Rica and laboratory work was conducted at the Inter-American Institute of Agricultural Sciences. It was organized with reference to the following objectives:

1. To map the levels of available potassium over the plantation and to correlate these with soil types and productivity classes.
2. To determine the effect of potassium fertilization upon the potassium content of the pseudo-stem and leaves of the abacá plant.

3. To ascertain the rate of downward movement of potassium fertilizer applied on the soil surface.

This investigation showed that there are low levels of available potassium in the soils of many areas of the Good Hope plantation, Bataán, Costa Rica. The downward movement of potassium applied in the form of fertilizer was effective only to a depth of 3 to 4 inches during a period of about 3 years. The analyses of plant tissue samples indicated that the stalk analyses, particularly those of relatively young plants were more indicative of the amounts of potassium applied than the corresponding leaves.

II. REVIEW OF LITERATURE

Soil Requirements

According to Robison and Johnson (28), abacá needs a fertile soil for economic production, due to the fact that the crop is grown in the same land for 10 to 15 years without rotation or application of fertilizers. They stated that friable loams, very fine sandy loams or silty clay loams, of volcanic or alluvial origin are the best and most productive soils for growing abacá. The soils must have sufficient permeability and slope to insure good natural drainage as well as the structure to insure retention of moisture.

Blanco Macías (5) believed that alluvial soils are best adapted for the cultivation of abacá and that these soils must be rich in nitrogen, phosphorus, potassium and calcium. He agrees with Robinson and Johnson (28) in saying that physical characteristics of the soil such as texture, structure, and good drainage should be taken into consideration. He considers that an ideal profile would be as follows:

0- 50 cm:	Loam or sandy clay loam
50-100 cm:	Fine sandy loam that insures drainage and root aeration.

Bielich Nash (3) stated that in Costa Rica coarse textured soils having good aeration and the water table below a depth of four feet seem to be the best soils for abacá and in such soils the plant had a better root development. While such conditions were ideal for Costa Rica, Roberts (27) brought out that in Honduras where periods of drought are encountered, the coarse textured soils are poor for abacá.

Goulding (21) stated that abacá requires a loose, moist soil, rich in humus and well drained.

According to Rojales (33) in the Philippines, the soil is second in importance to favorable climatic conditions in the successful production of abacá. He stated that abacá may be produced on a poor soil provided that the climatic condition is favorable but the richer the soil the more production obtained. He found a high percentage of organic matter in the soil to be associated with high production, due probably to the fact that the organic matter besides being a source of nutrients for the plants, serves in storage of moisture.

According to Edwards and Saleeby (20), the best results with abacá in the Philippines are obtained in the following types of soils:

(1) Moist, mellow loams of volcanic origin.
(2) Alluvial plains subject to some overflow by streams or rivers.
(3) Moist and well drained loams.

In a study of the soils of Davao, Philippines, made by Mariano (25), it is reported that the principal abacá producing soil is the Tubcok clay loam. This soil lies in gently rolling country, is of volcanic origin, deep and well drained. Kidapawan clay loam is not inferior to Tubcok clay loam as an abacá soil but the topography is rougher. Other soils recommended for abacá in Davao are Miral clay loam, San Manuel and Cabangan silt loams and Matina clay.

In the province of Misamis Oriental in the Philippines, Lopez(24) found clays, clay loams and loams with good internal drainage and of volcanic and alluvial origin to be suited for the commercial production of abacá.

In the Philippines, Sherman (40) analyzed chemically the dust from the Mayon volcano to find its potential nutritive value, and compared the values found with those from samples of abacá soil taken two years before. He gives the following results:

	Mayon dust %	Abacá soil 2 years before	Average rich soil %
Nitrogen	0.091	0.141	-
P_2O_5	0.266	0.193	0.15 - 0.30
K_2O	1.605	0.130	1.03 - 1.10

Robinson and Johnson (28) reported that in the province of Albay, Camerines, and Sorsogon in the Philippines, the finest abacá is grown on the lower slopes of old volcanos, where the soil is a rich mellow loam, derived from the disintegration of volcanic rock and the deposits of volcanic ash.

At Los Baños, Philippines, according to Bishop and Curtler (4) a deep sandy loam was shown to be the most desirable soil for abacá. The authors stated that the two main soil conditions required by abacá are a plentiful supply of plant nutrients and good drainage. They also stated that the soil type is important due to the fact that abacá has been shown to be a surface feeder and roots growing in a fine grained soil do not develop as well as those growing in a more open soil.

In 1951, a survey of the soils of the Good Hope plantation, Bataán, Costa Rica, in relation to their suitability for abacá production was made by Robinson and Striker (30). The 38 types classified were grouped into four classes based upon their relative suitability for abacá. Class I, which is considered the best, includes silt loams and fine sandy loams, with good to perfect internal drainage; class II includes silt loams, fine sandy loams and silty clay loams with good internal drainage; class III includes fine sandy loams, silt loams, sandy loams and silty clay loams, which have imperfect internal drainage; class IV includes clays, silty clays and silty clay loams which are very slowly permeable to water and air, and in which the water table is high throughout the year.

Fertilization

Robinson and Johnson (28) reported some of the results of fertilization of abacá carried on by the Philippine Government, in 1928 and 1931. Results from tests carried on in 1928 on young abacá of the Itom variety indicated that the highest yield of fine fiber was obtained when P_2O_5 and K_2O were applied at the rate of 69 and 26 pounds per acre respectively. The application of N, P_2O_5 and K_2O at the rates of 11, 69 and 26 pounds per acre respectively gave the second highest yield. The application of P_2O_5 alone at the rate of 69 pounds per acre and the check gave the lowest yields. Records from application of a mixture containing 440 pounds of Nitrate of Soda, 440 pounds of Calcium phosphate, and 1320 pounds of copra cake gave the following results:

Rate of application of mixture Lbs. per acre	Yield in pounds per acre of coarse fiber	
	Treated	Untreated
356	482	438
515	253	175

In 1931, the Director of the Plant Industry Department of the Philippine Government stated that the application of a complete fertilizer at the rate of 17 pounds of nitrogen, 52 pounds of P_2O_5 and 27 pounds of K_2O per acre, gave a yield of 1,041 pounds of fiber as compared to 677 pounds of fiber per acre where no fertilizer had been applied.

In a publication issued by the Philippine Department of Agriculture and Commerce in 1939 (26), it was stated that abacá requires a mixture containing 4 per cent nitrogen, 8 per cent P_2O_5, and 12 per cent K_2O, applied at the rate of 534 to 712 pounds per acre.

In the Philippines, Sherman (38) conducted an experiment with abacá grown in nutrient solutions. He found that after growing the plants for six months, the plants that did not receive potassium lacked rigidity in the main stalk and in the leaf midribs. This lack of firmness of the plants receiving no potassium or too little potassium was thought to be one of the causes of the weak fiber. He stated that potassium, estimated as potassium oxide (K_2O) constitutes nearly 40 per cent of the mineral matter of the ash of abacá fiber.

Sherman (39) also found that the abacá grown for ten months in a solution deficient in potassium had the lowest tensile strength of all the group. Abacá grown in solution lacking magnesium but concentrated in potassium gave the highest tensile strenght of all the group.

Croucher and Mitchell (16) in experiments carried out with Gros Michel bananas in Jamaica stated that a continuous supply of nitrogen should be maintained throughout the life cycle of the plant. Their conclusions regarding potassium were as follows:

Soil test Lbs. K_2O per acre		Positive reaction to potash application
Below	300	Highly probable
Between	300-500	Probable
Between	500-600	Possible
Over	600	Improbable

The method of application of fertilizers used by these authors was to broadcast the fertilizer on the surface of the soil in the form of a circle around the "root". As the plants grew, this circle was increased to a maximum of approximately four feet.

Holmes (23) stated that a typical mixture of fertilizer used for bananas in the Canary Islands is one containing 10.3 per cent nitrogen, 3.4 per cent P_2O_5 and 14.4 per cent K_2O. According to the author an application of approximately 1/2 lb. of $NaNO_3$ per stool in February is given to plants that appear to be lacking vigorous vegetative growth after the winter months. The fertilizers are usually applied in two thirds of a circle of radius two to three feet around the sucker.

Baillon, et al (1) presented data in which they show that the potassium uptake by the banana plant is very high, as compared with moderate uptake of nitrogen and relatively little uptake of phosphorus. They stated that a fertilizer mixture considered only for the purpose of supply-ing the nutrients taken up by the plant and for replenishing the actual exhaustion of the soil by the plant should be moderate in nitrogen, low in phosphate and high in potash content.

Royer (35) presented data of fertilizer experiments carried on at the Good Hope plantation, Bataán, Costa Rica. Highly significant increases were obtained by the application of potassium. The N-K treatment gave significant increases while the application of phosphorus did not increase yields. In a replicate of this experiment, on a different soil, significant increases were obtained by the application of potassium, while the N-K treatment and responses to phosphorus were not significant. He recommends that the fertilizer should be applied in a ring around the mat and between 1 and 2 feet from the mat.

Bielich Nash (3) stated that probably the best zone for the application of fertilizers is between the 2nd and 3rd foot from the border of the mat; it seems to be in this area where the higher root absorption surface is found.

The soils of the Good Hope plantation as described by Robinson and Striker (30) have developed from recent alluvium deposited by the Barbilla and Madre de Dios rivers, and their tributaries. The Barbilla has deposited fine textured sediments especially in the low areas back from the natural stream levees. Dark calcareous sands containing shell fragments were found in many places occurring at depths ranging from 4 to 8 feet, indicating that the recent deposition is underlain by coastal plain sediments and beach deposits. The present surface deposit is derived from limestone, shale, granite and some volcanic material. It is slightly weathered, has alkaline to medium acid reaction and very little profile development. Many of the soils have developed under a rather high water table as indicated by conspicuous mottling of rusty brown iron and manganese staining at various depths, and by gray colors.

III. MATERIALS AND METHODS

Soil Sampling

Soil samples to survey the status of the available potassium were taken at the Good Hope plantation, Bataán, Costa Rica, during the second half of 1953 and in January and February of 1954. A soil map constructed by Robinson and Striker (30) was used to determine the sampling sites according to the different soil types and abacá productivity land classes. Two hundred and four sites were selected to cover the plantation throughly.

In order that sampling would be as representative as possible, irregularities due to mule paths, spoil banks of drainage canals, center of old mats, etc., were avoided. Samples were taken from the center of the intermat area to avoid the areas where fertilizers were normally applied. The samples were taken at depths of 0 to 6 and 12 to 18 inches, with a soil tube approximately 0.75 inch in diameter. Each sample was composited of ten borings. The samples were placed in plastic bags, labeled and taken to a laboratory for drying and analyzing. Soils were dried on paper sheets for 4 to 5 days until they were sufficiently dry to roll and pass through a 2 mm. sieve. They were air dried for 2 to 3 weeks and placed in bottles with appropriate labels.

A series of soil samples was also taken to determine the depth of penetration of potassium applied to the surface of the soil. The area selected for sampling had been treated with potassium application for 3 years at the rate of 500 lbs. K_2O per acre per year. Composite samples at several depths were taken from a circular area one foot from the mat where fertilizers had been applied. Another group was taken from the intermat area of the same plot where fertilizers had not been applied. Samples were obtained by taking a shovel slice approximately 1 inch thick. From each slice, a vertical section 1 inch wide a 6 inches deep (figure 1) was divided into depths of 0-1, 1-2, 2-3, and 4-6 inches. These were placed in separate bags according to depth and each complete sample was a composite of five such sections. These were prepared for analysis in the same manner as above. Therefore, for each plot sampled there were 5 depth samples from the area of fertilizer application and 5 depth samples from the intermat area where fertilizers had not been applied. Table 1 shows the section and experimental plot location, soil types, and fertilizer treatments of area and depths sampled for potassium analysis.

TABLE 1

Sections and Experimental Plot Location, Soil Type and Fertilizer Treatments of Area and Depths Sampled for Potassium Analysis

Section and Plot Nos.		Soil Type and Symbol	Treatment pounds/A/year	Area Sampled In Ring	Area Sampled Outside Ring
30	163	Manila Silt Loam 525*	500 K_2O	5 depths	5 depths
30	153	" " " 525	150 P_2O_5	5 "	5 "
27	263	Celina Silt Loam 535*	200 N 50 P_2O_5 250 K_2O 3000 $CaCO_3$	-	5 "
27	251	" " " 535	500 K_2O	-	5 "

* See explanation to symbols at the end of the Key to Soil Samples.

Profile samples from selected sites at Good Hope, Goschen and Monte Verde all in Costa Rica, were taken to determine the type of minerals that had been and were being deposited by the rivers of the relative nearby located areas. The samples were taken from a pit one meter in depth. Along one face of the pit a section of the profile 3 to 4 inches wide and about 3 to 4 inches thick was cut (figure 2). The soil from 0 to 50 cms. of this column composed one sample and that from 50 to 100 cms. composed the second sample. The mineralogical analyses were made by Dr. Cesar Dondoli, of the Ministerio de Agricultura e Industrias de Costa Rica.

Table 2 shows the location soil type and soil class of soil samples taken for the mineralogical analyses.

TABLE 2

Location, Soil Type and Soil Class of Soil Samples Taken for Mineralogical analyses

Area	Sect.	Soil Type	Soil Class	Nearest River
Good Hope	155	545B	I	Barbilla
Good Hope	111	525	III	Barbilla
Good Hope	215	545	I	San Miguel
Monte Verde	217	545	I	Pacuare
Goschen		545	I	Madre de Dios

Plant Sampling

Plant tissue samples to determine the effect of potassium fertilization upon the potassium content of the pseudo-stem and leaves were taken

FIG. 1 SAMPLING METHOD USED IN FERTILIZER PLOTS

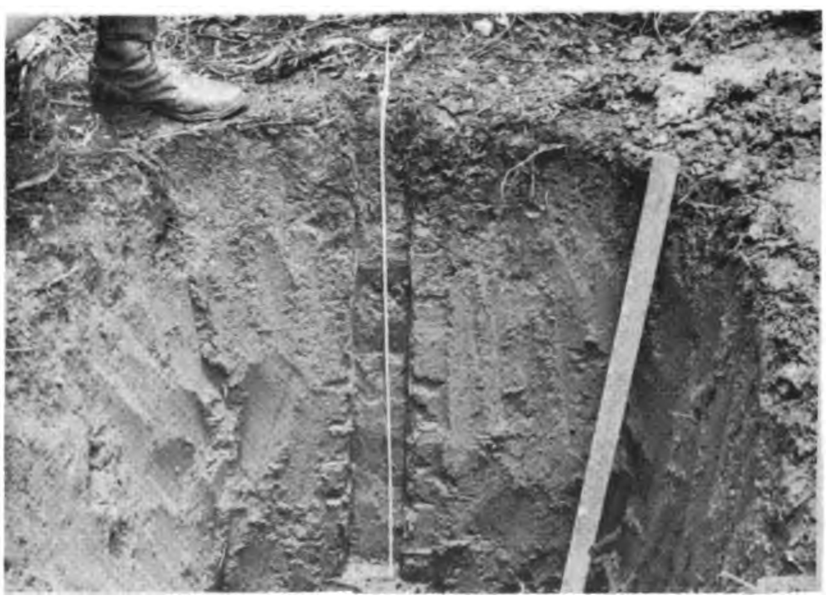


FIG. 2 PIT SAMPLING METHOD USED TO OBTAIN PROFILE SAMPLES FOR MINERALOGICAL ANALYSES

from the Good Hope experiment fertilizer plots, Bataán, Costa Rica. Samples were taken from plants fertilized with potassium and in various combinations with nitrogen and phosphorus.

Three plants 72 inches in height (± 5 inches) and three plants 120 inches in height (± 5 inches) were sampled from each treatment. The center 12 inches of the leaf blade of the third leaf from the top of each plant 72 inches in height were composited to form the leaf sample, as recommended by Drosdoff and Pearson (19). A composite stalk sample was made from the same three plants by taking a section approximately 5 inches long from the middle of the stalk. Likewise composite leaf and stalk samples were taken from three plants 120 inches in height from the same treatment and in the same manner as for the 72 inch plants. The samples were placed in paper bags and taken to the laboratory for drying and analyzing. The plant tissue samples were dried in a forced draft oven at 80° centigrade ground in a Wiley mill to pass the 20 mesh screen and placed in bottles with appropriate labels.

The location, soil type, soil class and treatments of the Good Hope fertilizer experiment plots which were sampled for plant tissue analyses are shown in table 3.

Methods of Analysis

Available potassium was determined by the cobaltinitrite method described by Bray (7). The procedure was as follows: 1 gram of air dried soil was shaken for one minute with 10 ml. of 22 per cent $NaNO_3$ extracting solution and filtered into a funnel tube using Whatman #1 filter paper. This

TABLE 3

Location, Soil Type, Soil Class, and Treatments of the Good Hope Fertilizer Experiment Plots Sampled for Plant Tissue Analyses

No.	Treatments N	P	K		Section 27 Plot No.	Soil Type	Soil Class	Section 30 Plot No.	Soil Type	Soil Class
1	0	0	0		6	535	II	1	525	III
2	2	2	2		3	"	"	14	"	"
3	2	2	1		22	"	"	8	"	"
4	2	2	0		11	"	"	28	"	"
5	2	1	2		25	"	"	25	"	"
6	2	0	2		12	"	"	6	"	"
7	1	2	2		30	"	"	22	"	"
8	0	2	2		15	"	"	5	"	"
9	1	2	2	esml*	17	"	"	24	"	"
10	0	1	2	esml*	8	"	"	19	"	"
11	0	0	0	esml*	28	"	"	9	"	"
12	0	0	1		20	"	"	17	"	"
13	0	0	2		21	"	"	23	"	"
14	0	1	0		14	"	"	29	"	"
15	0	2	0		29	"	"	12	"	"
16	1	0	0		19	"	"	30	"	"
17	2	0	0		23	"	"	20	"	"

* Es-Min-El, a by product mixture of essential minor elements manufactured by the Tennessee Corporation, applied at the rate of 337 pounds per acre per year.

The annual application rates in pounds per acre of the various treatment levels were as follows:

N_0 - 0 lbs N	P_0 - 0 lbs P_2O_5	K_0 - 0 lbs K_2O
N_1 - 50 lbs N	P_1 - 50 lbs P_2O_5	K_1 - 250 lbs K_2O
N_2 - 200 lbs N	P_2 - 150 lbs P_2O_5	K_2 - 500 lbs K_2O

filtrate was designated as solution "A". In separate tubes kept in a cooling pan at a temperature of 19.5°C ($\pm$ 1°C) a mixture was prepared by adding 7 drops (approximately 0.3 ml.) of sodium cobaltinitrite to 2ml. of Ethyl alcohol. This mixture was designated as solution "B".

Using a 2 ml. medical syringe, 2 ml. of solution "A" were injected into solution "B" so as to mix the two solutions instantaneously. After two minutes, the turbidity of the precipitate formed was read in the Cenco photolometer.

A curve covering the range 0-70 p.p.m. of K_2O was constructed using standard solutions made up in 22 per cent $NaNO_3$. The photolometer readings of unknowns were then referred tothis standard curve to obtain the concentrations in p.p.m. of K_2O, which were converted to pounds of K_2O per acre by multiplying the p.p.m. by 20

Soil pH was determined with the Beckman pH meter using a soil water ratio of 1:1. 5 ml. of distilled water were added to 5 grams of soil, stirred occasionally for 20 to 30 minutes and read in the pH meter.

Farm maps obtained from the Compañía Bananera de Costa Rica were used to construct the potassium fertility map. The results obtained in the analysis of the top soil samples (0 to 6 inches) were used in the construction of the map (see Key to Soil Samples and figure 13).

The plant tissue analyses were made by Dr. Robert Pearson, Alabama Polytechnic Institute, Auburn, Alabama.

IV. RESULTS

Mineralogical Analyses

The results of the mineralogical analyses of various profile samples taken at the Good Hope, Monte Verde and Goschen plantations are shown in table 4. It can be seen from the study of this table that the minerals present in the most abundance were plagioclases, pyroxenes and weathered grains of plagioclases and pyroxenes. The minerals present in least amount were quartz and iron oxides respectively. All these samples contained some micas, which are potassium bearing minerals, but they do not appear in the analysis due to the fact that they were washed out during the process of extracting the mineral content of the soil (18).

Farms 2 and 3 of the Good Hope plantations have received sediments from the Barbilla river. Farms 4 and 5 are subject to overflow and deposits from the San Miguel river. Samples were taken from sections 155 and 215 which have received recent sediments from the Barbilla and San Miguel rivers respectively. A sample was taken from section 111 which is low lying heavy soil and has received some heavier textured materials from the Barbilla river. Soil samples were also taken from Monte Verde section 217 near the Pacuare river and at Goschen, near the main tram between the Madre de Dios river and the Caño Azul.

The samples taken at Good Hope section 155 from a depth of 0-50 cms. had 86.95 per cent of the total mineral content composed of plagioclases,

TABLE 4

Mineral Content of Five Abacá Soils Taken from Good Hope, Monteverde and Goschen Plantations Bataán, Costa Rica, 1954

Sample No.	Depth Cms.	Mineral Content %	% Minerals Present in the Soil					Location and Nearest River
			Iron Oxides	Pyrox-enes	Plagio-clase	Weathered* Grains	Quartz	
1	0– 50	10.00	0.435	1.304	2.174	5.217	0.870	Good Hope Sect. 155 Barbilla River
2	50–100	25.25	1.993	6.645	5.980	6.645	3.986	" " "
3	0– 50	10.00	0.197	0.784	2.353	5.882	0.784	Goschen Madre de Dios River
4	50–100	5.00	0.139	0.278	1.388	2.778	0.417	" " "
5	0– 50	2.50	0.091	0.318	0.545	1.364	0.182	Monteverde Sect. 217 Pacuare River
6	50–100	1.25	0.040	0.078	0.273	0.781	0.078	" " "
7	0– 50	1.25	0.024	0.098	0.294	0.736	0.098	Good Hope Sect. 215 San Miguel River
8	50–100	5.00	0.278	0.834	1.528	2.082	0.278	" " "
9	0– 50	10.00	0.227	1.136	3.864	4.091	0.682	Good Hope Sect. 111 Barbilla River
10	50–100	25.00	1.088	3.260	7.607	10.870	2.175	" " "

* Weathered grains of pyroxenes and plagioclases.

pyroxenes and weathered grains of plagioclases, pyroxenes and 13.05 per cent composed of iron oxides and quartz. The samples taken from a depth of 50-100 cms. had 76.32 per cent of the mineral content composed of plagioclases, pyroxenes and weathered grains of plagioclases and pyroxenes, and 23.68 per cent of quartz and iron oxides. The description of the profile is as follows:

0- 4 inches:	Recent silt, low in O.M. Yellowish brown. Single grain structure.
4- 6 inches:	Dark colored material - Silt loam, original surface soil high in O.M.
6-12 inches:	Mottled grayish brown silty clay loam, nuttry structure.
12-24 inches:	Yellowish brown silty clay loam.
24-33 inches:	Yellowish brown silty loam.
33-40 inches:	Yellowish brown sand.

The samples taken at Good Hope section 215 from a depth of 0-50 cms. had a low mineral content of which 90.24 per cent was composed of plagioclases, pyroxenes and weathered grains of plagioclases and pyroxenes and 9.76 per cent composed of quartz and iron oxides. From a depth of 50-100 cms. this soil had 88.88 per cent of its mineral content composed of plagioclases, pyroxenes and weathered grains of plagioclases and pyroxenes and 11.12 per cent composed of quartz and iron oxides. The description of the profile is as follows:

0- 1 inches:	Dark brown silt loam with O.M.
1-12 inches:	Light brown silt loam.
12-18 inches:	Light brown silty clay loam mottled yellow-gray and brown; granular structure.
18-24 inches:	Brown silty clay loam slightly mottled with yellow and gray; granular structure.
24-28 inches:	Brown silt loam.
28-33 inches:	Brown fine sandy loam mottled yellow-brown and gray.
33-40 inches:	Brown sand with some yellow and gray mottling.

The sample taken at Good Hope section 111 from a depth of 0-50 cms. had a high mineral content of which 90.91 per cent was composed of plagioclases, pyroxenes and weathered grains of plagioclases and pyroxenes and 9.09 per cent was composed of quartz and iron oxides. From a depth from 50 to 100 cms. 86.95 per cent of the mineral content was composed of plagioclases, pyroxenes and weathered grains of plagioclases and pyroxenes and 13.05 per cent composed of quartz and iron oxides. The description of the profile is as follows:

0- 2 inches:	Dark brown silt loam, with organic matter.
2-10 inches:	Dark brown silty clay loam.
10-16 inches:	Grayish brown sandy loam.
16-25 inches:	Grayish clay loam with brown and yellow mottling.
25-33 inches:	Grayish fine sandy clay loam, with yellow mottling.
33-40 inches:	Gray sandy loam with yellow mottling.

The sample from Monte Verde section 217 to a depth of 0-50 cms. had 89.08 per cent of its mineral content composed of plagioclases, pyroxenes and weathered grains of plagioclases and pyroxenes, and 10.92 per cent composed of quartz and iron oxides. From 50 to 100 cms.,90.56 per cent of the mineral content was composed of plagioclases,pyroxenes and weathered grains of plagioclases and pyroxenes and 9.44 per cent of quartz and iron oxides. The description of the profile is as follows:

0- 1 inches:	Brown silt loam, O.M. in surface; blocky structure.
1-17 inches:	Yellow brown silt loam.
17-40 inches:	Silty clay loam, slightly mottled yellow-brown, blocky structure.

The sample taken at Goschen, near the main tram, between the

Madre de Dios river and the Caño Azul to a depth of 0-50 cms. had 90.19 per cent of the total mineral content composed of plagioclases, pyrox - enes and weathered grains of plagioclases and pyroxenes, and 9.81 per cent composed of quartz and iron oxides. The sample taken from a depth of 50-100 cms. had 88.88 per cent of the mineral content composed of plagioclases, pyroxenes and weathered grains of plagioclases and pyroxenes and 11.12 per cent composed of quartz. The description of the profile is as follows:

The first 1/4 inch is duff material.

0- 3 inches:	Dark silt loam high in O.M.
3-12 inches:	Yellowish silty clay loam. Blocky structure.
12-35 inches:	Yellowish fine sandy loam.
35-40 inches:	Silty clay, mottled yellow, gray and brown.

Soil Tests

The results of the soil tests are shown in the Key to Soil Samples. The available potassium of the Good Hope plantation ranged from 103 to 1177 pounds per acre in surface soil (0-6 inches) and from 87 to 564 pounds per acre in the subsoil (12-18 inches).

Available Potassium of the Different Soil Types.

Class I includes soils with medium texture as silt loam and fine sandy loam with a drainage profile No. 4 (30) which indicates perfect drainage conditions. Some soils with drainage profile No. 3, which is good but less desirable than No. 4, are included in this class because of the calcareous condition of their surface. The ranges in the available K_2O content and pH of these soils are shown in table 5.

TABLE 5

Available Potassium and pH of Different Soil Types
Classified in Productivity Class I
Good Hope Plantation, Bataán, Costa Rica

Soil Type	No. Samples taken		Available K_2O Lbs. per Acre									
	0-6"	12-18"	0-6"			12-18"			0-6"		12-18"	
			Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Min.	Max.
545	9	8	196	479	303	121	225	172	5.2	6.1	5.3	6.0
545B	3	1	332	889	548	-	-	560	7.4	7.5	7.4	7.4
545L	5	4	196	369	276	103	225	155	6.2	7.7	6.1	7.5
547	6	2	299	912	523	274	372	323	5.3	6.1	6.8	6.0
535L	12	9	165	564	304	112	196	152	6.0	7.7	6.1	7.1

Class II includes soils whose textures range from silty clay loam to very fine sandy loam in the surface and from silt loam to fine sandy loam in the subsoil, having a drainage profile No. 3, which is indication of moderately good drainage. The ranges in the available K_2O content and pH of these soils are shown in table 6.

TABLE 6

Available Potassium and pH of Different Soil Types
Classified in Productivity Class II
Good Hope Plantation, Bataán, Costa Rica

Soil Type	No. Samples taken		Available K_2O Lbs. per Acre						pH			
	0-6"	12-18"	0-6"			12-18"			0-6"		12-18"	
			Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Min.	Max.
535	30	20	103	1085	274	87	190	131	5.3	6.2	5.3	6.2
537	12	8	125	628	296	94	208	145	5.3	6.1	5.0	6.3
235	1	-	-	-	409	-	-	-	5.8	5.8	-	-
537B	2	1	352	515	434	-	-	232	6.6	6.9	7.5	7.5

Heavier textured soils having a No. 2 drainage profile, which is indication of imperfect natural drainage are included in Class III. Some soils with silt loam to sandy loam textures and drainage profiles Nos. 3 and 4 are included in this class due to the fact that they are underlain with sand or gravel, making conditions somewhat adverse to the growth of abacá. Table 7 shows the ranges of the available K_2O content and pH of these soils.

Class IV includes those soils with fine texture such as silty clay loam and silty clay with drainage profile Nos.1 and 2 which indicates poor internal drainage. These soils are very slowly permeable to water and air and have a high watertable throughout much of the year. Soils having silty clay loam, silt loam, fine sandy loam and sandy loam texture with a drainage

TABLE 7

Available Potassium and pH of Different Soil Types
Classified in Productivity Class III
Good Hope Plantation, Bataán, Costa Rica

Soil Type	No. Samples taken		Available K_2O Lbs. per Acre						pH			
			0-6"			12-18"			0-6"		12-18"	
	0-6"	12-18"	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Min.	Max.
222	9	7	145	619	361	112	222	165	5.6	6.4	5.8	6.3
727L	1	-	-	-	280	1	1	1	7.7	7.7	-	-
527	9	7	145	296	193	121	211	145	5.7	5.9	5.9	6.4
525	60	44	151	1177	305	94	241	146	5.0	7.5	4.6	7.7
525L	12	7	160	635	375	125	212	158	6.1	7.4	6.1	7.1
225	14	11	178	1027	338	103	211	157	5.4	6.0	5.2	6.1
2227	1	1	-	-	302	-	-	215	5.7	5.7	6.0	6.0
522	1	1	-	-	219	-	-	190	5.4	5.4	5.6	5.6
547/S	2	1	187	201	194	-	-	145	5.8	6.4	5.8	5.8
548/G	2	1	121	174	148	-	-	145	5.8	5.9	5.9	5.9

profile No. 1, which indicates very poor internal drainage, and those underlain by gravel are also included in this class. The ranges in the available K_2O content and pH are shown in table 8.

TABLE 8

Available Potassium and pH of Different Soil Types
Classified in Productivity Class IV
Good Hope Plantation, Bataán, Costa Rica

Soil Type	No. Samples taken		Available K_2O Lbs. per Acre						pH			
	0-6"	12-18"	0-6"			12-18"			0-6"		12-18"	
			Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Min.	Max.
221	7	3	300	947	483	130	270	177	5.8	6.1	5.5	6.0
215	1	1	-	-	216	-	-	169	6.0	6.0	6.2	6.2
65G	2	-	414	469	442	-	-	-	5.8	5.8	-	-
73G	1	1	-	-	138	-	-	138	5.9	5.9	6.2	6.2

No correlation was found between yields and available potassium in the soil at a depth of 0-6 inches but a significant positive correlation was found between pH and available potassium in the soil at a depth of 0-6 inches. The correlation coefficients found by statistical analysis were as follows:

Factors correlated	r value
Available potassium x yields	.104
Available potassium x pH	.172*

* Significant at the 5% level.

The results of the analyses of samples taken from the fertilizer plots are shown in table 9. The results show that the application of 500 pounds of K_2O per acre per year, increased considerably the available potassium content in the zone of application of the fertilizer (1 foot from the mat) as compared with the plot where no potassium was applied (figure 3). The available potassium in the intermat area was also higher in the plot that received the potassium treatment than in the unfertilized plot. The downward movement of potassium in the soil over a period of about 3 years, was rather slow as can be seen by the potassium content at different depths (figure 3). At a depth of 1 inch, in the samples taken 1 foot from the mat, the potassium content of the fertilized plot was two times as great as that in the second inch and was almost six times as great as that of the 3-6 inch depth. This shows that the movement was effective only to a depth of 3 to 4 inches. A similar decreasing relationship can be observed in the intermat area of the fertilized plot. In the plot where potassium was not applied (0-2-0 treatment) the available potassium was much lower than in the fertilizer plot, but it also can be seen that the amount of available potassium in the soil varied inversely with depth, and that the higher amount of available potassium was found in the first 3 inches. The pH was lower in the area 1 foot from the mat than in the intermat area, this being the case in both the potassium fertilized and unfertilized plot. Table 9 also shows that the available potassium from samples taken in the intermat area of fertilized plots was higher in the plot that received 3000 pounds of lime than in the plot where lime was not applied (figure 4). This is true for the first 3 inches in depth, but from 3 to 6 inches the available potassium was higher in the unlimed plot. The lime was effective in changing the pH of the soil only in the surface 3 inches over a period of 3 years (figure 5).

Leaf Analyses

The potassium content of stalk and leaves of abaca suckers grown in sand solution cultures are shown in table 10.

The potassium content in the leaves of the plants that received the complete solution ranged from 4.33 per cent in the younger (1st) leaf to 2.30 in the older (6th and 7th composited) leaves; the potassium content in the stalk of the plants that received the complete solution was 5.62 per cent; the potassium content in the leaves of plants that received only water was 2.70 per cent and that of the stalk 1.90 per cent.

TABLE 9

Location, Description, Available K_2O and pH of Soil Samples, from Fertilizer Plots
Good Hope Plantation, Bataán, Costa Rica

Sample No.	Section No.	Plot No.	Depth Inches	Location of Sample in Plot	pH	ppm K O in Soil	Fertilizer* Treatment N - P - K - Ca
409	30	163	0-1	1 foot from mat	5.7	4828	0 - 0 -500- 0
410	30	163	1-2	"	5.5	2274	" " " "
411	30	163	2-3	"	5.3	1329	" " " "
412	30	163	3-4	"	5.5	1085	" " " "
413	30	163	4-6	"	5.5	864	" " " "
414	30	163	0-1	Intermat area	6.2	1282	" " " "
415	30	163	1-2	"	6.1	845	" " " "
416	30	163	2-3	"	6.1	603	" " " "
417	30	163	3-4	"	6.2	333	" " " "
418	30	163	4-6	"	6.2	190	" " " "
419	30	152	0-1	1 foot from mat	5.8	777	0-150 - 0 - 0
420	30	152	1-2	"	5.9	590	" " " "
421	30	152	2-3	"	5.9	432	" " " "
422	30	152	3-4	"	5.9	325	" " " "
423	30	152	4-6	"	5.9	143	" " " "
424	30	152	0-1	Intermat area	6.2	402	" " " "
425	30	152	1-2	"	6.1	325	" " " "
426	30	152	2-3	"	5.9	227	" " " "
427	30	152	3-4	"	5.9	157	" " " "
428	30	152	4-6	"	6.0	120	" " " "
429	27	263	0-1	Intermat area	7.5	1274	200- 50 -250-3000
430	27	263	1-2	"	7.3	649	" " " "
431	27	263	2-3	"	7.1	260	" " " "
432	27	263	3-4	"	6.6	104	" " " "
433	27	263	4-6	"	6.1	89	" " " "
434	27	251	0-1	"	6.1	266	0 - 0 -500- 0
435	27	251	1-2	"	6.1	172	" " " "
436	27	251	2-3	"	5.9	147	" " " "
437	27	251	3-4	"	5.9	145	" " " "
438	27	251	4-6	"	5.8	98	" " " "

* Treatments in pounds of nitrogen, P_2O_5, K_2O and $CaCO_3$. No fertilizer was applied in the intermat area.

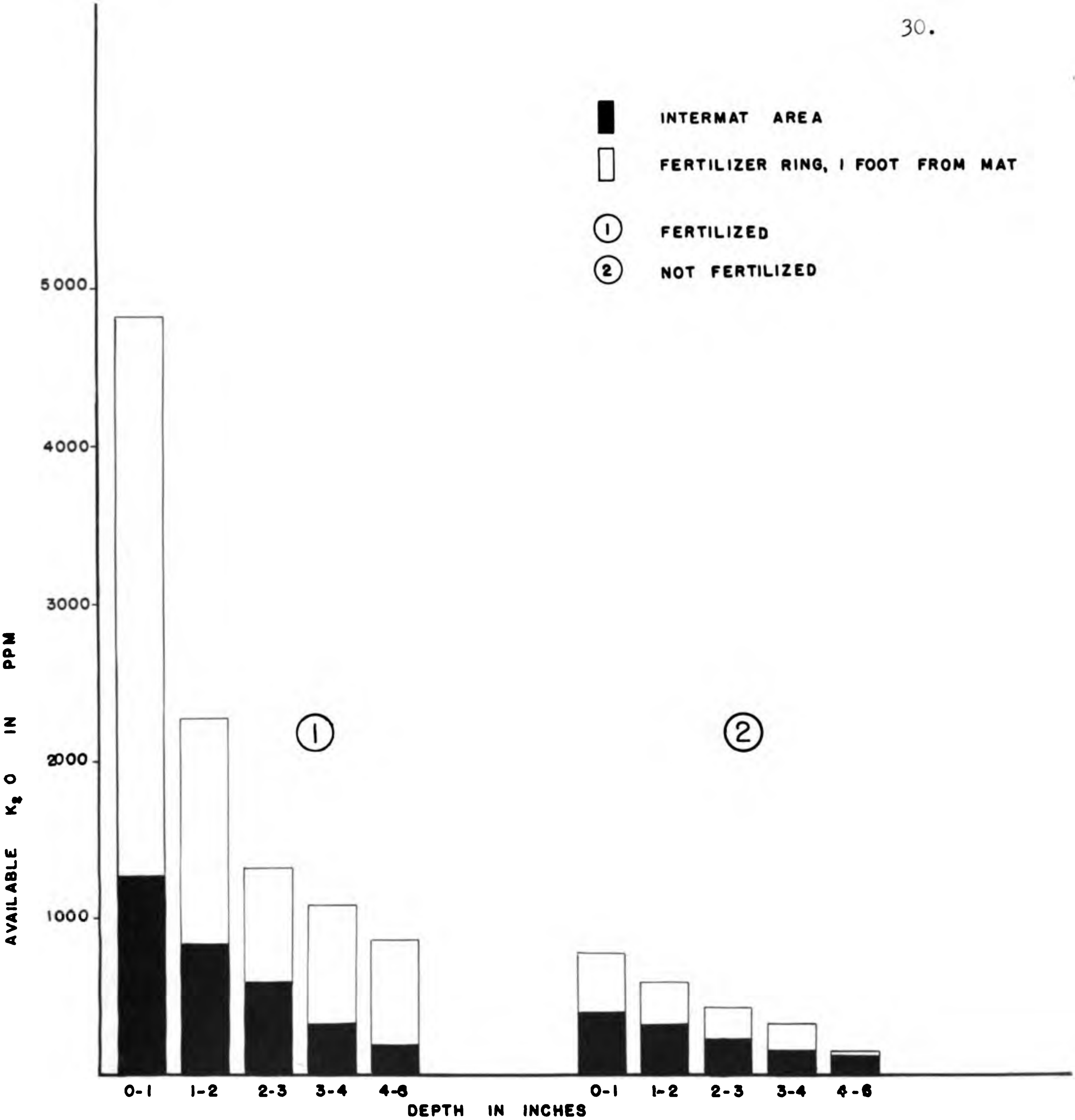


FIG. 3 AVAILABLE POTASSIUM AT VARIOUS SOIL DEPTHS IN THE ZONE OF POTASIUM FERTILIZER APPLICATION AND INTERMAT AREA

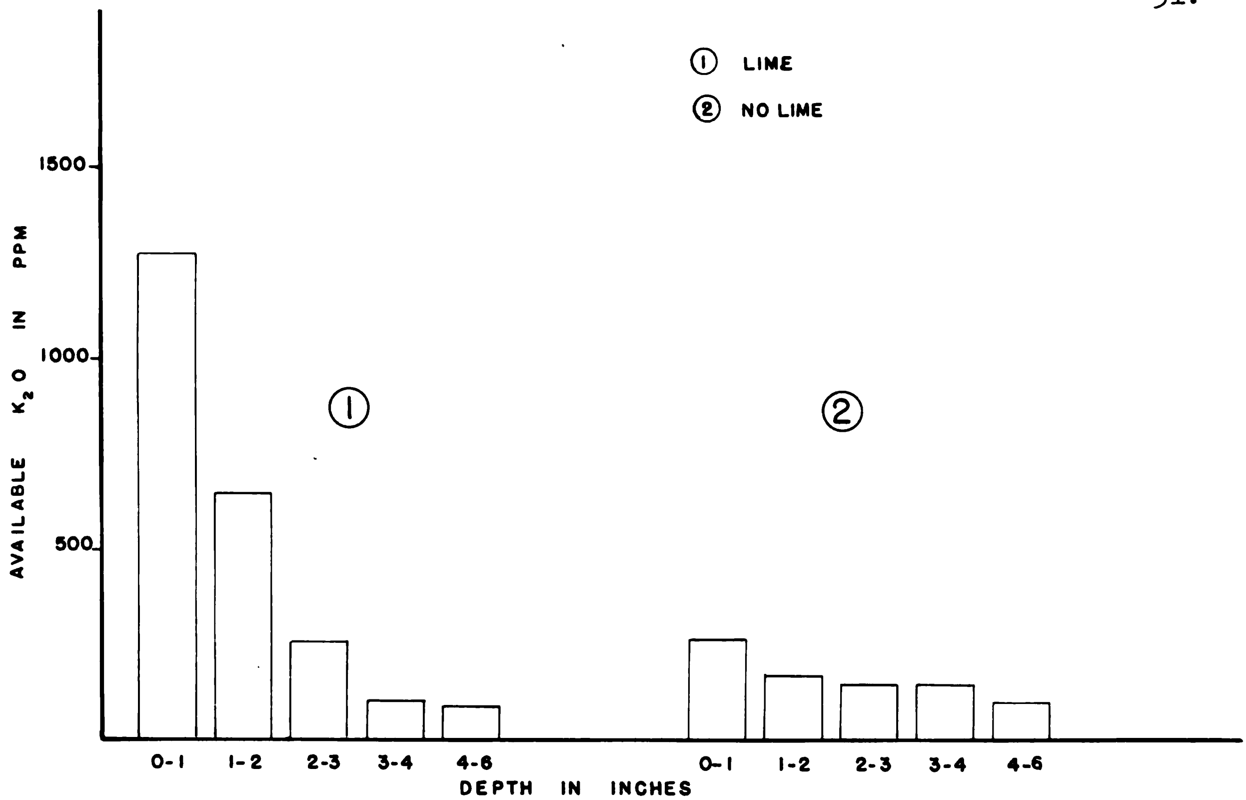


FIG. 4 EFFECT OF LIME UPON THE AVAILABLE SOIL POTASSIUM AT VARIOUS SOIL DEPTHS AFTER A PERIOD OF THREE YEARS

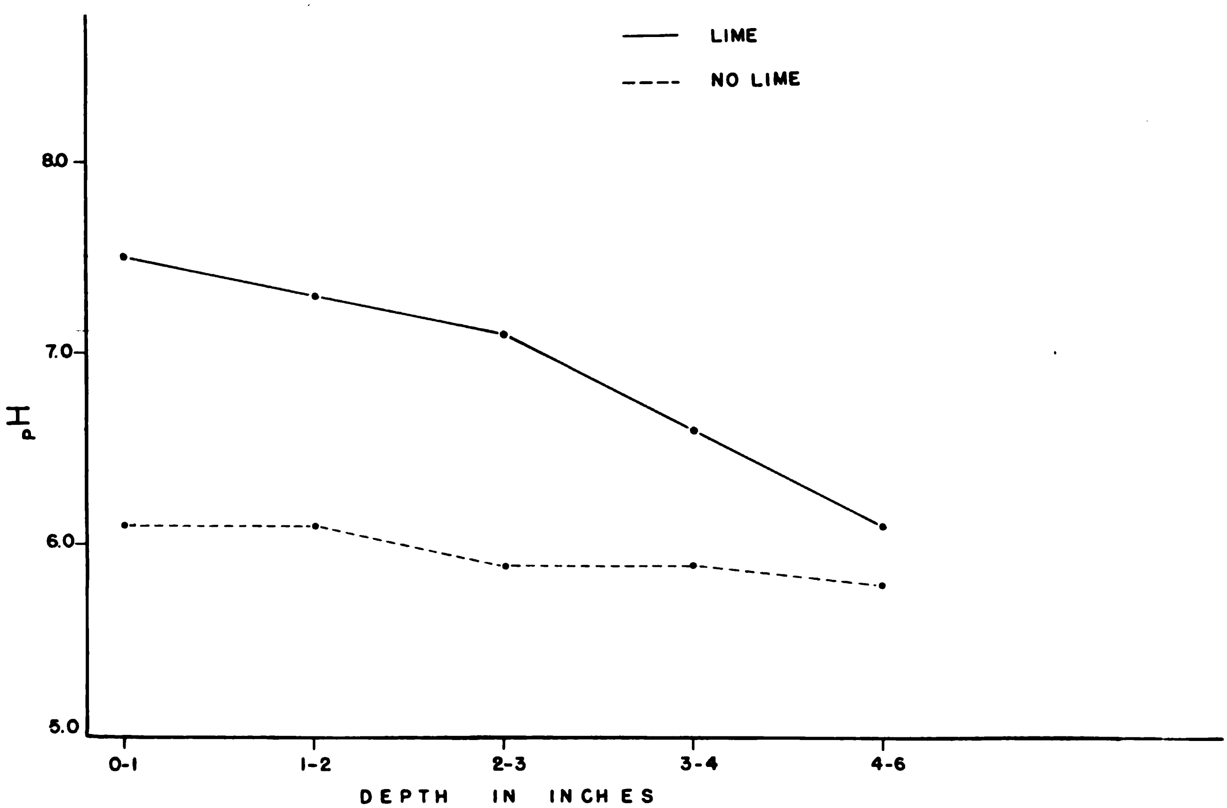


FIG. 5 EFFECT OF LIME UPON pH AT VARIOUS SOIL DEPTHS AFTER A PERIOD OF THREE YEARS

Effect of Nutrient Deficiencies on the Potassium Content of Abacá Plants

Potassium Deficiency.

The plants deficient in potassium showed the lowest potassium content of all the plants grown in solution cultures. The potassium content decreased as the deficiency increased and the leaves grew older. The younger (1st) leaf showed a potassium content of 2.95 per cent while the 4th leaf showed a low 0.65 per cent. The 5th, 6th and 7th leaves composited were somewhat higher than the 4th leaf. The potassium content of the stalk was 1.68 per cent.

Nitrogen Deficiency.

The potassium content of the nitrogen deficient leaves was higher than that of the leaves of similar age from healthy plants grown under the same conditions. These results seem to be in agreement with results obtained by Chapman and Brown (11) in orange leaves. The potassium content of the stalk was lower in the nitrogen deficient plants than in the stalk of healthy plants.

Phosphorus Deficiency.

The potassium content of the phosphorus deficient leaves was markedly higher than that of the leaves of similar age from healthy plants grown under the same conditions. Similar results were obtained by Chapman and Brown (11), (12) in orange leaves. The potassium content of the stalk was also much higher in the phosphorus deficient plants than in the stalk of healthy plants.

Calcium Deficiency.

The potassium content of the 1st, 2nd, 4th and 5th leaves of the calcium deficient plants was lower than the corresponding leaves of normal healthy plants, but there was a slight increase in potassium content of the 3rd leaf of the calcium deficient plants over the 3rd leaf of healthy plants. The potassium content of the stalk of the calcium deficient plants was considerably lower than that of the stalk of healthy plants.

Magnesium Deficiency.

The potassium content of the magnesium deficient leaves was higher than that of the leaves of similar age from healthy plants grown under similar conditions. The potassium content of the stalk of magnesium deficient plants was also higher than that of the stalk of healthy plants. Boynton and Comptom (6) found that in apple orchards showing magnesium deficiency the leaf potassium tends to be abnormally high.

Sulfur Deficiency.

The potassium content of young leaves of sulfur deficient plants (1st and 2nd leaves) was higher than that of the leaves of approximately the same age of healthy plants grown under similar conditions. The potassium content was somewhat lower in the older leaves (3rd and 4th + 5th + 6th leaves composited) of the sulfur deficient plants than in the corresponding leaves of healthy plants. The potassium content of the stalk of the sulfur deficient plant was abnormally higher than that of the stalk of healthy plants grown under similar conditions. The findings of Chapman and Brown (13) showed that the potassium in young leaves of orange trees deficient in sulfur was abnormally high as compared with healthy young leaves, but there was no difference in the potassium content of old leaves of sulfur deficient and healthy trees.

By studying table 10 and figure 6, it can be seen that the potassium content of the leaves of healthy plants, and the leaves of plants deficient in phosphorus and sulfur, decreased with the age of the leaves, that is, the potassium was higher in the younger leaves than in older leaves.

In the case of the nitrogen deficient plants the potassium content of the younger leaf (1st leaf) was highest, but that of the older leaves (6th + 7th) was second highest in potassium content.

In the case of the potassium deficient plants the potassium content of the 4th leaf was slightly lower than older leaves (5th and 6th + 7th leaves composited). The 3rd leaf in the calcium deficient plants was higher in potassium than the 2nd leaf, but was lower than the 1st leaf. In the case of the magnesium deficient plants the 4th leaf was slightly higher than the 2nd and 3rd leaves which are younger, but was lower than the younger (1st) leaf.

Effect of Fertilization on the Potassium Content of Abacá Stalk and Leaves

The results of chemical analyses of abacá tissue samples in table 11 show the effects of applying potassium, phosphorus and nitrogen fertilizers alone and in various combinations. The potassium content in the stalk of the 72-inch plants ranged from 1.80 to 5.50 per cent and that in the 120-inch plant ranged from 0.55 to 2.90 per cent. The potassium content in the

TABLE 10

Potassium Content on Stalk and Leaves of Abaca Suckers
Grown in Sand Solution Cultures
(Percentage Potassium Expressed on Dry Weight Basis)
Inter-American Institute of Agricultural Sciences
Turrialba, Costa Rica

Leaf No.	TREATMENT							
	All	-N	-P	-K	-Ca	-Mg	-S	Water Only
	PERCENTAGE POTASSIUM							
1	4.33	5.37	5.27	2.95	3.73	4.60	5.50	
2	3.68	4.60	4.68	1.60	3.45	4.05	4.28	
3	3.55	4.15	4.68	1.10	3.68	4.05	3.40	2.70**
4	3.50	3.78	4.55	.65	2.68	4.10		
5	2.95	3.75	4.48	.73	2.90	4.03	2.65*	
6 + 7	2.30	4.63	4.28	.78	2.95	3.55		
Stalk	5.62	4.40	7.75	1.68	3.30	7.50	9.25	1.90

* Sample composited of the 4th, 5th and 6th leaves.
** Sample composited of all leaves.

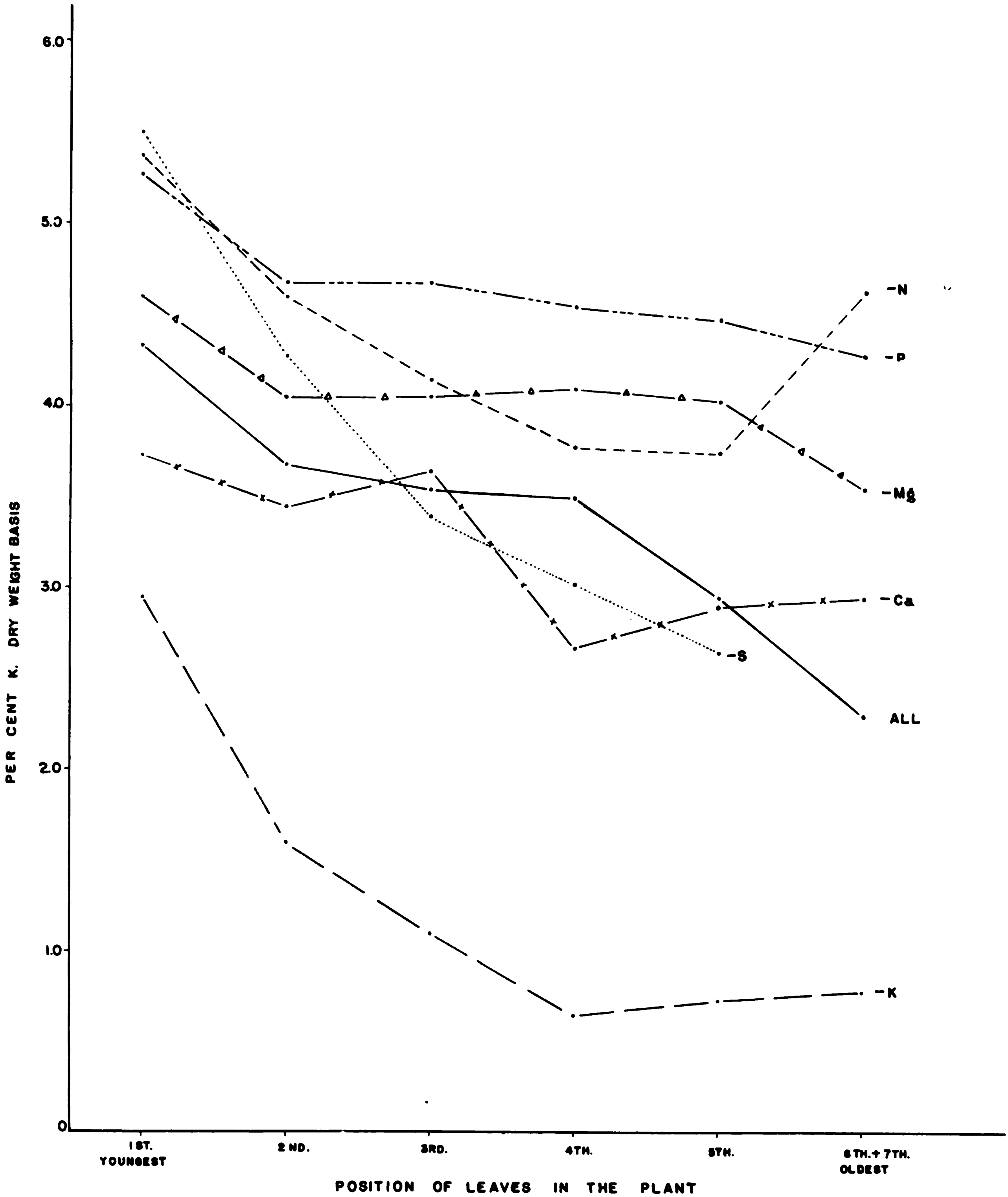


FIG. 6 EFFECT OF NUTRIENT DEFICIENCIES ON THE POTASSIUM CONTENT OF LEAVES OF ABACA PLANTS GROWN IN SAND SOLUTION CULTURES

leaves of the 72-inch plants ranged from 2.05 to 3.90 per cent. Figures 7 to 12 show that in all cases, the stalk and leaves of the 72-inch plants have a higher potassium content than those of the 120-inch plants. It can be seen from the study of these figures that the potassium content of the stalks is usually higher than that of the leaves and the fluctuations brought about by treatments are also higher in the stalk than in the leaves.

These figures also show that the stalk of plants that received nitrogen, phosphorus or potassium alone were lower in potassium content than those which received full treatment. This was also the case of the leaves of plants receiving nitrogen. The leaves of the 72-inch plants which received phosphorus alone had a higher potassium content than those receiving the full treatment (N+P+K) but those of the 120-inch plants showed practically no difference with the two treatments. The leaves of plants that received potassium alone had a higher potassium content in both the 72-inch and the 120-inch plants than those that received the full treatment(N+P+K).

Effect of Potassium Alone.

The effect of potassium alone on the potassium content of abacá stalk and leaves is shown in figures 7 and 8.

The application of potassium at the K_1 level decreased the potassium content of the stalk of the 72-inch and 120-inch plants, slightly decreased the potassium content of the leaves of the 120-inch plants but did not affect the potassium content in the leaves of the 72-inch plants. The K_2 level produced an increase over the K_1 level in the potassium content in the stalk of the 72-inch and 120-inch plants, and in the leaves of both the 72-inch and 120-inch plants. These changes were much more pronounced in the stalk than in the leaves.

Effect of Potassium in the Presence of Nitrogen and Phosphorus.

The effect of potassium in the presence of nitrogen and phosphorus on the potassium content of abacá stalk and leaves is shown in figures 7 and 8.

The application of potassium at the K_1 level in the presence of nitrogen and phosphorus decreased the potassium content of the stalk and leaves of all plants. The K_2 level increased the potassium content of stalk and leaves of all plants, over the K_1 level. These changes were more pronounced in the leaves than in the stalk.

Effect of Phosphorus Alone.

The effect of phosphorus on the potassium content of abacá stalk and leaves is shown in figures 9 and 10. The application of phosphorus at the P_1 level decreased the potassium content in the stalk of both the 72 - and 120 inch plants. It increased the potassium content in the leaves of the 72-inch plants but decreased it in the leaves of the 120-inch plants. The application of phosphorus at the P_2 level produced an increase on the potassium content of the stalk of the 72-inch plants and also increased, although to a less extent, that in the leaves of the 72-inch plants, over the P_1 level. The P_2 level decreased the potassium content in the stalk of the 120-inch plants from the P1 level but practically did not affect the potassium content in the leaves of the 120-inch plants.

Effect of Phosphorus in the Presence of Nitrogen and Potassium.

The effect of phosphorus in the presence of nitrogen and potassium on the potassium content of abacá stalk and leaves is shown in figures 9 and 10.

The application of phosphorus at the P1 level in the presence of nitrogen and potassium produced a decrease on the potassium content of the stalk of the 72-inch and 120-inch plants, but the P_2 level increased the potassium content of the same plants over the P_1 level although not to the level where no nutrients had been applied. In the leaves of the 72-inch plants the P_1 level decreased the potassium content slightly and the P_2 level did not have a significant effect over the P_1 level. In the 120-inch plants the P_1 level decreased the potassium content of the leaves, but the potassium content was not decreased by the P_2 level.

Effect of Nitrogen Alone.

The effect of nitrogen on the potassium content of abacá stalk and leaves is shown in figures 11 and 12. The application of nitrogen at the N_1 level decreased the potassium content of both stalk and leaves of the 72-inch plant. The decrease was considerable in the stalk while that in the leaves was very slight. The stalk and leaves of the 120-inch plants behaved similarly in that the N_1 level, decreased the potassium content in both of them, but the decrease was greater in the stalk than in the leaves. The N_2 level increased the potassium content of the stalk and leaves of the 72-inch plants over the N_1 level but again the increase was greater in the stalk.

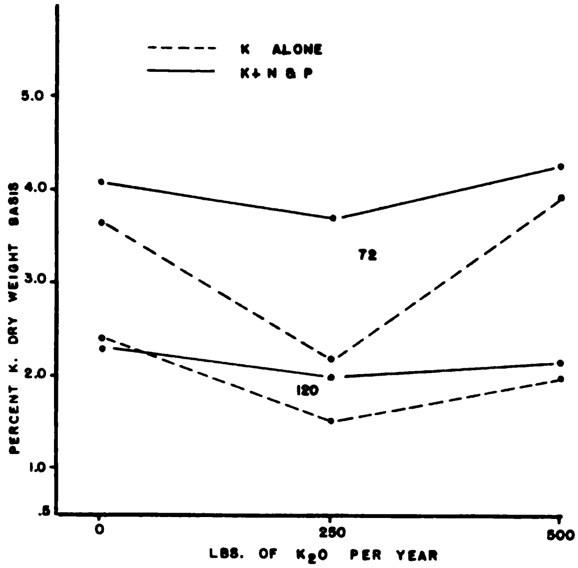


FIG. 7 EFFECT OF FERTILIZER POTASSIUM ON K. CONTENT OF ABACA STALK

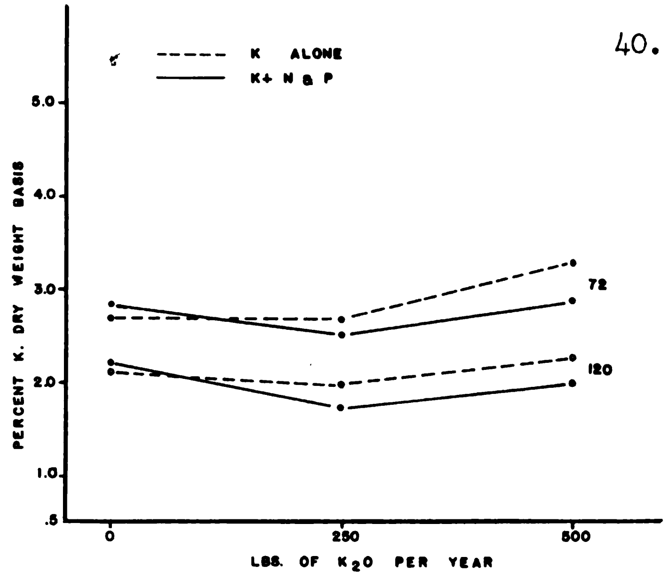


FIG. 8 EFFECT OF FERTILIZER POTASSIUM ON K. CONTENT OF ABACA LEAVES

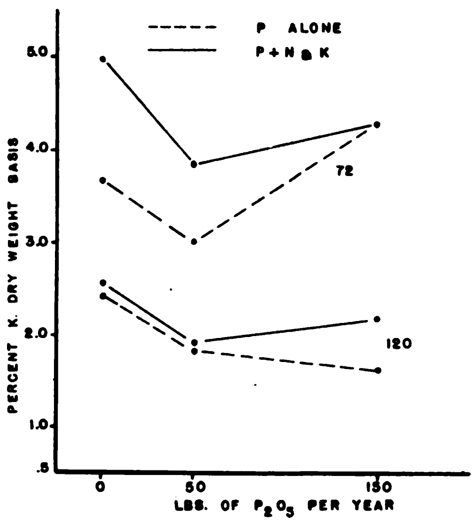


FIG. 9 EFFECT OF FERTILIZER PHOSPHORUS ON K CONTENT OF ABACA STALK

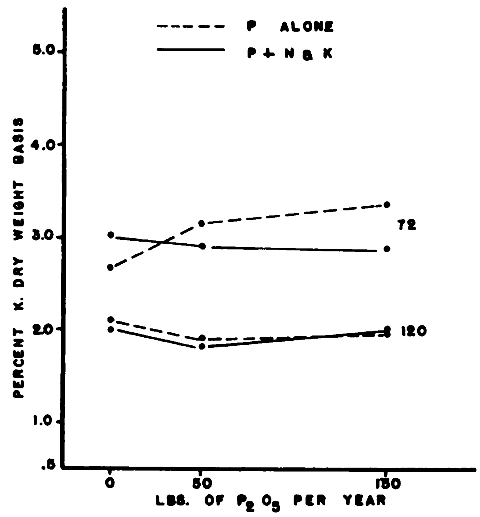


FIG. 10 EFFECT OF FERTILIZER PHOSPHORUS ON K CONTENT OF ABACA LEAVES

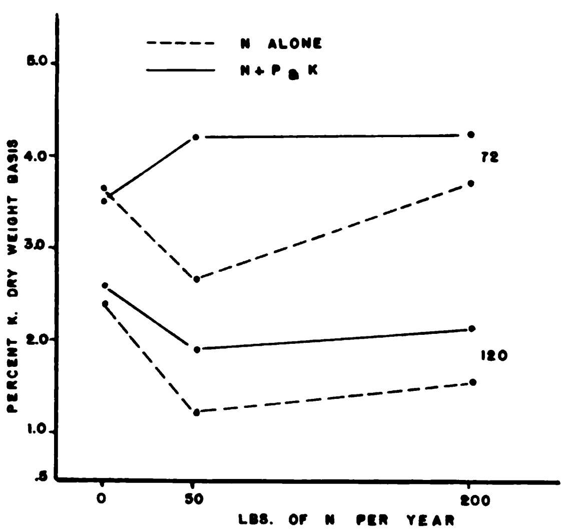


FIG. 11 EFFECT OF FERTILIZER NITROGEN ON K. CONTENT OF ABACA STALK

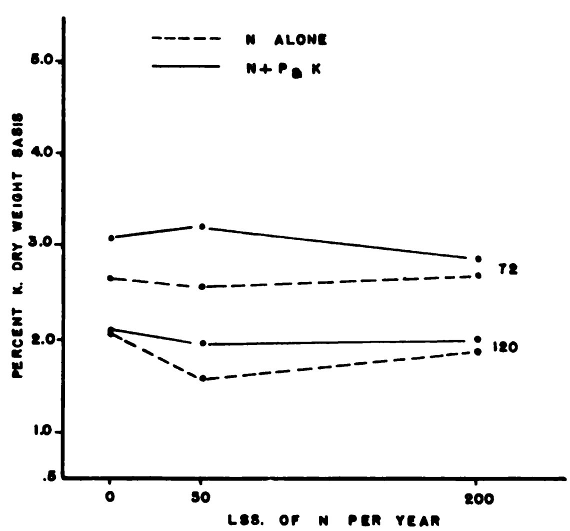


FIG. 12 EFFECT OF FERTILIZER NITROGEN ON K. CONTENT OF ABACA LEAVES

Effect of Nitrogen in the Presence of Phosphorus and Potassium

The effect of nitrogen in the presence of phosphorus and potassium on the potassium content of abacá stalk and leaves is shown in figures 11 and 12. The potassium content of the stalk and leaves of the 72 inch plants increased with the N_1 level, and as in the case of nitrogen alone, the change was greater in the stalk than in the leaves.

The N_2 level did not increase the potassium content of the stalk over the N_1 level but decreased that of the leaves. In the stalk and leaves of 120-inch plants the N_1 level decreased the potassium content, more so in the stalk than in the leaves but the N_2 level increased the potassium content of the stalk and slightly increased that of the leaves.

Effect of Lime on Potassium Content of Abacá Stalk and Leaves.

The treatment receiving 1000 pounds of $CaCO_3$ and $N_2P_1K_1$, resulted in a potassium content in the stalk of the 72-inch plants of 3.05 per cent and 1.45 per cent in the stalk of the 120-inch plants. The potassium content in the leaves of the 72-inch plants was 2.05 per cent and that of the 120-inch plants 1.80 per cent. The potassium content of the stalk and leaves of the 72-inch plants increased from 3.05 per cent and 2.05 per cent in the 1000 pound treatment to 4.33 and 2.30 per cent respectively in the 2000 pound application, and the stalk and leaves of the 120-inch plants from the same treatments increased from 1.45 and 1.80 per cent to 2.20 and 1.95 per cent respectively. There were practically no difference in the potassium content of the stalk of the 72-inch plants receiving 3000 pounds of $CaCO_3$ as compared to the same sized plants of the 1000 pound application. However, that of the leaves increased from 2.05

(Ca_1 level) to 2.20 per cent, but was lower than the Ca_2 level. The potassium content in the stalk of the 120-inch plants of the Ca_3 level did not change in relation to the Ca_1 level, but was lower than the Ca_2 level by 1.25 per cent. Also, the potassium content of the leaves of the Ca_3 level was lower than both the Ca_1 and Ca_2 levels by 0.12 and 0.27 per cent respectively (table 11).

Effect of Essential Minor Elements on Potassium Content of Abaca Stalk and Leaves.

The stalk of the 72 and 120-inch plants which received no fertilizer treatment ($N_0P_0K_0$) showed a potassium content of 3.67 and 2.42 per cent respectively as compared with 3.52 and 1.53 per cent respectively when es-min-el was applied. The leaves of the 72-inch plants with no fertilizers applied showed a potassium content of 2.67 per cent as compared to a higher potassium content of the Es-Min-El treatment which was 2.88 per cent. The leaves of the 120-inch plants with no treatment had a potassium content of 2.10 per cent as compared with 1.86 per cent with es-min-el treatment. The potassium content in the stalk of the 72 and 120-inch plants which received the $N_1P_2K_2$ treatment was higher (4.22 and 1.92 per cent respectively) than that of the plants that received the same treatment plus es-min-el (3.89 and 1.87 per cent respectively). The potassium content in the leaves of the 72-inch plants which did not receive es-min-el was slightly higher than those which received es-min-el (3.22 versus 3.18 per cent) but the potassium content in the leaves of the 120-inch plants which did not receive es-min-el was lower than those which received es-min-el (1.95 versus 2.15 per cent)(table 11).

TABLE 11. Potassium Content of Abaca Stalk and Leaves from Fertilizer Plots
Good Hope Plantation, Bataán, Costa Rica

TREATMENT	% K (dry weight basis)												Yield of Green Peeled Stalk
	Stalk						Leaves						
N-P-K-Ca	Plants 72" in height			Plants 120" in height			Plants 72" in height			Plants 120" in height			
	Sec.30	Sec.27	Ave.	Sec.30	Sec.27	Ave.	Sec.30	Sec.27	Ave.	Sec.30	Sec.27	Ave.	
0 0 0	3.95	3.40	3.67	1.95	2.90	2.42	3.20	2.15	2.67	2.15	2.05	2.10	49712
2 2 2	4.38	4.15	4.26	1.85	2.45	2.15	3.22	2.55	2.88	2.10	1.90	2.00	66218
2 2 1	4.47	2.90	3.70	2.00	2.00	2.00	2.95	2.05	2.50	1.73	1.70	1.71	60722
2 2 0	4.64	3.55	4.09	2.60	2.05	2.32	2.97	2.70	2.83	2.50	1.90	2.20	38348
2 1 2	4.27	3.35	3.81	2.65	1.15	1.90	2.90	2.95	2.92	2.35	1.30	1.82	65756
2 0 2	5.50	4.48	4.99	2.70	2.40	2.55	3.10	3.05	3.07	2.30	1.73	2.01	69294
1 2 2	3.83	4.60	4.22	2.05	1.80	1.92	3.10	3.35	3.22	2.45	1.45	1.95	52762
0 2 2	4.23	2.85	3.54	2.80	2.45	2.62	3.30	2.90	3.10	2.50	1.75	2.12	67206
1 2 2 Es-Min-El*	4.10	3.68	3.89	2.00	1.75	1.87	2.95	3.40	3.18	2.50	1.80	2.15	54496
0 1 2 Es-Min-El*	4.80	3.45	4.12	2.00	2.70	2.35	3.45	2.85	3.15	2.40	1.80	2.10	57590
0 0 0 Es-Min-El*	3.94	3.10	3.52	1.97	1.10	1.53	3.12	2.65	2.88	2.20	1.52	1.86	43582
0 0 1	3.56	1.80	2.68	2.12	0.95	1.53	3.20	2.15	2.67	2.65	1.29	1.97	47668
0 0 2	4.77	3.10	3.93	2.55	1.40	1.97	3.64	2.90	3.27	2.85	1.68	2.26	55298
0 1 0	3.83	3.15	3.49	2.70	0.95	1.82	3.10	3.20	3.15	2.45	1.35	1.90	42824
0 2 0	4.15	4.40	4.27	2.15	1.05	1.60	3.90	2.80	3.35	2.35	1.60	1.97	45918
1 0 0	3.73	2.65	3.19	1.95	0.55	1.25	3.10	2.05	2.57	2.10	1.05	1.57	50964
2 0 0	3.83	3.65	3.74	2.05	1.10	1.57	3.30	2.10	2.70	2.30	1.45	1.87	43764
2 1 1 +Ca_1**		3.05			1.45			2.05			1.80		54908
2 1 1 +Ca_2**		4.33			2.20			2.30			1.95		40452
2 1 1 +Ca_3**		3.00			1.45			2.20			1.68		65376

* Essential minor elements applied at the rate of 337 pounds per acre per year.
** Ca_1 - 1000 lbs. $CaCO_3$. Ca_2 - 2000 lbs. $CaCO_3$. Ca_3 - 3000 lbs. $CaCO_3$ per acre.
*** Average of treatments from Sec. 30 and 27. Section 30 includes Harvests 5-13 and Section 27 includes Harvests 5-11.

V. DISCUSSION

Mineralogical Analyses

As indicated by the mineralogical analyses, the soils of the Good Hope plantation that have received sediments from the Barbilla river had the highest mineral content of all the samples studied (table 4). The soils receiving the sediments from the San Miguel river, a tributary of the Barbilla river, had a much lower mineral content than those receiving sediments from the Barbilla. From the mineralogical point of view, the soils north of the Barbilla river in its flood plain would be expected to have a better potential fertility than those south of the Barbilla along the San Miguel river. However, it should be noted that in all soils studied from different flood plains, over 75 per cent of their mineral contents was made up of pyroxenes, plagioclases and weathered grains of these two minerals. Pyroxenes are minerals that consist of silicates of calcium, magnesium, iron, aluminum, sodium and lithium. Plagioclases are feldspars that contain calcium and sodium.

The soils receiving sediments from the Madre de Dios river had a good percentage of mineral content but were lower than those in soils receiving sediments by the Barbilla river. The soils that received sediments from the Pacuare river contained the lowest percentage of minerals of all soils studied, indicating that these soils would be expected to have the lowest potential fertility of all the soils. The fact that the present surface deposits are partly derived from shale, (30, 31, 32) indicates that some potassium bearing minerals such as muscovite and biotite are present. These are referred to as micas. The release of the potassium from the micas is rather slow due to the fact that these minerals decompose chemically very slowly. These soils also being derived partly from granite, should contain some orthoclase, which is a potassium feldspar resistant to weathering.

The fact that the present surface deposits are derived from limestone, shale, granite and some volcanic material (30, 31, 32), confirms the belief of Dondoli that the formation of the alluvial soils of this region, were influenced by volcanic rocks of the high part of Talamanca mountains as well as some sedimentary rocks, limestone and sandstone coming from the flanks of this same mountain range (18).

Soils Tests

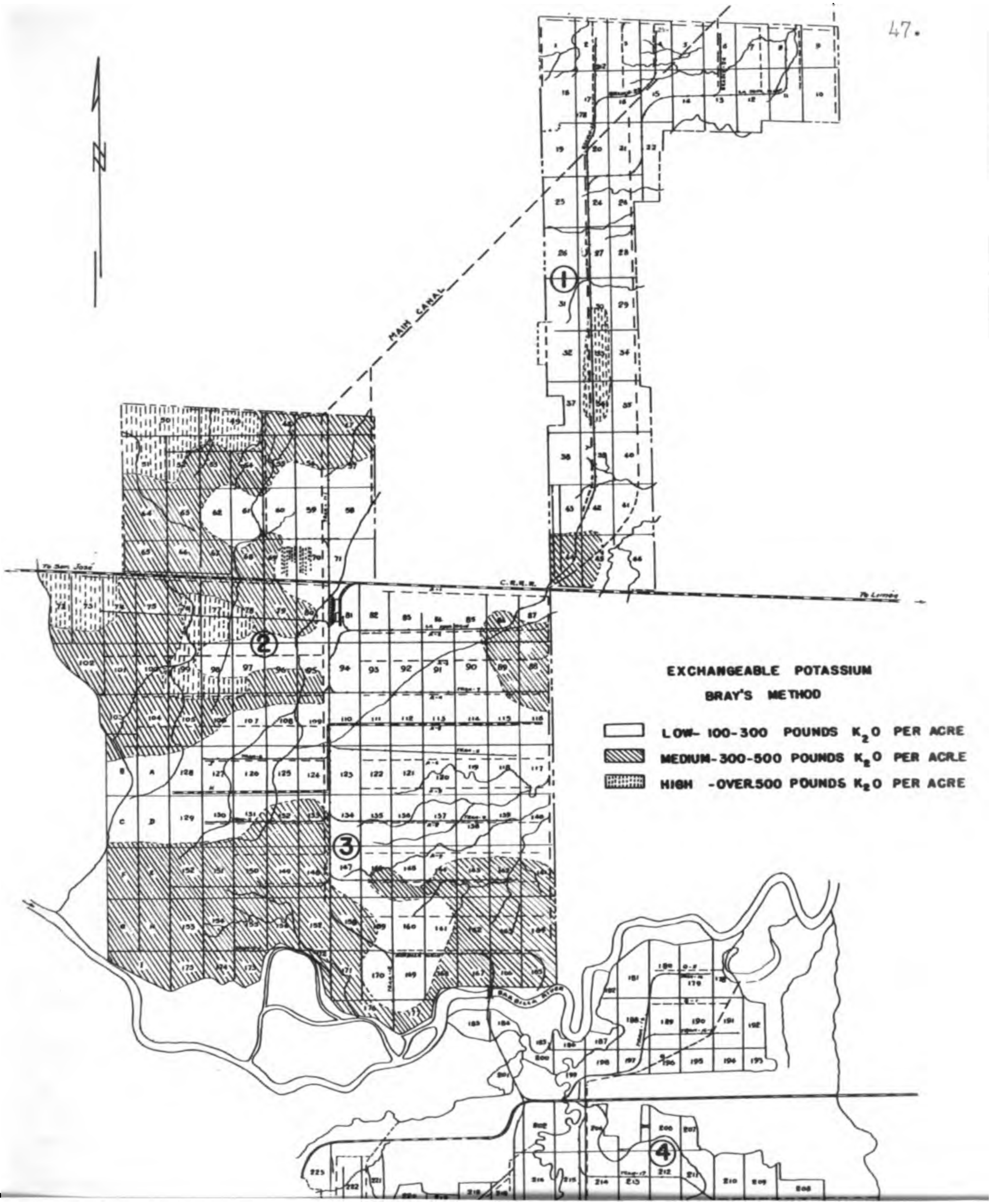
The total amount of potassium present in the soil usually amounts to about 40,000 pounds of K_2O per acre in the plowed layer (14). However, the problem with potassium is not the total amount present in the soil but the amount that is available to the plant. The potassium present in the soil that is available to the plants may vary from less than 100 pounds per acre to over 400 pounds per acre (42). The reason for this small amount of available potassium in relation to the high total amount may be due to the fact that the greater portion of potassium is present in complex silicate forsm which are very slowly soluble (15).

According to Royer (34) the "exchangeable potassium is the principal available form of potassium in the soil, and it maintains an equilibrium concentration of soluble potassium in the soil solution. The exchangeable and water-soluble forms of potassium constitute, for practi -

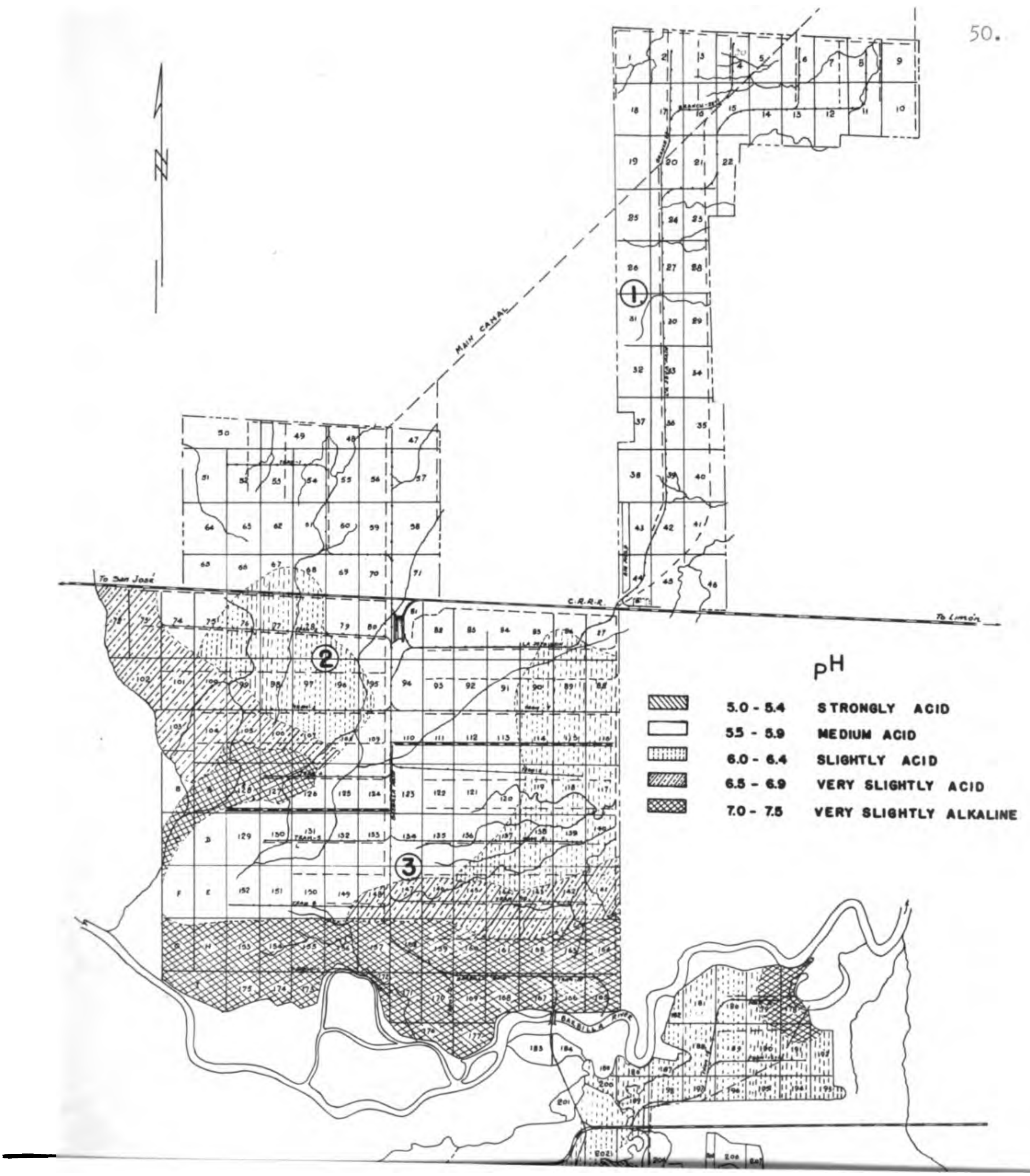
cal purposes, the total available potassium", due to the fact that the amount of potassium released from unavailable mineral forms during a growing season has only minor effects on the immediate crop (7).

The potassium test used in this work was that developed by Bray (7) which extracts and measures the total exchangeable and water soluble potassium in soils. Wide variations in the available potassium of the surface and subsoil samples of the Good Hope plantation were found, i. e., from the 103 to 1177 pounds per acre in the surface soil and 84 to 564 pounds per acre in the subsoil. Similar results were found in Coastal cocoa soils by Sands (37). From studying the Key to Soil Samples and results on the map shown in figure 13, it can be seen that over fifty per cent of the Good Hope plantation was found to be within the range of 100 to 300 pounds of K_2O per acre, which seems to be an indication that there may be a potassium deficiency in these coastal soils for abacá. These low levels of available potassium which were found for Good Hope may be due to the fact that an annual crop of abacá of 44,000 pounds of fresh stalk removes about 300 pounds of K_2O every year (19), and that the crop being grown in the same land for many years, without the use of potassium fertilizer, eventually will diminish the available potassium in the soil.

Some soils classified in class I and II, especially those north to the Barbilla river and west of the main tram, have good physical conditions, as well as a desirable pH, and medium to high content of potassium (above 300 lbs. K_2O per acre); still they are not producing as much as these conditions would seem to justify. This might be explained on the grounds of competition by weeds, not only for potassium but also for


MAIN CANAL
To San José
C.E.R.R.
To Limón
EXCHANGEABLE POTASSIUM
BRAY'S METHOD
LOW- 100-300 POUNDS K2O PER ACRE
MEDIUM-300-500 POUNDS K2O PER ACRE
HIGH -OVER 500 POUNDS K2O PER ACRE

nitrogen and other plant nutrients. The damage due to the banana root borer also may severely limit production. Abaca is known to be a surface feeder, and grasses having a shallow root system can compete with the abaca root system for moisture and available nutrients. With soils of class III, which are border line soils insofar as productivity is concerned and class IV, which are soils with poor drainage, the weed problem becomes more serious. A heavy stand of grasses not only competes for nutrients and moisture but also will not permit the free external flow of water, producing adverse conditions for the development of abaca. In soils having poor aeration the lack of oxygen and the accumulation of CO_2 decreases the availability and absorption of potassium by plants (10). Unpublished data by Royer and Bermudez (36) showed that aeration is important in promoting the development of a good root system in abaca. The fact that no correlation was found between exchangeable potassium and yield, may be an indication that yield is being limited by other factors such as weeds, drainage, insects, diseases, etc. as well as low levels of exchangeable potassium in the soil. Another factor that should be taken into account in the rapid depletion of potash by the removal of the crop is the method of harvesting the stalks. It is the common practice in Costa Rica to cut the stalk and bring it to the mill for the extraction of the fiber. Of the stalk only from 3.00 to 4.00 per cent is extracted as fiber, and the rest is thrown away as waste and not returned to the field. In contrast the methods used in the Philippines according to Sherman (41) and Buñuelos and Sherman (2) is to prepare tuxies - stalk peelings containing fiber - which represent about 15 per cent of the stalk weight, and only the tuxies are removed from the field to fiber separation centers for further cleaning. The remaining 85 per cent of stalk material is left in the field with its mineral and organic benefit to the soil. Further a great amount of abaca has been hand stripped and cleaned in the field in the past in the Philippines and only the cellulose fiber has been removed. The pH determinations of the Good Hope plantation shown in the Key to Soil Samples varied from 4.9 to 7.7. When studying figure 14, it can be seen that the higher pH which is slightly alkaline occur in soils that are near the Barbilla river. This is explained by the fact that the river had deposited some calcareous materials over the adjacent land. As the soils become heavier away from the river, the pH decreases with increasing clay content of the soils. The low pH is indication of a low proportion of bases such as calcium, magnesium, potassium, sodium, etc., in the soil exchange complex and a large proportion of hydrogen. A high pH on the other hand indicates a high proportion of bases in the exchange complex. The soil tests bring out areas of high and low supplies of available potassium despite of the fact that potassium fertilization has been done over the plantation rather widely. The application of potassium fertilizers and the irregular fertility pattern that results tend to give some high tests and thus increase the variability of the test results. However, as shown earlier under results, the correlation coeficient between available potassium in the soil and pH is so small that it can be considered neglegible. This would indicate that the high pH is determined mainly by other bases such as calcium and magnesium and to a less extent by potassium.


MAIN CANAL
To San José
C.R.R.R.
To Limón
BARBILLA RIVER
pH
5.0 - 5.4 STRONGLY ACID
5.5 - 5.9 MEDIUM ACID
6.0 - 6.4 SLIGHTLY ACID
6.5 - 6.9 VERY SLIGHTLY ACID
7.0 - 7.5 VERY SLIGHTLY ALKALINE

Field experiments at Good Hope have shown that abacá responds well to the application of potassium fertilizer, at the rate of 250 and 500 pounds of K_2O per acre per year (35). The soils of these experiments showed an available potassium content of 366 pounds of K_2O per acre for section 30 and 660 pounds of K O per acre for section 27. The available potassium in the sample taken in section 27 is rather high and may be due to the fact that the sample might have been contaminated with fertilizer. This might be indicated by a sample taken in the intermat area of plot 251 of section 27, that showed a potassium content of only 276 pounds of K_2O per acre despite receiving an application of 500 pounds of K_2O per acre per year in the fertilizer ring at a distance of 1 foot from the mat.

The results of soil tests from fertilized plots (table 9) indicated that the downward movement of potassium was effective only in the first four inches. This may be explained by the fact that when fertilizers are added to the soil the potassium becomes adsorbed by the colloids and thus downward movement is greatly retarded. This finding would clearly indicate that the application of the fertilizer would have a much greater benefit if it could be distributed in some manner through a greater surface depth, probably placing it at a depth of 3 to 5 inches.

Gourley and Wander (22) reported results of Volk, N.J., and Volk, G. W., in which they found that alternate wetting and drying of a mixture of a soluble potassium salt and certain soils at 70°C caused a large amount of the potassium to be fixed in a difficultly available form. In this manner the potassium applied in the surface of the soil may not move downward to any appreciable extent due to the fact that this zone is subject to alternate wetting and drying. The soils used in the Good Hope experiments were

Celina silt loam and Manila silt loam, but different results should be expected with lighter (sandy) soils due to the fact that sandy soils have much less colloidal material than heavier soils. These results agree with those found by Chandler (9) in orchard soils in Maryland.

The higher content of available potassium in the intermat area of the fertilized plots as compared with the unfertilized plots may be explained by the fact that in the fertilized plots more trash high in potassium content was accumulated or that less potassium was removed from the intermat areas since the roots had ample supplies in the zone of fertilizer application. It is also possible that the roots transported the potassium to the intermat area after absorption.

The pH was higher in the intermat area than in the fertilizer ring in both the fertilized and unfertilized plots. This is probably due to the fact that when the mats are cleaned, all the leaves and decaying matter are left in the intermat area. In this way, more bases are returned to the soil in the intermat area than in the fertilizer ring (1 foot from the mat).

The application of lime as shown in table 9 changed the pH only in the first three inches, indicating that the movement of lime was slow during the three year period. The available soil potassium was higher in the plot that received lime than in the unlimed plot. This may be due to the better conditions of the soil brought about by the increase in pH and possibly by converting some of the soil potassium available with difficulty to the more readily available forms.

Leaf Analyses

The potassium content of the potassium deficient plants as compared with the plants receiving a complete nutrient solution was much more lower. The younger (1st leaf) showed a rather high potassium content of 2.95 per cent as compared with the extremely low potassium content of the older leaves (0.73 and 0.78 per cent). This is due to the fact that potassium is quite mobile in the plant tissue and moves to the younger tissues in the case of a deficiency, the older leaves suffering the higher deficiency. It is noted from table 10 that the potassium content decreases considerably with increase in deficiency.

In the case of plants deficient in nitrogen, phosphorus, magnesium and sulfur, there was a tendency of potassium to accumulate in the leaves, the accumulation being generally greater in the younger leaves. In the case of calcium deficiency, the potassium content of the leaves was lower than those receiving the complete solution. It may be that in the absence of calcium, some other element, probably magnesium, is absorbed in greater quantities therefore inhibiting the absorption of potassium.

Effect of Fertilization on the Potassium Content of Abacá Stalk and Leaves

The leaves and stalks of the plants 120 inches high with nitrogen, phosphorus, potassium or no nitrogen, phosphorus or potassium showed a lower percentage of potassium content than leaves or stalks of plants only 72 inches high (figures 7 to 12 inclusive). The taller plants were the older. The results showing higher mineral content in younger plants agree in general with analyses of tissues of many other plants.

With potassium, phosphorus or nitrogen applications alone the potassium content of abaca stalk was in all cases lower than when these three nutrients were applied in combination (figures 7, 9 and 11).

In younger plants a higher potassium content was found in the stalks than in the leaves for all fertilizer applications. This result is also in agreement with what might be expected from analyses of many other plants.

In eleven out of twelve comparisons the highest levels of nitrogen, phosphorus and potassium gave higher potassium contents of stalks or leaves than the medium level. However, the medium level of these nutrients in most cases gave a lower potassium content of stalks or leaves than no nutrient applications at the lowest level (figures 7 to 12 inclusive).

Some variabilities of results that have been discussed here may be accounted for in the greater increase in dry matter resulting from stimulated growth resulting from nutrient applications. This may be the explanation of the medium levels giving lower potassium contents in comparison with the lowest level of no application.

Cain (8) working with apple trees found that the leaves of plants which had received nitrogen showed a lower potassium content than the leaves of plants not receiving nitrogen. He attributed it to an over -

all dilution brought about by an increased production of dry matter due to stimulated growth by nitrogen applications.

The applications of lime to soils of single plots not replicated shown in table 11 give no definite trend or relationship of potassium content of abacá stalk and leaves to lime. Unfortunately the $N_2 P_1 K_1$ no lime plot was not included in the stalk and leaf potassium analyses. However, if the lime plots are compared with the $N_2P_2K_1$ minus lime or with the $N_0P_0K_0$ minus lime there appears to be no definite benefit or detriment due to the presence of lime for the period for which the experiment has been run.

The application of Es-Min-El to a plot that received no fertilizer ($N_0P_0K_0$), (table 11), decreased the potassium content in the stalk of both plants and in the leaves of the 120-inch plants, but increased that of the leaves of the 72-inch plants. The Es-Min-El applied to a plot receiving the $N_1P_2K_2$ treatment, slightly decreased the potassium content of the stalk of the 72-inch and 120-inch plants and in the leaves of the 72-inch plants but slightly increased that of the leaves of the 120-inch plants. When Es-Min-El was applied to a plot receiving the $N_0P_1K_2$ treatment, the potassium in the stalk of the 72-inch plants was increased over the check plot ($N_0P_0K_0$), decreased the potassium content of the stalk of the 120-inch plants and leaves of the 72-inch plants but did not change the potassium content in the leaves of the 120-inch plants. The differences, from Es-Min-El are so small and varied that conclusions on single non replicated plots can not be drawn unless one concludes that there are no outstanding benefits to date.

VI. CONCLUSIONS

From the data presented in this investigation, the following conclusions can be drawn:

1. The Barbilla river has deposited the highest mineral containing sediments of four rivers in the Good Hope coastal region. Therefore, the soils subject to overflow by the Barbilla river should have the highest potential fertility of all the soils studied.
2. All sediments of the four rivers studied have been influenced by volcanic and sedimentary rocks that have been brought down from the Talamanca mountains.
3. There seems to be a potassium deficiency for abacá in some of the soils of the Good Hope plantation as shown by soil analyses, in areas where the soil conditions are favourable for the growth of abacá. It is believed also that there are other factors such as weeds, drainage, insects, diseases, etc. that seem to be limiting the production of abacá.
4. The downward movement of applied fertilizer potassium during a three year period was found confined to the upper three or four inches of the soil.
5. Lime was likewise found effective in changing the pH in the shallow surface soil, and made potassium more available in the first three inches of the soil in a period of three years.
6. Potassium fertilizers should be applied in areas that show low potassium content but other factors that may be limiting the

production of abacá should be controlled before applications of fertilizers are made if these are to be of some benefit.

7. Leaves of abacá plants showing a potassium concentration of 1.60 per cent on dry weight basis may be suffering from a slight potassium deficiency and if this value falls below 1.10 the plants may be suffering from a severe potassium deficiency.

8. Fertilization affects the potassium concentration in the stalks, especially young stalks, more than that of the leaves.

VII. SUMMARY AND RECOMMENDATIONS

The present investigation was conducted as a part of the program of the Abaca Project, United States Department of Agriculture, in cooperation with the Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica.

The mineralogical analyses of samples taken at Goschen, Monteverde and Good Hope plantations showed that over 75 per cent of the mineral content of these soils was composed of pyroxenes, plagioclases and weathered grains of these two minerals. The sediments deposited by the Barbilla river contained the highest mineral percentage of all the soils studied while those deposited by the Pacuare river contained the lowest mineral percentage of all the soils studied. The potassium analyses of the soil samples taken over the Good Hope plantation indicated that many areas in the plantation were below 300 pounds of available potassium per acre and that there seems to be a potassium deficiency for abacá in some of these coastal soils.

The application of potassium fertilizers increased considerably the available potassium in the place of fertilizer application, but the downward movement of potassium was confined to the first 3 or 4 inches of the soil in a period of 3 years. The soil types used for these experiments were Celina Silt loam and Manila Silt loam, but different results should be expected from lighter textured soils. The application of lime increased the available potassium and was effective in changing the pH of the soil in the first 3 inches in a period of three years.

The analyses of abacá leaves of plants grown in sand solution cultures showed that the leaves of plants deficient in nitrogen, phosphorus, magnesium and the younger leaves of plants deficient in sulfur had a higher potassium content than the leaves of plants that received a complete nutrient solution. The plants that received a solution lacking potassium were considerably lower than those receiving a complete nutrient solution and those receiving nutrient solutions lacking nitrogen, phosphorus, magnesium, calcium and sulfur. The leaves of plants receiving a nutrient solution lacking calcium had a lower potassium content than the plants receiving a complete nutrient solution but had a higher potassium content than the potassium deficient plants. The analyses of abacá stalk of plants grown in sand solution cultures showed that the potassium content in the stalks of plants deficient in phosphorus, magnesium and sulfur was considerably higher than in the stalks of plants that received a complete nutrient solution. The potassium content in the stalk of plants deficient in nitrogen and calcium was lower than that in the plants that received a complete nutrient solution. Of all the plants sampled, the potassium deficient plants showed the lowest potassium content in the stalk.

The analyses of abacá plant tissue samples taken from the fertilizer experiment plots showed that the stalks were more sensitive to different levels of fertilizer applications than the leaves, especially the stalks of young plants.

The following recommendations are given:

1. Potassium fertilizers should be applied to all areas that show less than 300 pounds of K_2O per acre.
2. The rate of application recommended is of 250 pounds of K_2O per acre per year.
3. The fertilizers should be applied in a ring around the mat between the first and second foot from the mat until more knowledge as to the zone of maximum absorption by the roots is obtained.
4. An investigation should be carried on to find out the zone of maximum absorption by the roots, to obtain the greatest benefits when applying fertilizers.
5. The application of fertilizers should be supervised with greater efficiency than has been up to date to obtain the maximum benefits from fertilizer placement.
6. In areas where potassium is not a factor limiting abacá production, other limiting factors such as weeds, insects, diseases, etc. must be controlled to increase production.
7. In areas where potassium fertilization is needed, other factors limiting abacá production named in No. 6 should be controlled if fertilization is to be of some benefit in increasing abacá production.

VIII. RESUMEN Y RECOMENDACIONES

La presente investigación fué llevada a cabo como parte del Programa del Projecto Abacá del Departamento de Agricultura de los Estados Unidos, en cooperación con el Instituto Interamericano de Ciencias Agrícolas, Turrialba, Costa Rica.

Los análisis mineralógicos de muestras tomadas en las plantaciones de Goschen, Monteverde y Good Hope, mostraron que más del 75 por ciento del contenido mineral de estos suelos estaba compuesto de piroxenos, plagioclasas y granos edafizados de estos dos minerales. Los sedimentos depositados por el río Barbilla tuvieron el porcentaje mineral más alto de todos los suelos estudiados mientras que los sedimentos depositados por el río Pacuare tuvieron el porcentaje mineral más bajo de todos los suelos estudiados.

Los análisis de potasio de las muestras tomadas en toda la plantación de Good Hope indicaron que muchas areas en la plantación tuvieron un contenido de potasio disponible menor de 300 lbs. por acre y que parece haber una deficiencia de potasio para abacá en estos suelos de la costa.

La aplicación de fertilizantes potásicos aumentó considerablemente el potasio disponible en el lugar donde se aplicó el fertilizante, pero el movimiento vertical del potasio fué limitado a las primeras 3 o 4 pulgadas del suelo en un período de 3 años. Los tipos de suelos usados en este experimento fueron dos suelos franco limosos, pero resultados diferentes se deberían esperar en suelos de textura más liviana.

La aplicación de cal aumentó el potasio disponible y cambió el pH del suelo solamente en las tres primeras pulgadas en un período de 3 años. Los análisis de las hojas de plantas de abacá cultivadas en arena con soluciones nutritivas mostraron que las hojas de plantas deficientes en nitrógeno, fósforo, magnesio, y las hojas más jovenes de plantas deficientes en azufre, tuvieron un contenido de potasio más alto que las hojas de plantas que recibieron la solución nutritiva completa.

El contenido de potasio de las hojas de las plantas deficientes en potasio fué menor que el de las hojas de las plantas que recibieron la solución nutritiva completa y menor que el de las hojas de plantas deficientes en nitrógeno, fósforo, magnesio, calcio y azufre.

El contenido de potasio de las hojas de las plantas deficientes en calcio fué menor que el contenido de potasio de las hojas de las plantas que recibieron la solución nutritiva completa, pero fué mayor que el de las plantas deficientes en potasio.

Los análisis de los tallos de plantas de abacá cultivadas en arena con soluciones nutritivas mostraron que el contenido de potasio en los tallos de plantas deficientes en fósforo, magnesio y azufre fué considerablemente más alto que el de los tallos de las plantas que recibieron la solución nutritiva completa. El contenido de potasio en los tallos de plantas deficientes en nitrógeno y calcio fué menor que el de las plantas que recibieron la solución nutritiva completa.

Las plantas deficientes en potasio mostraron el contenido de potasio más bajo en el tallo.

Los análisis de las muestras de hojas y tallos de abacá tomados en las parcelas experimentales de fertilizantes mostraron que los tallos, especialmente los de plantas jóvenes, fueron más sensitivos a los diferentes niveles de aplicación de fertilizantes que las hojas.

Se sugieren las siguientes recomendaciones:

1. Los fertilizantes potásicos deberían ser aplicados en todas las areas que muestran menos de 300 lbs. de K_2O por acre.
2. La cantidad recomendada es de 250 lbs. de K_2O por acre por año.
3. Los fertilizantes se deberían aplicar a un círculo alrededor de la planta entre el primer y segundo pie de distancia de la planta, hasta que se tenga un mayor conocimiento de la zona radicular de máxima absorción.
4. Se debería llevar a cabo una investigación para averiguar la zona máxima de absorción de las raíces, a fin de obtener el mayor beneficio al aplicar los fertilizantes.
5. La aplicación de fertilizantes debería ser supervisada con mayor eficiencia de lo que ha sido hasta ahora, a fin de obtener mayores beneficios.
6. En areas donde el potasio no es un factor limitante en la producción de abacá, otros factores limitantes tales como malezas, insectos, enfermedades, etc. deberían ser controlados para aumentar la producción.
7. En areas donde es necesario aplicar fertilizantes potásicos, los factores limitantes citados en No. 6 deberían ser controlados si se espera que las aplicaciones de fertilizantes sean de algún beneficio para aumentar la producción.

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X. APPENDIX

KEY TO SOIL SAMPLES

Location, Description and Analysis of Soil Samples
from Good Hope Plantation, Bataán, Costa Rica

Sample No.	Section	Side Section	Tram	Side Tram	Depth Inches	Soil Class	Soil Type	pH	K_2O Lbs/A.
1	30 ck. plot 1	Luzon Fert. Exp.			0- 6	III	525	6.2	366
2	30 ck. plot 1	Luzon Fert. Exp.			12-18	III	525	6.5	169
5	G.H. 158				0- 6	I	535L	7.7	432
6	G.H. 158				12-18	I	535L	7.1	184
23	G.H. 257				0- 6	IV	65G	5.8	469
24	G.H. 256				0- 6	IV	65G	5.8	414
25	G.H. 96				0- 6	III	525	5.9	324
26	G.H. 107				0- 6	III	525	5.6	380
27	G.H. 109				0- 6	III	525	5.9	224
28	G.H. 2	South end	23	East	0- 6	III	527	5.8	212
29	G.H. 4	Tram end	23-1	East	0- 6	II	537	6.0	250
30	G.H. 8	South end	Joya	East	0- 6	III	525	5.7	174
31	G.H. 13	West side	Joya	South	0- 6	III	525	6.0	258
32	G.H. 15	East side	Joya	South	0- 6	III	525	6.1	187
33	G.H. 27	South end	Joya	East	0- 6	II	535	5.6	660
34	G.H. 33	North end	Joya	East	0- 6	III	525	5.6	901
35	G H. 36	North end	Joya	East	0- 6	III	525	5.8	1177
36	G.H. 39	North end	Joya	East	0- 6	II	535	6.0	308
37	G.H. 44	North end	Joya	West	0- 6	III	525	5.8	901
38	G.H. 51	West side	1	South	0- 6	III	225	6.0	615
39	G.H. 53	West side	1	South	0- 6	IV	221	5.9	338
40	G.H. 54	West side	1	North	0- 6	IV	221	6.1	947
41	G.H. 61	N.E. cor.	1	West	0- 6	IV	221	5.8	402
42	G.H. 69	N.W. cor.	1	South	0- 6	IV	221	6.0	787
44	G.H. 74	East side	2	North	0- 6	III	525	5.5	346
45	G.H. 77	West side	2	North	0- 6	II	535	6.1	1085
46	G.H. 79	West side	2	North	0- 6	III	225	5.7	450
47	G.H. 100	West side	3	North	0- 6	II	537B	6.6	352
48	G.H. 97	West side	3	North	0- 6	III	525	6.3	610

Sample No.	Section	Side Section	Tram	Side Tram	Depth Inches	Soil Class	Soil Type	pH	K_2O Lbs/A.
49	[illegible] 5	West side	3	North	0- 6	III	525	6.1	427
50	G.H. 127	West side	4	North	0- 6	III	727L	7.7	280
51	G.H. 125	West side	4	North	0- 6	III	525	5.9	296
52	G.H. 130	West side	5	North	0- 6	I	547	5.3	299
53	G.H. 132	West side	5	North	0- 6	II	537	5.5	324
54	G.H. 152	West side	6	North	0- 6	I	547	5.9	564
55	G.H. 150	West side	6	North	0- 6	I	547	6.0	369
56	G.H. 154	West side	1-1	North	0- 6	I	545B	7.4	424
57	G.H. 156	West side	1-1	North	0- 6	I	545B	7.5	332
58	G.H. 86	West side	Joya	North	0- 6	III	222	6.2	410
59	G.H. 82	East side	Joya	North	0- 6	III	525	5.8	195
60	G.H. 89	East side	7	North	0- 6	III	222	6.2	446
61	G.H. 91	West side	7	North	0- 6	II	235	5.8	409
62	G.H. 118	West side	8	North	0- 6	III	225	6.0	355
63	G.H. 121	West side	8	North	0- 6	III	527	5.6	296
64	G.H. 139	East side	9	North	0- 6	I	535L	6.0	230
65	G.H. 135	East side	9	North	0- 6	II	535	5.5	200
66	G.H. 142	West side	10	North	0- 6	I	535L	6.9	564
67	G.H. 147	East side	10	North	0- 6	I	535L	6.7	294
68	G.H. 164	West side	13	North	0- 6	III	525L	7.4	630
69	G.H. 167	West side	Barbilla	South	0- 6	III	525L	7.3	397
70	G.H. 169	East side	Barbilla	South	0- 6	III	525L	7.4	377
71	G.H. 177	Near Tram End	12	East	0- 6	I	545L	7.5	334
72	G.H. 275	West side	Main	North	0- 6	II	535	5.7	130
73	G.H. 259	West side	19	North	0- 6	III	525	6.0	158
74	G.H. 257	West side	20	North	0- 6	III	547 S	6.4	201
75	G.H. 257	East side	18	South	0- 6	I	545	5.5	479
76	G.H. 232	South side	Main	West	0- 6	II	535	5.4	274
77	G.H. 235	Middle	17	South	0- 6	II	537	5.6	532
78	G.H. 212	East side	17	South	0- 6	III	548 G	5.8	174
79	G.H. 265	East side	15	North	0- 6	II	537	5.4	345
80	G.H. 243	Middle		South	0- 6	II	535	5.5	538
81	G.H. 190	East side	16-1	North	0- 6	II	535	5.5	195
82	G.H. 222	South end	15-1-1	East	0- 6	III	525	5.1	200
83	G.H. 227	East side	15-1-1	South	0- 6	II	535	5.7	424

Sample No.	Section	Side Section	Tram	Side Tram	Depth Inches	Soil Class	Soil Type	pH	K_2O Lbs/A.
84	G.H. 135	East side	9	North	0- 6	II	535		184
85	G.H. 169	East side	13	South	0- 6	III	525L		219
130	G.H. 146	East side	10	North	0- 6	III	525L	6.4	483
131	G.H. 266	East side	15	Near	0- 6	II	537	5.3	187
132	G.H. 266	East side	15	Tram end	12-18	II	537	5.3	138
133	G.H. 280	North side	Main	West	0- 6	II	535	5.3	160
134	G.H. 280	North side	Main	West	12-18	II	535	5.6	87
135	G.H. 281	Middle	Main	East	0- 6	II	535	5.5	224
136	G.H. 281	Middle	Main	East	12-18	II	535	5.3	103
137	G.H. 274	West side	Main	North E.	0- 6	I	545	5.5	222
138	G.H. 274	West side	Main	North E.	12-18	I	545	5.5	160
139	G.H. 264	East side	15	North	0- 6	II	537	5.5	249
140	G.H. 264	East side	15	North	12-18	II	537	5.5	123
141	G.H. 250	East side	15	South	0- 6	II	537	5.4	628
142	G.H. 250	East side	15	South	12-18	II	537	5.5	208
143	G.H. 215	North side	Main	West	0- 6	I	545	5.2	237
144	G.H. 215	North side	Main	West	12-18	I	545	5.3	125
145	G.H. 244	S.E. cor.	15	North	0- 6	III	525	5.0	254
146	G.H. 244	S.E. cor.	15	North	12-18	III	525	5.1	121
147	G.H. 71	Middle	Main	East	0- 6	III	225	5.7	265
148	G.H. 71	Middle	Main	East	12-18	III	225	5.7	103
149	G.H. 80	West side	2	North	0- 6	III	525	5.8	324
150	G.H. 80	West side	2	North	12-18	III	525	6.0	153
151	G.H. 47	S.W. cor.	1-1	Near	0- 6	IV	221	5.7	353
152	G.H. 47	S.W. cor.	1-1	Tram end	12-18	IV	221	5.5	120
153	G.H. 56	N. Middle			0- 6	IV	221	5.8	300
154	G.H. 56	N. Middle			12-18	IV	221	5.5	270
155	G.H. 57	S,W. cor.	1-1	East	0- 6	III	225	5.7	261
156	G.H. 57	S.W. cor.	1-1	East	12-18	III	225	5.8	160
157	G.H. 92	S.W. cor.	7	North	0- 6	III	225	5.7	274
158	G.H. 92	S.W. cor.	7	North	12-18	III	225	5.9	160
159	G.H. 93	S.W. cor.	7	North	0- 6	III	525	5.5	187
160	G.H. 93	S.W. cor.	7	North	12-18	III	525	5.8	160
161	G.H. 76	West side	2	South	0- 6	III	525	6.0	356
162	G.H. 76	West side	2	South	12-18	III	525	5.8	138
163	G.H. 85	West side	Joya	North	0- 6	III	225	5.6	202

Sample No.	Section	Side Section	Tram	Side Tram	Depth Inches	Soil Class	Soil Type	pH	K_2O Lbs/A.
164	G.H. 85	West side	Joya	North	12-18	III	225	5.2	209
165	G.H. 157	South East	11	West	0- 6	I	535L	7.2	373
166	G.H. 157	South East	11	West	12-18	I	535L	7.1	172
167	G.H. 158	South East	Barbilla	North	0- 6	III	525L	7.2	542
168	G.H. 158	South East	Barbilla	North	12-18	III	525L	6.9	169
169	G.H. 160	South West	Barbilla	North	0- 6	III	525L	7.4	238
170	G.H. 160	South West	Barbilla	North	12-18	III	525L	7.0	130
171	G.H. 163	S.W. cor.	13	North	0- 6	III	525L	7.1	332
172	G.H. 163	S.W. cor.	13	North	12-18	III	525L	6.4	163
173	G.H. 169	South side	12	East	0- 6	III	525L	7.2	247
174	G.H. 169	South side	12	East	12-18	III	525L	7.1	165
175	G.H. 170	East side	12	South W.	0- 6	III	525L	7.4	239
176	G.H. 170	East side	12	South W.	12-18	III	525L	6.9	145
177	G.H. 171	W. Middle	11	East	0- 6	I	545B	7.5	889
178	G.H. 171	W. Middle	11	East	12-18	I	545B	7.4	560
179	G.H. 222	Tram end	15-1-1	East	0- 6	III	525	7.4	160
180	G.H. 222	Tram end	15-1-1	East	12-18	III	525	6.3	160
181	G.H. 225	Center	15-1-1	South W.	0- 6	III	525	5.2	193
182	G.H. 225	Center	15-1-1	South W.	12-18	III	525	4.6	160
183	G.H. 226	East side	15-1-1	South	0- 6	III	525	5.8	228
184	G.H. 226	East side	15-1-1	South	12-18	III	525	4.8	112
185	G.H. 73	West side	2	North	0- 6	II	537B	6.9	515
186	G.H. 73	West side	2	North	12-18	II	537B	7.5	232
187	G.H. 106	West side			0- 6	III	525	6.9	432
188	G.H. 106	West side			12-18	III	525	7.6	158
189	G.H. 107	West side			0- 6	III	525	6.6	224
190	G.H. 107	West side			12-18	III	525	7.6	163
191	G.H. 108	West side			0- 6	III	525	6.4	266
192	G.H. 108	West side			12-18	III	525	7.1	135
193	G.H. 99	East side	3	North	0- 6	III	525	6.5	607
194	G.H. 99	East side	3	North	12-18	III	525	7.2	232
195	G.H. 2	End of Tram	23	East	0- 6	II	537	6.0	206
196	G.H. 2	End of Tram	23	East	12-18	II	537	6.3	158
197	G.H. 16	West side	23-1	South	0- 6	III	525	6.0	320
198	G.H. 16	West side	23-1	South	12-18	III	525	6.3	190

Sample No.	Section	Side Section	Tram	Side Tram	Depth Inches	Soil Class	Soil Type	pH	K_2O Lbs/A.
199	G.H. 17	S.W. cor.			0- 6	III	527	5.7	178
200	G.H. 17	S.W. cor.			12-18	III	527	6.0	143
201	G.H. 19	East Middle			0- 6	III	527	5.7	145
202	G.H. 19	East Middle			12-18	III	527	6.0	165
203	G.H. 88	South Middle			0- 6	III	222	6.3	479
204	G.H. 88	South Middle			12-18	III	222	6.2	242
205	G.H. 89	S.W. cor.	7	North	0- 6	IV	215	6.0	216
206	G.H. 89	S.W. cor.	7	North	12-18	IV	215	6.2	169
207	G.H. 90	S.W. cor.	7	North	0- 6	III	222	6.0	225
208	G.H. 90	S.W. cor.	7	North	12-18	III	222	6.1	125
209	G.H. 96	S.W. cor.			0- 6	III	525	6.0	362
210	G.H. 96	S.W. cor.			12-18	III	525	6.0	187
211	G.H. 98	S.W. cor.			0- 6	III	525	6.3	169
212	G.H. 98	S.W. cor.			12-18	III	525	6.5	97
213	G.H. 276	Center	Main	East	0- 6	III	525	5.8	218
214	G.H. 276	Center	Main	East	12-18	III	525	6.0	97
215	G.H. 277	North side	Main	West	0- 6	III	525	5.6	294
216	G.H. 277	North side	Main	West	12-18	III	525	5.9	103
217	G.H. 271	West side	21	North	0- 6	II	535	5.5	235
218	G.H. 271	West side	21	North	12-18	II	535	5.3	145
219	G.H. 270	West side	21	North	0- 6	III	525	5.7	286
220	G.H. 270	West side	21	North	12-18	III	525	5.8	169
221	G.H. 269	West side	22	South	0- 6	II	535	5.3	125
222	G.H. 269	West side	22	South	12-18	II	535	5.3	103
223	G.H. 268	West side	22	North	0- 6	III	525	5.5	216
224	G.H. 268	West side	22	North	12-18	III	525	5.6	121
225	G.H. 120	N.W. cor.	8	North	0- 6	III	527	5.7	231
226	G.H. 120	N.W. cor.	8	North	12-18	III	527	6.0	125
227	G.H. 122	N. Middle	8	North	0- 6	III	527	5.7	211
228	G.H. 122	N. Middle	8	North	12-18	III	527	6.1	211
229	G.H. 124	West side	4	North	0- 6	III	525	5.9	200
230	G.H. 124	West side	4	North	12-18	III	525	6.1	121
231	G.H. 134	East side	9	North	0- 6	II	535	5.8	165
232	G.H. 134	East side	9	North	12-18	II	535	5.9	125
233	G.H. 136	East side	9	North	0- 6	III	525	5.5	151
234	G.H. 136	East side	9	North	12-18	III	525	6.0	121
235	G.H. 137	East side	9	North	0- 6	III	525L	6.1	160

Sample No.	Section	Side Section	Tram	Side Tram	Depth Inches	Soil Class	Soil Type	pH	K_2O Lbs/A.
2[illegible]6	G.H. 137	East side	9	North	12-18	III	525L	6.1	125
237	G.H. 137	S.W. cor.			0- 6	I	535L	6.1	206
238	G.H. 137	S.W. cor.			12-18	I	535L	6.0	112
239	G.H. 138	East side	9	South	0- 6	I	535L	6.7	165
240	G.H. 138	East side	9	South	12-18	I	535L	6.4	125
241	G.H. 138	S.W. cor.			0- 6	I	535L	6.4	220
242	G.H. 138	S.W. cor.			12-18	I	535L	6.2	135
243	G.H. 82	West side	Joya	North	0- 6	III	225	5.5	196
244	G.H. 82	West side	Joya	North	12-18	III	225	6.1	135
245	G.H. 83	East side	Joya	North	0- 6	III	225	5.4	219
246	G.H. 83	East side	Joya	North	12-18	III	225	5.6	138
247	G.H. 95	N. Middle	Joya		0- 6	III	525	5.8	160
248	G.H. 95	N. Middle	Joya		12-18	III	525	5.9	121
249	G.H. 96	N.E. cor.			0- 6	III	525	6.2	262
250	G.H. 96	N.E. cor.			12-18	III	525	6.2	130
251	G.H. 97	N.E. cor.			0- 6	III	525	5.8	282
252	G.H. 97	N.E. cor.			12-18	III	525	6.0	184
253	G.H. 98	N. West			0- 6	III	225	5.9	234
254	G.H. 98	N. West			12-18	III	225	6.1	211
255	G.H. 109	W. Middle			0- 6	III	525	5.9	278
256	G.H. 109	W. Middle			12-18	III	525	6.0	160
257	G.H. 117	N. W. cor.			0- 6	III	222	6.4	260
258	G.H. 117	N. W. cor.			12-18	III	222	6.3	181
259	G.H. 119	N. W. cor.	8	North	0- 6	III	527	5.7	178
260	G.H. 119	N. W. cor.	8	North	12-18	III	527	5.9	130
261	G.H. 141	West side	10	Tram end	0- 6	I	535L	6.8	429
262	G.H. 141	West side	10	Tram end	12-18	I	535L	6.5	196
263	G.H. 144	East side	10	North	0- 6	I	535L	7.3	303
264	G.H. 144	East side	10	North	12-18	I	535L	6.6	160
265	G.H. 145	East side	10	North	0- 6	I	535L	7.4	247
266	G.H. 145	East side	10	North	12-18	I	535L	6.5	138
267	G.H. 146	East side	10	North	0- 6	III	525L	6.4	635
268	G.H. 146	East side	10	North	12-18	III	525L	6.2	212
269	G.H. 4	South side	23-1	East	0- 6	II	537	5.7	125
270	G.H. 4	South side	23-1	East	12-18	II	537	5.9	97
271	G.H. 6	Tram end	24	East	0- 6	III	525	5.8	165
272	G.H. 6	Tram end	24	East	12-18	III	525	5.7	106

Sample No.	Section	Side Section	Tram	Side Tram	Depth Inches	Soil Class	Soil Type	pH	K_2O Lbs/A.
273	G.H. 11	North side	Joya	East	0- 6	III	222	5.7	145
274	G.H. 11	North side	Joya	East	12-18	III	222	5.9	112
275	G.H. 12	West side	Joya	North	0- 6	III	525	5.6	202
276	G.H. 12	West side	Joya	North	12-18	III	525	5.8	130
277	G.H. 14	Center	Joya	North	0- 6	III	525	5.8	258
278	G.H. 14	Center	Joya	North	12-18	III	525	5.8	177
279	G.H. 15	West side	23-1	North	0- 6	III	525	5.6	160
280	G.H. 15	West side	23-1	North	12-18	III	525	5.6	106
281	G.H. 20	South side	23	East	0- 6	III	525	5.9	187
282	G.H. 20	South side	23	East	12-18	III	525	6.1	106
283	G.H. 21	East side	Joya	North	0- 6	III	525	5.8	218
284	G.H. 21	East side	Joya	North	12-18	III	525	6.0	158
285	G.H. 22	N.W. cor.	Joya	East	0- 6	II	535	5.7	135
286	G.H. 22	N.W. cor.	Joya	East	12-18	II	535	6.1	106
287	G.H. 23	N.W. cor.	Joya	South	0- 6	III	525	5.8	262
288	G.H. 23	N.W. cor.	Joya	South	12-18	III	525	6.0	184
289	G.H. 24	South side	Joya	East	0- 6	II	535	5.6	158
290	G.H. 24	South side	Joya	East	12-18	II	535	5.7	130
291	G.H. 25	S.E. cor.			0- 6	II	535	5.7	254
292	G.H. 25	S.E. cor.			12-18	II	535	5.7	145
293	G.H. 26	S.E. cor.			0- 6	II	535	5.7	210
294	G.H. 26	S.E. cor.			12-18	II	535	5.8	135
295	G.H. 28	S.W. cor.			0- 6	II	535	5.9	200
296	G.H. 28	S.W. cor.			12-18	II	535	6.0	130
297	G.H. 32	N.E. cor.			0- 6	III	525	5.6	165
298	G.H. 32	N.E. cor.			12-18	III	525	5.9	135
299	G.H. 34	S.W. cor.			0- 6	III	525	5.7	239
300	G.H. 34	S.W. cor.			12-18	III	525	6.0	174
301	G.H. 38	N. Middle			0- 6	III	227	5.7	302
302	G.H. 38	N. Middle			12-18	III	227	6.0	215
303	G.H. 40	N. West			0- 6	II	535	5.6	242
304	G.H. 40	N. West			12-18	II	535	5.8	169
305	G.H. 42	Center	Joya	East	0- 6	III	522	5.4	219
306	G.H. 42	Center	Joya	East	12-18	III	522	5.6	190
307	G.H. 45	N.W. cor.			0- 6	II	535	5.5	318
308	G.H. 45	N.W. cor.			12-18	II	535	5.6	181
309	G.H. 131	West side	5	North	0- 6	II	537	5.7	256
310	G.H. 131	West side	5	North	12-18	II	537	5.7	195

Sample No.	Section	Side Section	Tram	Side Tram	Depth Inches	Soil Class	Soil Type	pH	K_2O Lbs/A.
311	G.H. 133	West side	5	North	0- 6	III	525	5.9	383
312	G.H. 133	West side	5	North	12-18	III	525	6.1	241
313	G.H. 134	S.W. cor.	Barbilla	East	0- 6	II	535	5.7	296
314	G.H. 134	S.W. cor.	Barbilla	East	12-18	II	535	5.8	165
315	G.H. 135	S.W. cor.			0- 6	III	525	5.8	239
316	G.H. 135	S.W. cor.			12-18	III	525	6.1	195
317	G.H. 148	West side	6	North	0- 6	II	535	6.2	322
318	G.H. 148	West side	6	North	12-18	II	535	6.1	190
319	G.H. 149	West side	6	North	0- 6	I	547	5.9	912
320	G.H. 149	West side	6	North	12-18	I	547	5.8	372
321	G.H. 151	West side	6	North	0- 6	I	547	6.1	472
322	G.H. 151	West side	6	North	12-18	I	547	6.0	274
323	G.H. 179	East side	16	S. end	0- 6	I	545L	7.7	369
324	G.h. 179	East side	16	S. end	12-18	I	545L	7.5	225
325	G.H. 180	East side	16	South	0- 6	I	545L	6.9	196
326	G.H. 180	East side	16	South	12-18	I	545L	6.6	145
327	G.H. 188	East side	16	West	0- 6	I	545	6.2	196
328	G.H. 188	East side	16	West	12-18	I	545	5.9	184
329	G.H. 189	South side	16-1	South	0- 6	III	525	6.3	160
330	G.H. 189	South side	16-1	South	12-18	III	525	6.2	129
331	G.H. 197	North side	16	East	0- 6	I	545	6.1	444
332	G.H. 197	North side	16	East	12-18	I	545	6.0	178
333	G.H. 198	East side	16	North	0- 6	I	545L	6.2	247
334	G.H. 198	East side	16	North	12-18	I	545L	6.1	145
335	G.H. 208	South side	17	North	0- 6	II	535	5.9	130
336	G.H. 208	South side	17	North	12-18	II	535	6.2	130
337	G.H. 209	S.E. cor.	17	North	0- 6	II	535	6.0	187
338	G.H. 209	S.E. cor.	17	North	12-18	II	535	6.3	112
339	G.H. 210	West side	17	North	0- 6	II	537	6.1	153
340	G.H. 210	West side	17	North	12-18	II	537	6.3	94
341	G.H. 213	East side	17	South	0- 6	III	548/G	5.9	121
342	G.H. 213	East side	17	South	12-18	III	548/G	5.9	145
343	G.H. 236	Middle	17	South	0- 6	III	527	6.1	145
344	G.H. 236	Middle	17	South	12-18	III	527	6.4	121

Sample No.	Section	Side Section	Tram	Side Tram	Depth Inches	Soil Class	Soil Type	pH	K_2O Lbs/A.
345	G.H. 237	East side	17	West	0- 6	III	527	5.9	145
346	G.H. 237	East side	17	West	12-18	III	527	6.2	121
347	G.H. 240	E. Middle	Barbilla	West	0- 6	II	535	5.4	216
348	G.H. 240	E. Middle	Barbilla	West	12-18	II	535	5.5	153
349	G.H. 251	South side	19	Tram end	0- 6	III	535/S	5.6	367
350	G.H. 251	South side	19	Tram end	12-18	III	535/S	5.1	169
351	G.H. 252	S.E. cor.			0- 6	I	545	5.3	294
352	G.H. 252	S.E. cor.			12-18	I	545	5.5	184
353	G.H. 254	North side	Barbilla	West	0- 6	II	537	5.5	296
354	G.H. 254	North side	Barbilla	West	12-18	II	537	5.6	145
355	G.H. 258	West side	20	North	0- 6	III	547/S	5.8	187
356	G.H. 258	West side	20	North	12-18	III	547/S	5.8	145
357	G.H. 259	South side	Barbilla	West	0- 6	II	535	5.8	389
358	G.H. 259	South side	Barbilla	West	12-18	II	535	6.1	130
359	G.H. 261	West side	19	North	0- 6	III	535/S	5.7	307
360	G.H. 261	West side	19	North	12-18	III	535/S	5.5	169
361	G.H. 191	South side	16-1	South	0- 6	III	525	5.8	228
362	G.H. 191	South side	16-1	South	12-18	III	525	5.9	145
363	G.H. 58	S.W. cor.	1-1	East	0- 6	III	225	5.7	239
364	G.H. 58	S.W. cor.	1-1	East	12-18	III	225	5.9	129
365	G.H. 61	S.W. cor.			0- 6	III	525	5.9	224
366	G.H. 61	S.W. cor.			12-18	III	525	6.1	164
367	G.H. 52	West side	1	North	0- 6	III	222	5.9	619
368	G.H. 52	West side	1	North	12-18	III	222	6.2	222
369	G.H. 55	S.E. cor.			0- 6	IV	221	5.9	254
370	G.H. 55	S.E. cor.			12-18	IV	221	6.0	130
371	G.H. 62	N.E. cor.			0- 6	III	222	6.0	232
372	G.H. 62	N.E. cor.			12-18	III	222	6.1	145
373	G.H. 59	S.W. cor.	1	North	0- 6	III	225	5.5	209
374	G.H. 59	S.W. cor.	1	North	12-18	III	225	5.8	130

Sample No.	Section	Side Section	Tram	Side Tram	Depth Inches	Soil Class	Soil Type	pH	K_2O Lbs/A.
375	G.H. 63	N.E. cor.			0- 6	III	222	5.6	432
376	G.H. 63	N.E. cor.			12-18	III	222	5.8	130
377	G.H. 74	West side	2	North	0- 6	III	525	5.7	677
378	G.H. 74	West side	2	North	12-18	III	525	6.0	184
379	G.H. 78	West side	2	South	0- 6	III	225	6.0	1027
380	G.H. 78	West side	2	South	12-18	III	225	6.1	196
381	G.H. 87	North side	Joya	South	0- 6	III	225	5.9	178
382	G.H. 87	North side	Joya	South	12-18	III	225	6.0	160
383	G.H. 126	West side	4	North	0- 6	III	525	7.5	270
384	G.H. 126	West side	4	North	12-18	III	525	7.7	103
385	G.H. 199	East side	16	North	0- 6	I	545L	6.4	236
386	G.H. 199	East side	16	North	12-18	I	545L	6.2	103
387	G.H. 202	N.W. cor.	15	East	0- 6	I	535L	6.4	184
388	G.H. 202	N.W. cor.	15	East	12-18	I	535L	6.1	145
389	G.H. 203	South side	Barbilla	West	0- 6	I	545	5.5	232
390	G.H. 203	South side	Barbilla	West	12-18	I	545	5.9	121
391	G.H. 214	East side	17	South	0- 6	IV	73G	5.9	138
392	G.H. 214	East side	17	South	12-18	IV	73G	6.2	138
393	G.H. 227	West side	15-1	North	0- 6	III	525	5.0	280
394	G.H. 227	West side	15-1	North	12-18	III	525	4.9	169
395	G.H. 228	Center	15-1-1	North	0- 6	III	525	5.3	212
396	G.H. 228	Center	15-1-1	North	12-18	III	525	5.5	94
397	G.H. 229	West side	15-1	North	0- 6	III	525	5.3	284
398	G.H. 229	West side	15-1	North	12-18	III	525	5.4	130
399	G.H. 230	East side	15	East	0- 6	I	545	5.3	252
400	G.H. 230	East side	15	East	12-18	I	545	5.4	202
401	G.H. 233	West side	Barbilla	East	0- 6	II	535	5.8	103
402	G.H. 233	West side	Barbilla	East	12-18	II	535	5.9	94
403	G.H. 239	N.W. cor.	Barbilla	East	0- 6	II	535	5.6	165
404	G.H. 239	N.W. cor.	Barbilla	East	12-18	II	535	5.9	94
405	G.H. 241	S. Middle	18	North	0- 6	I	545	5.3	373
406	G.H. 241	S. Middle	18	North	12-18	I	545	5.3	225
407	G.H. 245	West side	15-1	North	0- 6	III	525	5.3	278
408	G.H. 245	West side	15-1	North	12-18	III	525	4.9	94

EXPLANATION OF SOIL SYMBOLS

from.

Robinson, G. H., and Striker, M. M. (30)

The soil types are shown by means of symbols. The symbols used are three digit numbers. The first digit indicates surface texture,the second digit indicates the natural drainage of the soil and the third digit indicates the texture of the subsoil.

The texture classes for both surface and subsoil: (first and third digits) are as follows:

1 - Silty clay
2 - Silty clay loam
5 - Silt loam and very fine sandy loam
7 - Fine sandy loam
8 - Sandy loam
G - Gravel

The second digit indicates natural drainage of the soil profile as follows:

1 - Indicates poor internal drainage
2 - Indicates imperfect internal drainage
3 - Indicates moderately good internal drainage
4 - Indicates good internal drainage

The letter L after a symbol indicates a thin deposit of calcareous material in the soil surface.

The letter B after a symbol indicates a recent flood plain (calcareous surface).

The letter S under a symbol indicates sand deposit at 30 to 42 inches.

The letter G under a symbol indicates gravel deposit at 30 to 42 inches.