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AT RALEIGH

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THE FERTILIZER REQUIREMENTS OF COUNTRIES IN LATIN AMERICA

INTRODUCTION

Soil fertility analyses programs in several Latin American countries were considerably expanded and substantially improved during the past two years. There was a marked increase in the number of soil samples analyzed in 1966 over the number analyzed in 1965 and a further large increase in 1967 over 1966. Most of the increases came through improved soil testing programs. The increased accuracy in soil analyses and greater efficiency in handling the samples and reporting the results, along with some effective educational programs, resulted in more demand for the soil fertility analyses services. Some new laboratories came into operation but the major progress has come through improvement of already existing facilities. Laboratories which were previously analyzing only 10 to 15 samples per day are now processing 65 to 80 samples per day, and several laboratories are averaging over 100 samples per day.

The initial phases of the soil fertility analyses programs in Latin America were centered around developing good laboratories which followed the best techniques and which had a capacity to handle the analyses loads necessary to meet the needs of the areas from which they received samples. Concurrent with the development of the laboratories attention was focused on local research. The validity of soil fertility analyses is based upon research, and the utility of the soil test results is dependent upon a correlation of crop responses to fertilizer with laboratory fertility indices. Additional progress remains to be made by several of the laboratories in efficiency of operations. This can be done by research on methodology, by acquisition of

the better equipment and apparatus, by improvement in organization and by further training of personnel. Greater precision can and will be made in fertilizer recommendations by increased and improved correlation research and by the detection and correction through soil test summaries of unusual crop limiting factors.

The greatest emphasis of the project during the past year was upon research. Particular attention was given to expanding and improving the research correlating soil analyses indices with crop responses to the addition of fertilizer. Also a concerted program is underway to summarize and analyze all past soil analyses data. This latter program is designed to provide preliminary information for natural resource planning, and will indicate where there are voids in fertility information or where there are crop and area biases in the summaries.

Staff Changes

The first resignation from the project took place during 1967. Dr. N.M. Berenyi resigned as Director of the Control Laboratory on April 1 to accept another position. Mrs. Carmen Skerrett, the bilingual secretary, also resigned on April 1 due to poor health.

Dr. A. H. Hunter, the Regional Director in Costa Rica, was returned to Raleigh to assume the duties as Director of the Control Laboratory. Prof. Carlos P. Bickford, who was on the staff of the Soil Science Department of North Carolina State University, undertook the responsibilities as Regional Director in Costa Rica, Panama and Nicaragua.

Mrs. Annette Cash was the bilingual secretary from April 1 until September 30 when she resigned to join her husband who had accepted a position in another city. Miss Maria Elisa Erdmenger of Guatemala accepted the bilingual secretarial position.

The amount of time allocated to the project by Dr. W. V. Bartholomew was increased from two months to nine months per year. Dr. Bartholomew assumes the responsibilities of Assistant Project Director and will be responsible also for the program in Mexico.

Short-Term Assignments

Dr. R. J. McCracken, Head of the Soil Science Department, North Carolina State University, and a well-known soil morphologist, spent a week in Costa Rica reviewing the soil classification program of that country. He also reviewed existing surveys to determine the possibility of bringing all of the information together into a usable form. Suggestions were made to the Ministry of Agriculture of Costa Rica by Dr. McCracken relative to their survey program. A copy of his report is in the Appendix, page 127.

INFORMATION FROM SOIL TESTS

Soil test information has two vital functions in the agriculture of a state or country. First, it provides scientific information on the fertility needs of a particular field or farm and thus enables the farmer to obtain the best economic yields and quality of his crops. Second, when enough samples have been analyzed from a given area, summaries by geographic or physiographic land units provide the state and industry with information needed in natural resource planning. Both objectives are undertaken in the International Soil Testing Project.

Summaries

Soil test summaries prepared in the United States indicate that an average of one sample per 200 to 400 acres of cultivated land will give a good estimate of the nutrient status of soils of a given area. (For example, 1,000

soil samples from an average county of 200,000 to 400,000 cultivated acres.) Only a few areas in Latin American countries have attained a level of one sample per 400 acres of cultivated land but some are approaching it.

Several procedures can be used in the preparation of summaries of soil test data; the most satisfactory approach will depend upon the use that is to be made of the information. Two-way tables showing the relative percentage of samples that are low, medium and high for phosphrous and potassium are very useful in determining the fertilizer grades that are needed for specific areas. If a sufficient number of samples have been analyzed for a specific crop, then two-way tables may be prepared for that crop only.

A nutrient index for each element is another useful approach, especially when preparing information to be superimposed upon soil survey or ecological maps.

Regardless of the final design that may be developed for the summaries, the first step involves assembling the data into a usable form. Since so much data will be utilized in preparing the summaries, it is imperative that this be done by a computer. Much if not all of the computer summaries will be made by the Control Laboratory at North Carolina State University. In order to have a uniform system of recording the data, two standard computer data preparation sheets were prepared for soil test summaries. These are shown in Figure 1 and Figure 2. The headings were translated into Spanish and Portuguese for use in the cooperating countries. The information on the cards has been arranged to fit into a system of computer recommendations whenever a program in some area has progressed to the place where soil test reports and recommendations can be made by a computer program.

As soon as sufficient data have been collected on the computer report

forms, the information will be transferred to punch cards and various types of summaries prepared.

A number of preliminary summaries have been prepared and are presented in this report as a means of indicating several ways of arranging the data to illustrate particular problems in the countries involved. An example is also presented showing how the data can be used to reveal economic advantages.

Guatemala: In Guatemala the results from soil analyses have been related to provinces within the country, to soils or physiographic regions and to crops for which the test was made.

The data from Guatemala were compiled by Ing. Jorge González, Director, National Soil Fertility and Analysis Program, Dirección General de Investigación y Extensión Agrícola, Ministry of Agriculture, Guatemala, and analyzed in cooperation with Dr. J. L. Walker, Regional Director, International Soil Testing Project.

The overall summary of the phosphorus and potassium deficiency status of the soils from Guatemala which were analyzed in 1967 is shown in Table 1. About 75 per cent of the soils tested were low in phosphorus whereas less than 10 per cent were low in potassium. Nearly 55 per cent had low phosphorus but adequate potassium. On the other hand, 16.5 per cent had high phosphorus and high potassium. Only 0.2 per cent had high phosphorus and low potassium. Almost all of the soils needed nitrogen for the production of most crops.

A map of the phosphorus status of the soils by states and provinces is shown in Figure 3 and that for the potassium status of the soils in Figure 4. Another nutrient status breakdown of the soils of Guatemala by crop planted is given in Table 2. Crop production patterns are related to but not always identical with physiological regions.

	1 2	3 4	5 6	7 8 9 10 11 12 13 14	15 16	17 18	19	20 21 22 23 24 25 26 27 28 29	30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52	53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72	73 74	75 76 77	78 79 80
	PROJECT CODE Código de Proyecto	COUNTRY PAIS	LABORATORY LABORATORIO	SAMPLE No. No. del Laboratorio	MONTH MES	YEAR AÑO	No de Tarjeta	FARMERS SAMPLE IDENTIFICATION Identificación de la Muestra	FARMERS NAME Nombre del Agricultor	FARMERS ADDRESS BOX No. Dirección (Calle, Apartado, Casilla, etc.)	DISTRICT/TOWN Distrito	COUNTRY MUNICIPALITY Municipalidad	STATE/PROVINCE Estado o Provincia Sauve de Sample
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3	S T						1						
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5	S T						1						
6	S T						1						
7	S T						1						
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INTERNATIONAL SOIL TESTING PROJECT

FIGURE I. COMPUTER CODE FORM FOR SAMPLE IDENTIFICATION.

	1 2	3 4	5 6	7 8 9 10 11 12 13 14	15 16	17 18	19	20 21 22 23	24 25 26	27 28 29 30	31 32 33	34 35 36 37	38 39 40 41	42 43 44 45	46 47 48 49	50 51 52 53	54 55 56 57	58	59	60 61 62 63 64 65 66 67 68 69 70	71	72 73	74 75 76	77 78 79 80
	PROJECT CODE Código de Proyecto	COUNTRY PAIS	LABORATORY LABORATORIO	SAMPLE No. No. del Laboratorio	MONTH MES	YEAR AÑO	No. de Tarjeta	LABORATORY DATA - DATOS DE LABORATORIO																
								N	P (ppm)	K (ppm)	pH	Ca	Mg	Ca + Mg	Al	O M %	ELECT. COND. mmhos/cm. COND. ELECT.	COLOR	TEXTURA	BLANK BLANCO	ALTURA	MONTO BRUTO DEL CULTIVO	CROP CULTIVO	SOIL ASOCIATION ASOCIACION DEL SUELO
													(m. e. / 100	cc Soil)										
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2	S T						2																	
3	S T						2																	
4	S T						2																	
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INTERNATIONAL SOIL TESTING PROJECT

FIGURE 2. COMPUTER CODE FORM FOR SAMPLE DATA (FERTILITY ANALYSES RESULTS & FIELD MANAGEMENT HISTORY)

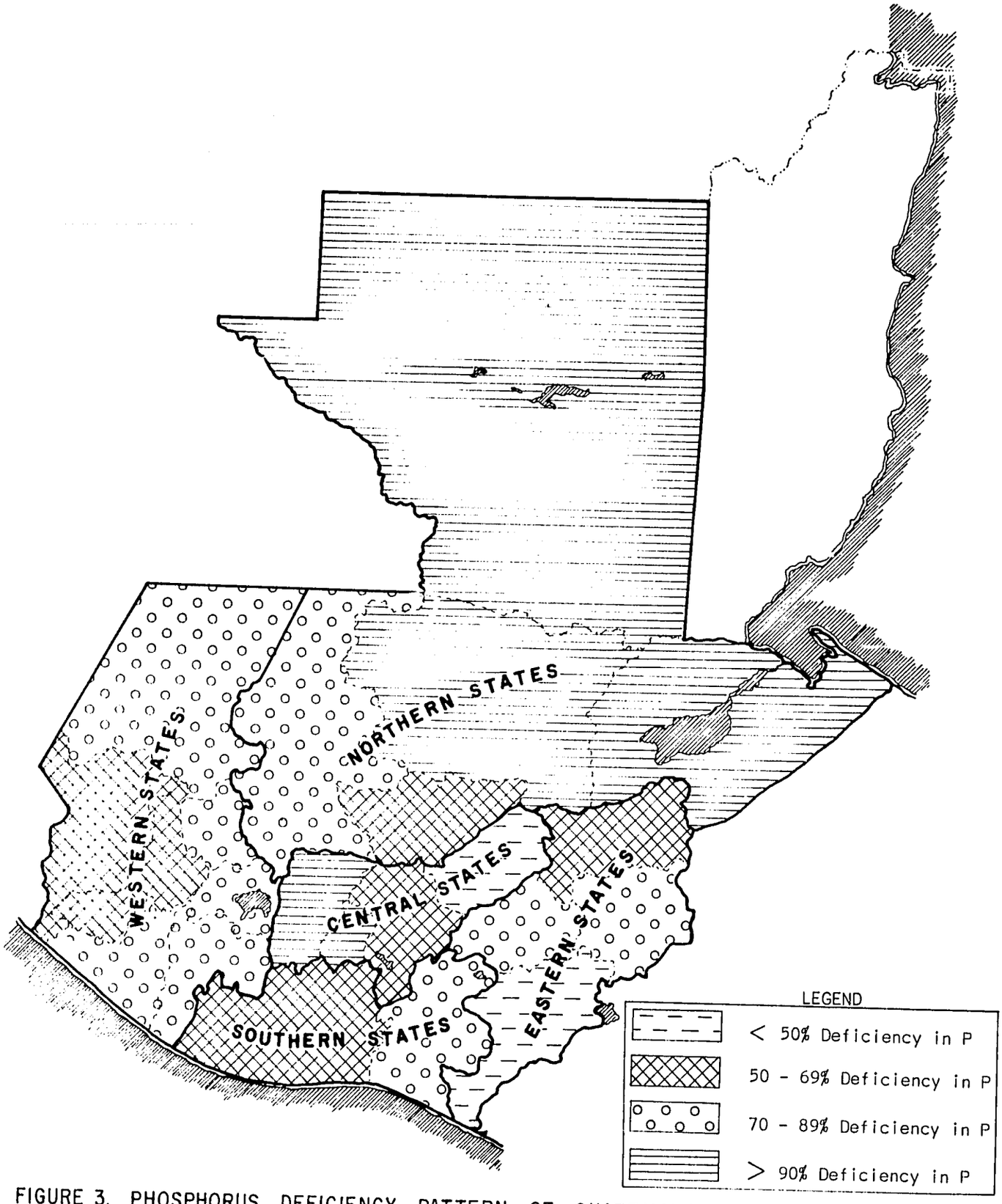


FIGURE 3. PHOSPHORUS DEFICIENCY PATTERN OF GUATEMALA BY REGIONS.

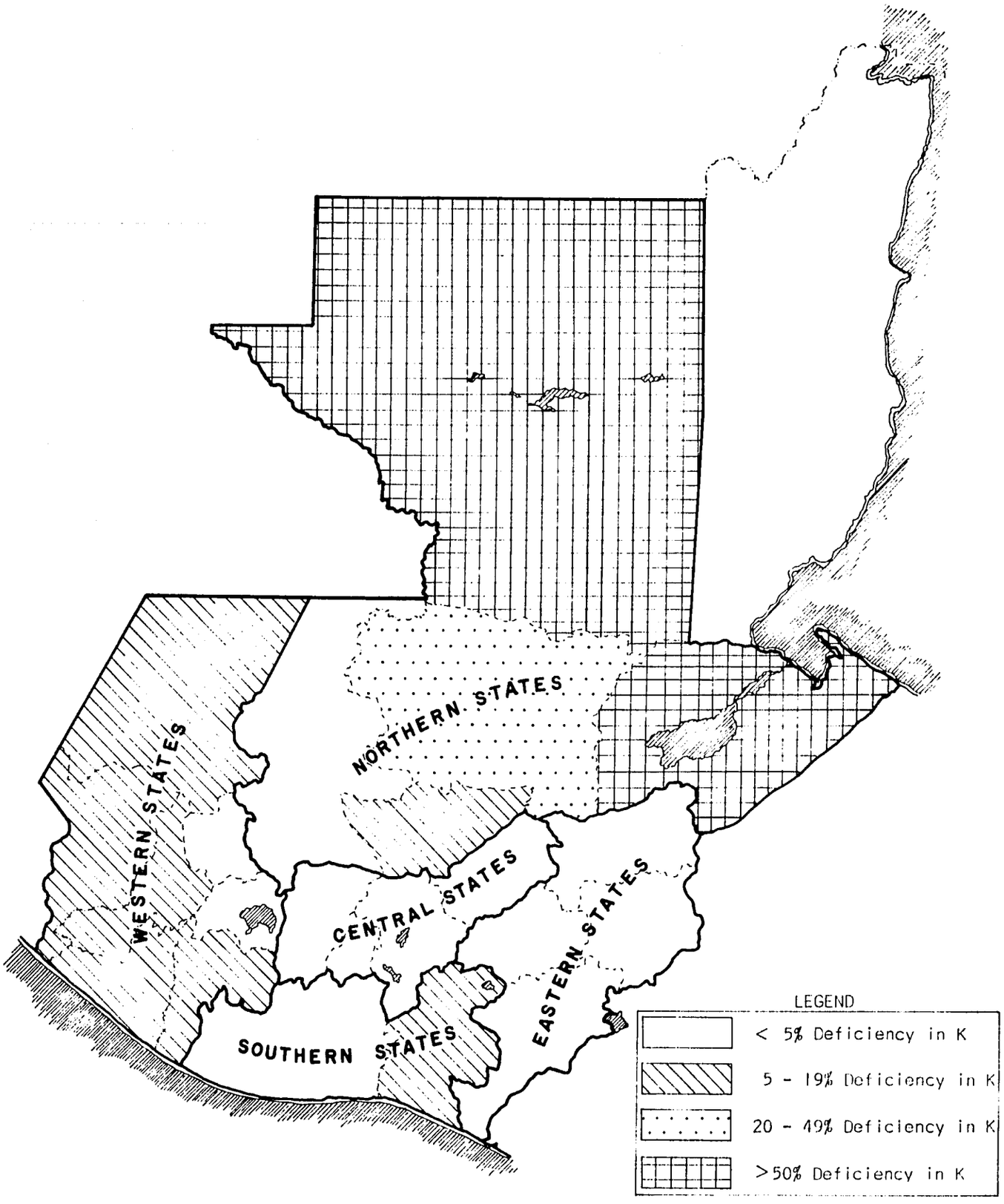


FIGURE 4. POTASSIUM DEFICIENCY PATTERN OF GUATEMALA BY REGIONS.

Table 1. A comparison of the frequency of phosphorus and potassium deficiencies found in soil samples analyzed in Guatemala.

			Potassium (K)*			
			Def. K	Med. K	Adeq. K	All K
Phosphorus (P)	Def. P	No.	771	950	4950	6311
		%	9.2	11.3	54.6	75.0
	Med. P	No.	15	86	453	534
		%	0.2	1.0	5.1	6.3
	Adeq. P	No.	21	159	1386	1566
		%	0.2	1.9	16.5	18.6
	All P	No.	807	1195	6409	
		%	9.6	14.2	76.2	

A summary of soil analyses results by physiographic regions is given in Table 3 and Figure 5. All samples tested were low in nitrogen and required the addition of this nutrient for good crop production. Nutrient deficiencies were most frequent in the Petén-Caribbean Lowlands area and least frequent in the Pacific Coastal Plain.

---

* Symbols and abbrevations are commonly employed in soil analyses reports. The following are used extensively in this report:

Chemical Symbols

P = Phosphorus
K = Potassium
Ca = Calcium
Mg = Magnesium
Al = Aluminum
N = Nitrogen

Soil Fertility Analyses Categories
(levels of availability of nutrients)

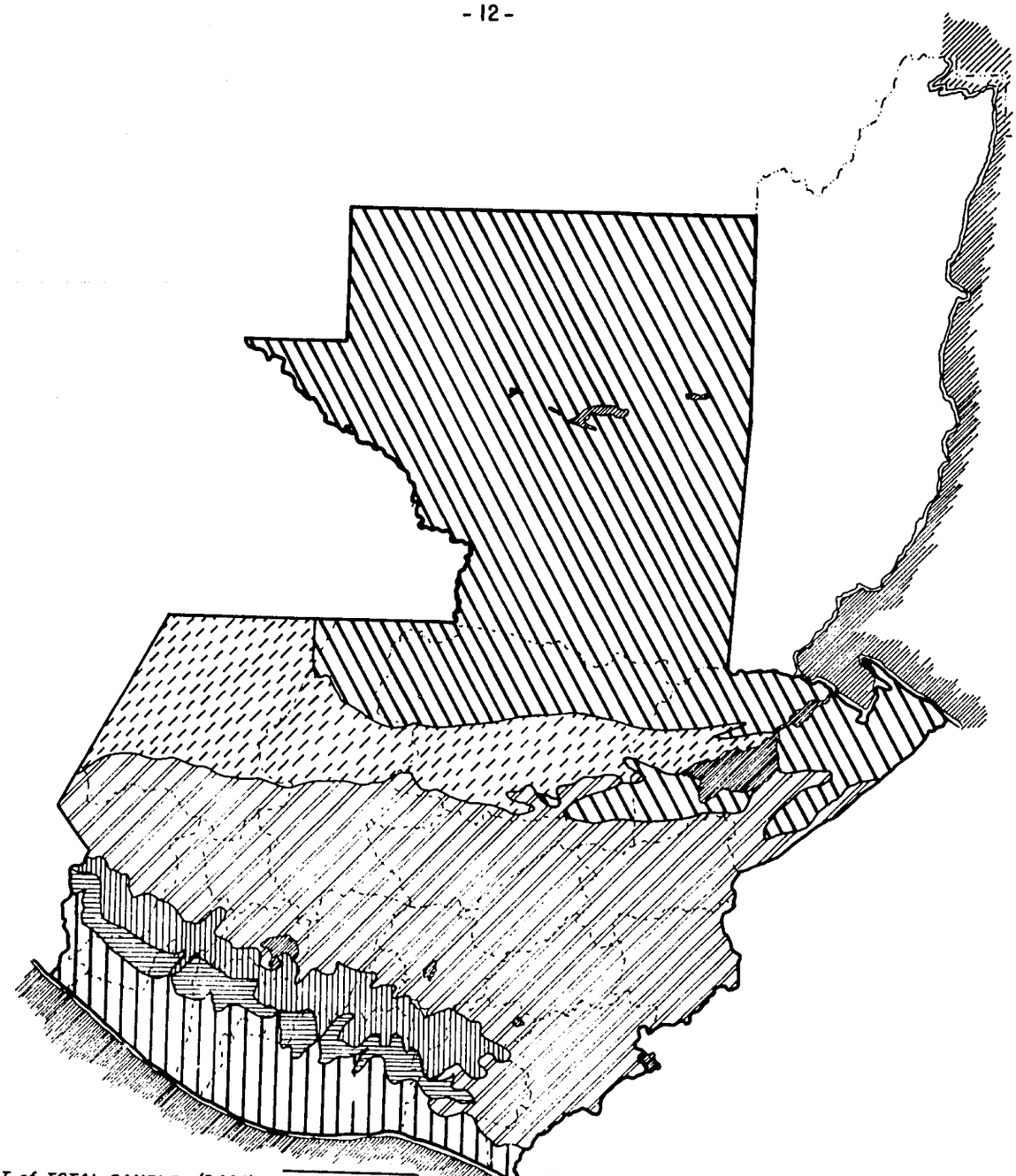
Def. = deficient = low
Med. = medium
Adeq. = adequate = high

Table 2. Soil test results summarized by crops in Guatemala.

Major crops for food	Samples for crop	P		K		P & K		N
		Def.	Med.	Def.	Med.	Def.	Med.	Def.
	No.							
Beans (dried)	68	56	4	1	5	1	0	68
Corn	1183	969	57	30	122	30	6	1182
Fruit	318	230	26	11	22	9	0	318
Pastures	134	110	11	25	23	25	1	134
Potatoes	31	23	3	0	3	0	0	30
Rice	255	234	5	54	105	49	1	255
Vegetables	107	84	7	0	8	0	1	107
Wheat	272	241	14	2	18	2	2	271
Major crops for export								
Bananas	63	46	2	16	27	15	0	63
Coffee	852	692	61	91	215	84	25	849
Cotton	123	90	4	1	12	1	1	123
Essential Oils	36	36	0	0	4	0	0	36
Sugar Corn	108	96	4	3	16	2	0	108

Table 3. Soil test summary data by physiographic regions in Guatemala.

Region	Samples for Reg.	P		K		P & K		P Def. K Adeq.	pH below 5.6
		Def.	Med.	Def.	Med.	Def.	Med.		
	No.								
Entire Country	8420	6320	534	807	1204	771	86	4590	695
Pacific Coastal Plain	602	263	47	46	24	46	1	195	4
Lower Pacific Slope	1171	904	90	113	233	106	11	606	86
Upper Pacific Slope	1315	999	110	82	316	66	35	726	148
Central Alti-Plain Volcanic Mountains	3094	2487	201	31	187	30	25	2313	68
Limestone Hills	303	280	8	38	102	38	1	142	60
Petén-Caribbean Lowlands	793	724	18	438	207	427	6	114	306



PERCENT of TOTAL SAMPLES (8420):	DEFICIENT P	DEFICIENT K	MEDIUM P	MEDIUM K	ADEQUATE P	ADEQUATE K
Pacific Coastal Plain	43.7	7.6	7.8	4.0	48.5	88.4
Lower Pacific Slope	76.6	7.9	8.0	22.1	15.4	70.0
Upper Pacific Slope	77.2 76.0	9.6 6.3	7.7 8.4	19.9 24.0	15.1 15.6	70.5 69.7
Central Altiplain and Volcanic Mountains	80.4	1.0	6.5	6.0	13.1	93.0
Limestone Hills	92.5	12.5	2.6	33.7	4.9	53.8
Petén-Caribbean Lowlands	91.3	55.2	2.2	26.1	6.5	18.7

FIGURE 5. DISTRIBUTION OF PHOSPHORUS AND POTASSIUM IN GUATEMALA BY PHYSIOGRAPHIC AREAS.

El Salvador: The results of soil fertility analyses for 1967 (Figures 6 and 7) have been summarized by Ing. Miguel Menéndez, Director, Ing. José Abilio Orellana and Dra. Julia M. Torres, National Soil Fertility and Analysis Program, Dirección General de Investigaciones Agronómicas, Ministry of Agriculture, El Salvador, and Dr. J. L. Walker, Regional Director, International Soil Testing Project.

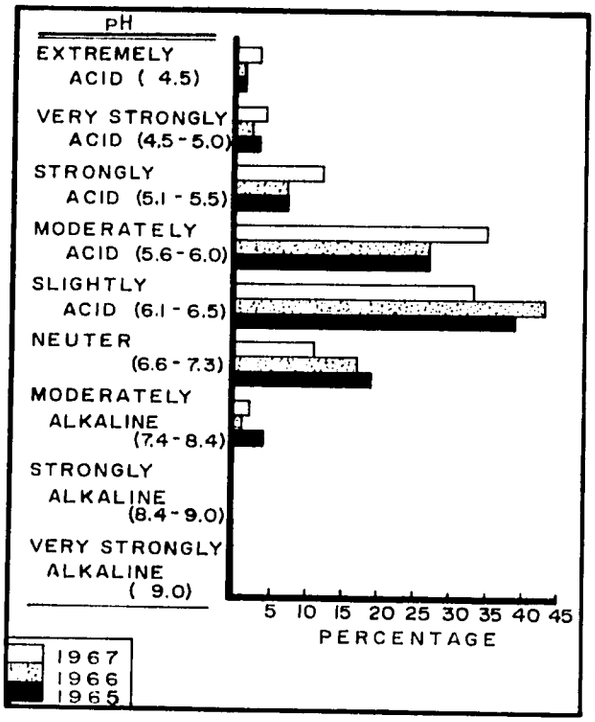
Phosphorus deficiency was found to be widespread. Potassium deficiency was seldom found. Nitrogen deficiency, however, was very extensive and nitrogen fertilizers are needed for the high production of most crops.

Nutrient Status of Farmers Soil Samples Analyzed in 1967*

	Number	Per Cent
Total Analyzed	3495	
Deficient in Phosphorus	1988	59.6
Deficient in Potassium	42	1.2
Medium level of Phosphorus	161	4.6
Medium level of Potassium	171	4.9
Adequate level of Phosphorus	1346	38.5
Adequate level of Potassium	3282	93.9

*Most of the samples came from the Pacific Coastal Plain and the summary may not accurately reflect the nutrient status of the soils of the entire country.

Honduras: The summary prepared by Ing. Carlos Rivera House, Director, Soil Testing Laboratory, Dirección General de Agricultura y Ganadería, Ministry of Natural Resources (Table 4), indicates that about 38 per cent of the soils tested are deficient in phosphorus but only 6.7 per cent are deficient in both phosphorus and potassium. Only 1580 samples are included in this summary and half of these came from the Choluteca area which contains some of the most fertile soils of Honduras. A summary by province is given in Figure 8.



THREE YEARS OF pH BEHAVIOR IN SOILS OF EL SALVADOR

FERTILIZER SUGGESTIONS GIVEN TO THE FARMERS AND EXTENSION AGENTS IN 1967

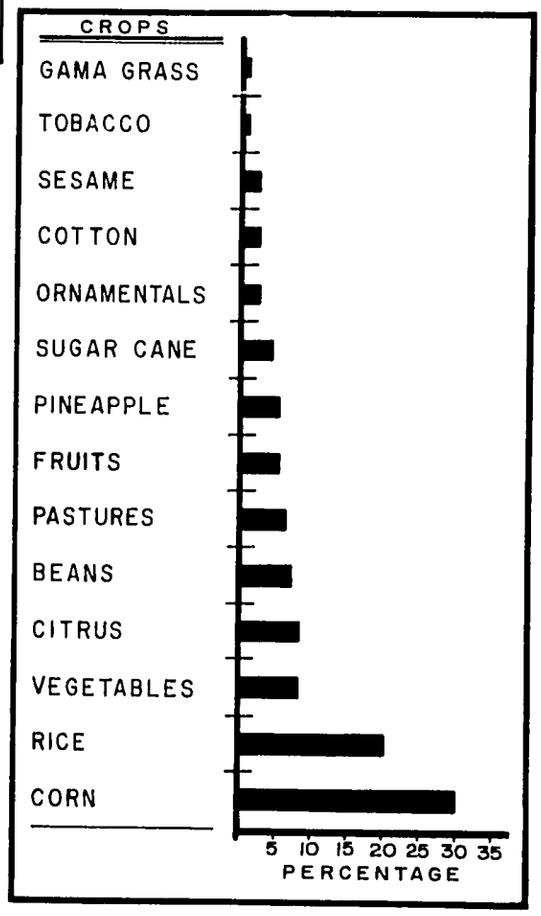
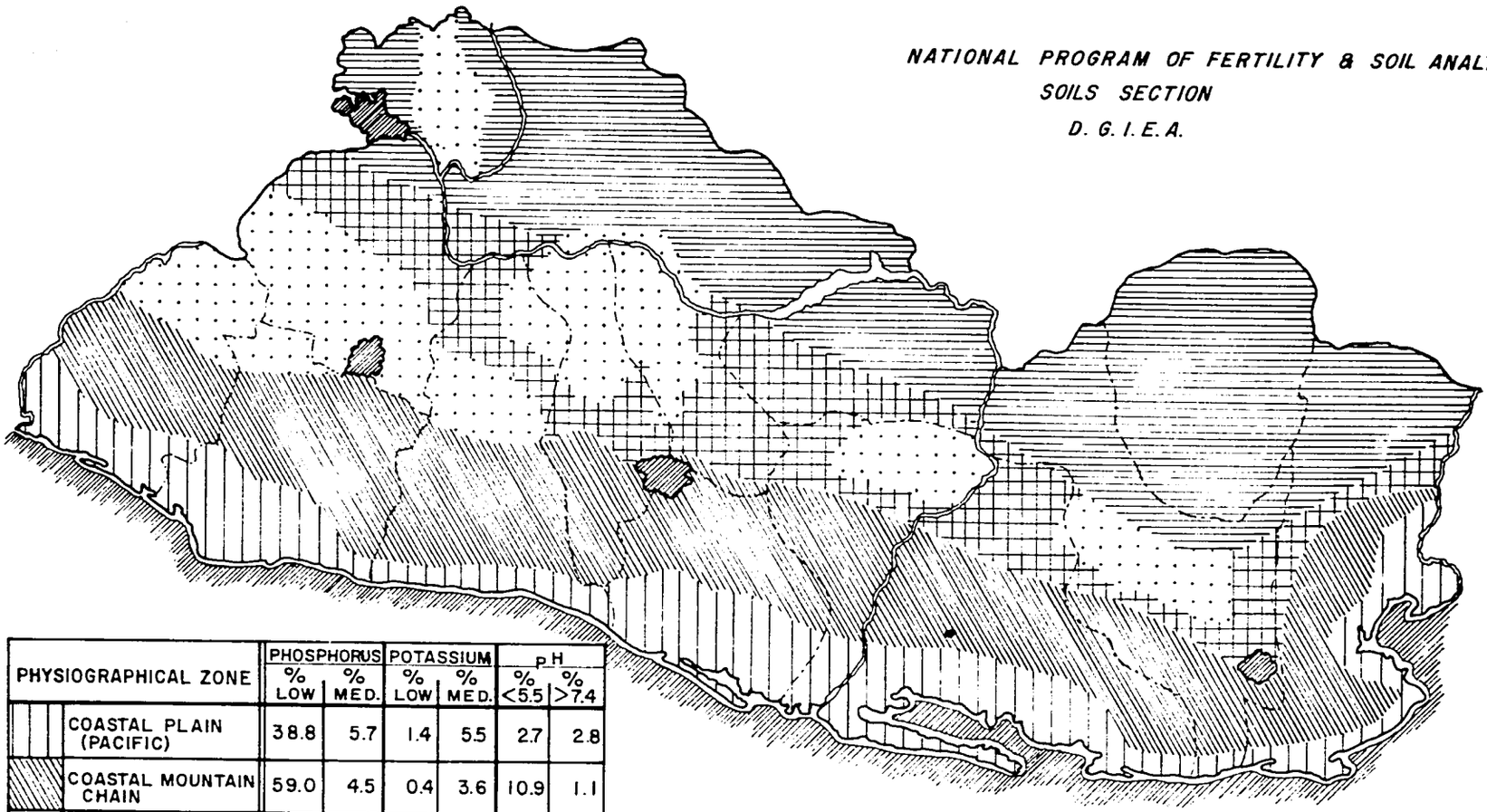


FIGURE 6. Acidity analyses distribution and fertilizer suggestions for El Salvador



PHYSIOGRAPHICAL ZONE	PHOSPHORUS % LOW	PHOSPHORUS % MED.	POTASSIUM % LOW	POTASSIUM % MED.	pH % <5.5	pH % >7.4
COASTAL PLAIN (PACIFIC)	38.8	5.7	1.4	5.5	2.7	2.8
COASTAL MOUNTAIN CHAIN	59.0	4.5	0.4	3.6	10.9	1.1
INTERIOR VALLEYS	55.3	6.2	1.7	4.5	18.0	1.1
MID-COUNTRY MOUNTAINS	53 3	3.2	0.0	2.6	27.0	0.0
NORTHERN MOUNTAINS	68.9	5.0	5.4	16.3	29.5	0.8

FIGURE 7. FERTILITY GUIDE MAP FOR THE REPUBLIC OF EL SALVADOR.

Table 4. Soil analyses summary for Honduras for 1967.

			Potassium Status of Soils			
			Def. K	Med. K	Adeq. K	All K
Phosphorus Status of Soils	Def. P	No.	107	124	352	583
		%	7.0	8.1	22.9	38.0
	Med. P	No.	18	23	65	106
		%	1.2	1.5	4.2	6.9
	Adeq. P	No.	15	53	777	845
		%	1.0	3.5	50.6	55.1
	All P	No.	140	200	1194	1534
		%	9.2	13.1	77.7	

Nicaragua: Summary data for soil analyses in Nicaragua have been compiled by Ing. Ramiro Montes V., Head of the Chemistry Department, Centro Experimental Agropecuario "La Calera". The results for 1967 are tabulated below:

Total Samples Tested	Deficient		Adequate	
	Phosphorus %	Potassium %	Phosphorus %	Potassium %
4,144	41	2	9	49

Soil Acidity	pH Measurement		
Total Samples Tested	Less than 6.0 %	6.0 to 7.3 %	Above 7.3 %
4,144	10	82	8

About 63 per cent of the samples tested were from fields to be planted to corn and 27 per cent for cotton. Other crops from which a number of samples were tested included rice, beans, coffee, bananas, tobacco, sorghum, sesame, sugar cane, vegetables, fruits and forages.

Costa Rica: A soil test compiled by Ing. Oscar Vargas is shown below. Approximately 3,700 samples were included in the summary.

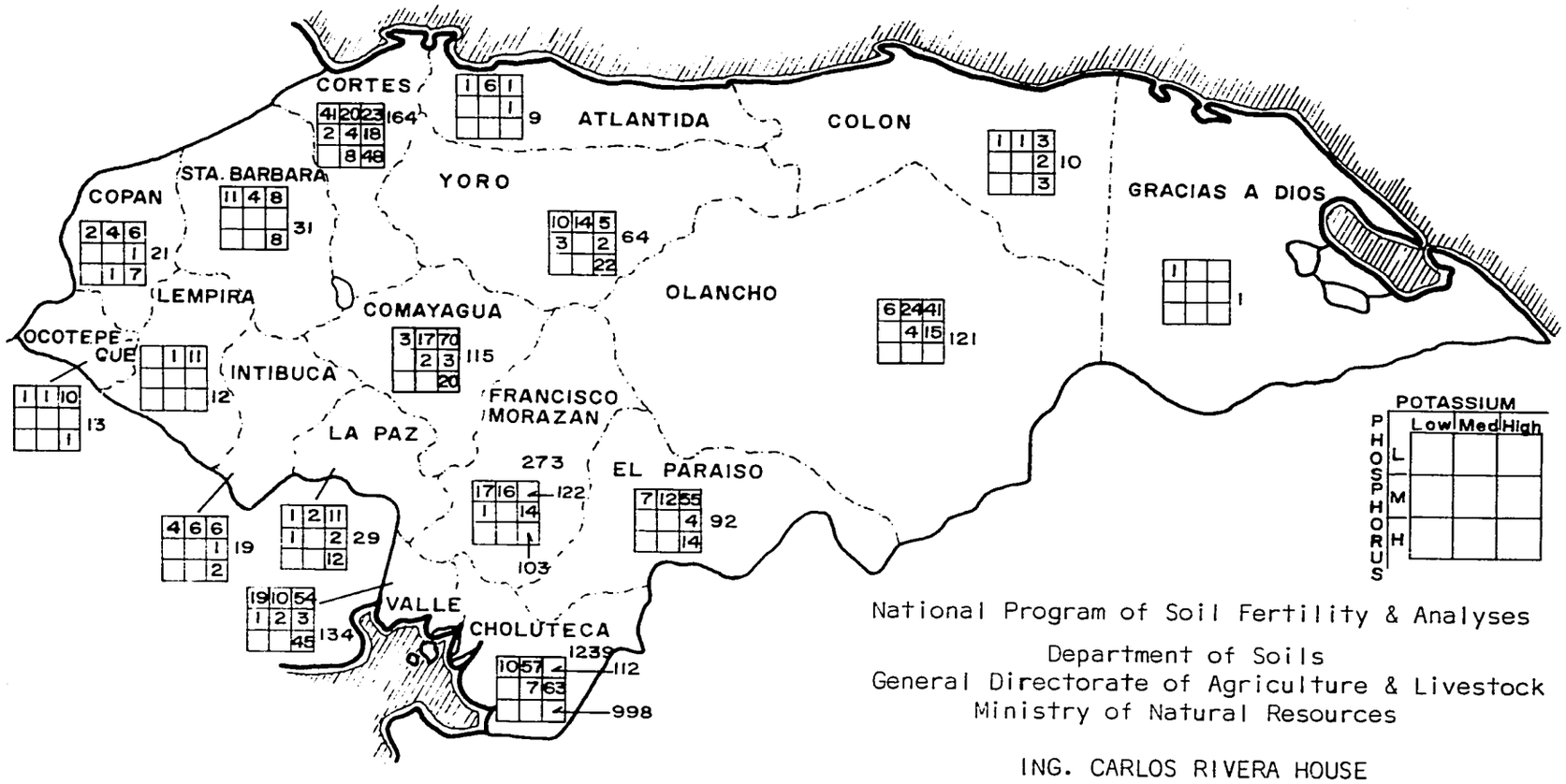


FIGURE 8. PHOSPHORUS AND POTASSIUM LEVELS OF HONDURAS FARMERS' SOIL SAMPLES ANALYZED IN 1967

1. Soil Reaction

Range	% of Samples
4.5 and below	6.3
4.6 - 5.0	13.1
5.1 - 5.5	22.2
5.6 - 6.0	31.6
6.1 - 6.5	17.4
6.6 and above	9.4

2. Available Phosphorus

Code	Range ppm	% of Samples
Low	below 18	56.4
Medium	18 - 40	24.4
High	above 40	19.2

3. Exchangeable Potassium

Code	Range ppm	% of Samples
Low	below 150	37.2
Medium	150 - 300	26.7
High	above 300	36.1

4. Calcium

Code	Range ppm	% of Samples
Low	below 1000	37.5
Medium	1000 - 2500	28.6
High	above 2500	33.9

5. Magnesium

Code	Range ppm	% of Samples
Low	below 120	26.2
Medium	120 - 300	27.6
High	above 300	46.2

6. Aluminum (2,614 samples included)

Code	Range ppm	% of Samples
Low	below 20	74.6
Medium	20 - 50	10.2
High	above 50	15.6

7. Iron (2,306 samples included)

Code	Range ppm	% of Samples
Low	below 20	52.2
Medium	20 - 50	22.4
High	above 50	25.3

It is interesting to note that more than 40 per cent of the soils tested in Costa Rica were quite acid in reaction (pH less than 5.5) and about one-fourth were near neutrality. Over half of the soils were deficient in phosphorus with about 20 per cent having an adequate amount. The distribution of samples between low and high potassium was about the same--37 and 36 per cent respectively.

Panamá: All of the samples tested during 1967 have not yet been summarized. A summary of the results of the first three months during which 396 samples were analyzed indicated that about 70 per cent of the soils were deficient in phosphorus and 35 per cent deficient in potassium. These deficiency figures are about 5 per cent higher than the results for 1966. About 13 per cent had sufficient phosphorus and about 30 per cent contained an adequate amount of potassium.

Colombia: A summary of preliminary work in Colombia is shown in Table 5. The data are summarized by regions within the country.

Although the number of samples tested is relatively small, the summary indicates that phosphorus deficiencies are rather widespread and the greatest needs for lime are in the mountains, Sabana de Bogota and the Llanos. Potassium appears most likely to be deficient along the Atlantic Coast, in the lower Magdalena River Valley, and in the Llanos.

Perú: The number of samples included in the summary from the various regions of Perú is not sufficient to give an accurate picture of the nutri-

Table 5. Soil test summary for Colombia of farmer samples tested in 1967. (Prepared by Gildardo Marin, Soils Section, ICA.)

Region	Altitude Meters	No. of Samples	pH			O. M.			P ppm			K me/100 g		
			<5.7	5.7-7.3	>7.3	<5%	5-10%	>10%	0-20 Low	20-40 Med.	>40 High	<0.15 Low	.15-.3 Med.	>.3 High
			% samples			% samples			% samples			% samples		
Cordilleras Andinas	500-5,700	487	64	33	3	44	28	28	73	11	16	21	32	47
Sabana De Bogota	2,600-2,750	44	57	43	-	25	26	39	39	18	43	4	14	82
Valle Del Alto Magdalena	300- 600	100	22	73	5	83	9	8	48	18	34	12	37	51
Valle Del Cauca	950-1,100	1,127	16	74	10	70	27	3	44	25	31	7	22	71
Costa Del Pacifico	0- 200	20	20	75	5	95	5	-	70	30	-	5	25	70
Costa Atlantica	0- 500	67	7	78	15	96	4	-	28	11	61	31	18	51
Valle Del Bajo Magdalena	0- 300	53	13	70	17	94	4	2	38	19	43	30	28	42
Llanos Orientales	200- 300	49	100	-	-	80	18	2	88	2	10	39	39	22
Selva Amazonica	100- 500	17	94	6	0	41	24	35	94	6	-	18	76	6

tive needs of the soils of the country but, as in Colombia, problem areas can be defined. Likewise a trend can be noted in the deficiencies. The soils in the higher precipitation areas generally are less fertile (Figures 9 and 10) than soils from other regions of Perú. However, the Central Coastal region has more deficiencies in potassium than anticipated from previous soil management experience.

Brazil: The first three laboratories to be established in Brazil (Rio, Campinas, and Recife) have so far analyzed a total of about 60,000 samples. On the basis of one sample per 200 hectares of cultivated land, sufficient data are now available to warrant the preparation of useful soil test summaries for the States of São Paulo, Rio de Janeiro, Alagõas, Pernambuco, and Paraiba. These data are expected to be transferred to punch cards and machine processed within a few months. With ten more laboratories now in operation, sufficient data should be available by the end of 1968 to warrant the preparation of preliminary soil test summaries for the States of Rio Grande do Sul, Parana, Minas Gerais, and Bahia. The remaining areas (including possible gaps in the above states) should be adequately sampled by the end of 1969.

The above refers to fertility data on Brazil's thirty million hectares of cultivated land, located mainly in the eastern third of the country, usually within 300 miles of the Atlantic Coast. Preliminary, exploratory maps resulting from an USAID/USDA agreement with the Ministry of Agriculture indicate the existence of three hundred million hectares or more of potential agricultural land in the northwestern two-thirds of the country. The survey of this area has included relatively intensive "fertility" sampling, keyed to mapping units. Results will be published as part of the overall Brazil-United States agreement. However, preliminary summarization of 860 samples indicate that 95 per cent of

AGRARIAN ZONE NUMBER	NUMBER OF SAMPLES TESTED	PERCENT (%) OF SOIL SAMPLES LOW IN:	
		P	K
1	189	46	15
2	123	46	7
3	323	51	26
4	550	48	31
5	136	62	8
6	143	66	4
7	1,538	70	2
8	60	80	85
9	17	70	65
10	132	63	61
11	733	51	45
12	59	31	5
	4,003		

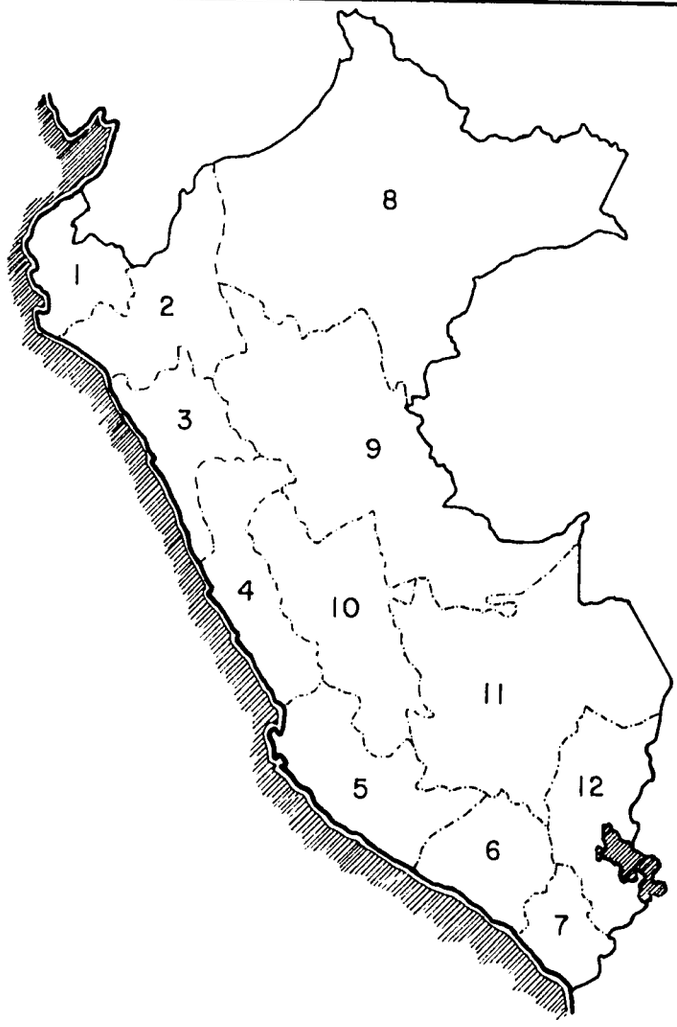


FIGURE 9. A SUMMARY BY AGRARIAN ZONE OF SOIL FERTILITY MEASURED IN SOIL TESTS OF PERU.

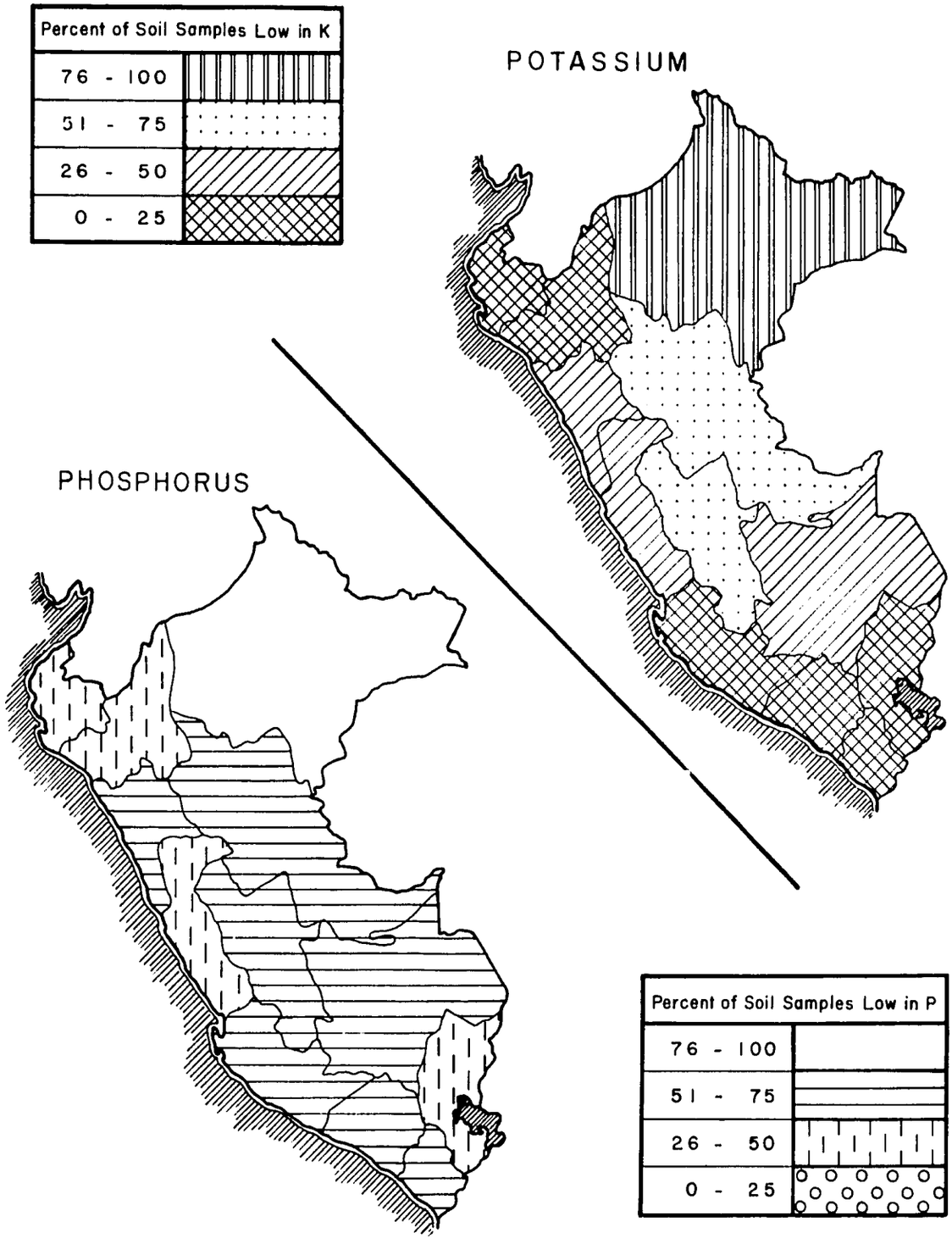


FIGURE 10. Phosphorus and Potassium relationship in soil fertility studies of Peru.

the soils are low in phosphorus and 40 per cent are low in potassium. Although most of the soils are acid, they only need about two tons of lime per hectare for high production. Also, an International Soil Testing Project-sponsored laboratory study has indicated that P fixation is not a particularly serious problem in the soils of Northwest Brazil.

The fertility survey by regions in the State of Pernambuco, Brazil is shown in Figure 11. Where sufficient data were not available, the areas are left clear.

The Cost of Making the Wrong Decision on the Use of Fertilizers

The objective of soil testing is to gain information to use as a guide in the proper use of fertilizers, lime and other soil amendments in order to obtain the greatest economic return for the money invested in crop production. An excellent example of the value of soil test information is shown in Tables 6 and 7. Presented in Table 6 are data compiled in the Coastal region of Perú showing the response obtained from nitrogen and phosphate fertilizers applied to corn. The average return for all of the 112 small and medium sized operation farmers included in the survey was $1.88 per dollar invested for nitrogen and $1.58 per dollar invested for phosphorus. This would indicate that it paid all of the farmers to apply both nitrogen and phosphate to their corn. However, when the fields were separated into those low in phosphorus and those high in phosphorus, a different economic picture is presented. On the fields that were low in phosphorus, a return of $2.13 could be obtained for each dollar invested in phosphate, with $1.48 return for each dollar invested in nitrogen. The reverse is true of the soils high in phosphate; only $.66 was returned for each dollar spent for phosphate but $2.31 could be returned for each dollar spent for nitrogen. The largest return per dollar invested was for nitrogen

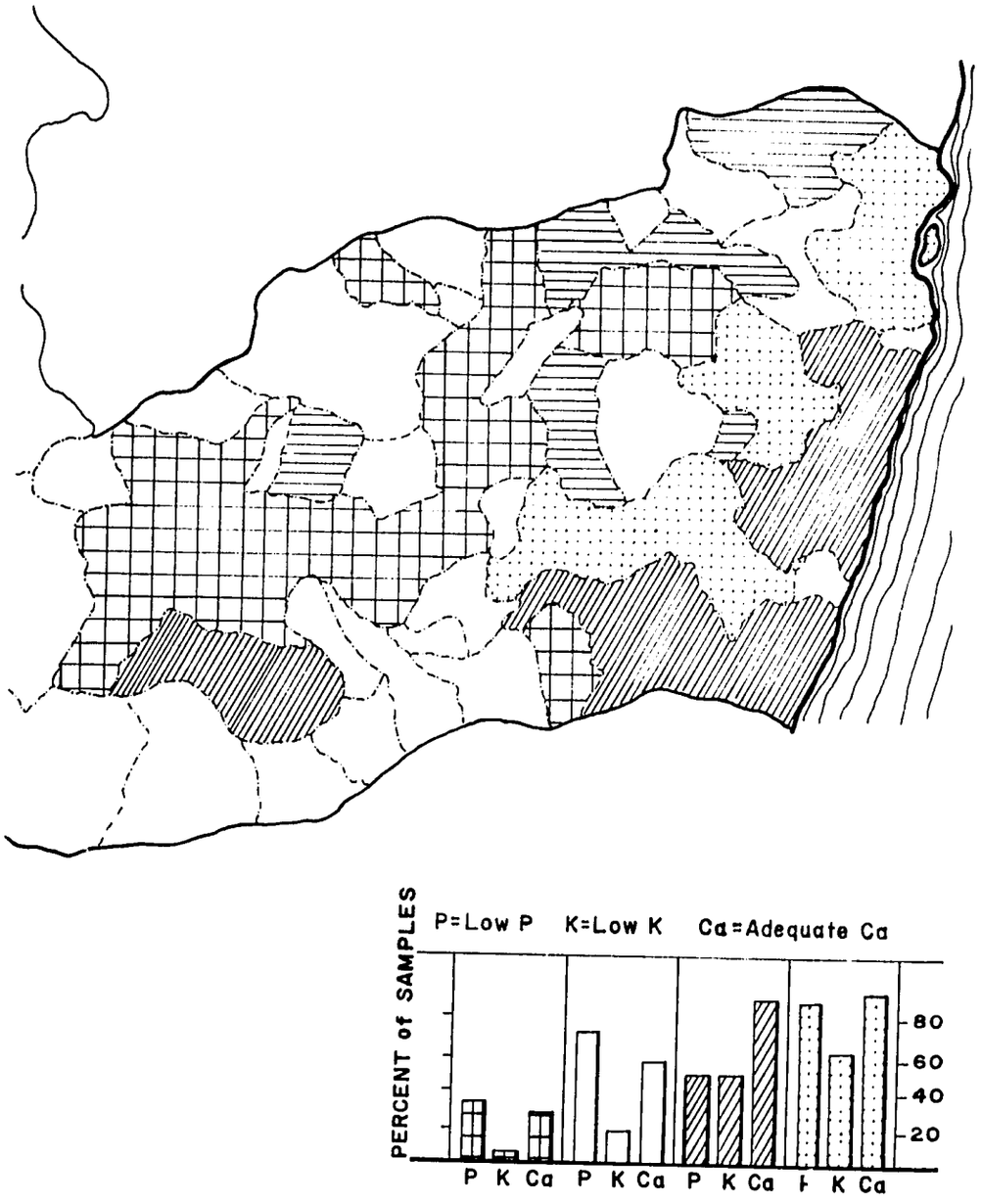


FIGURE 11. Soil fertility map of a portion of the State of Pernambuco, N. E. Brazil (1800 samples)

Table 6. Response of corn on the coast of Perú to nitrogen and phosphorus fertilization as a function of soil phosphorus level measured by soil test.[1/]

Fertilizer applied	Corn yield	Increase over check		Cost of fertilizer applied[3/]		Net profit from fertilizer		Return per dollar invested in fertilizer	
$N-P_2O_5-K_2O$		Yield	Crop value[2/]	N	P_2O_5	N	P_2O_5	N	P_2O_5
kg/ha	kg/ha	kg/ha	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$
All Soils									
Check	1435	-	-	-	-	-	-	-	-
140-0-0	3011	1576	$ 78.80	$ 42.00	-	$ 36.40	-	$ 1.88	-
142-52-0	3428	1993	$ 99.65	$ 42.60	$ 13.42	$ 36.40	$ 7.53	$ 1.88	$ 1.58
Soils Low in P by Soil Test									
144-0-0	2715	1280	$ 64.00	$ 43.20	-	$ 20.80	-	$ 1.48	-
149-65-0	3406	1971	$ 98.55	$ 44.70	$ 16.25	$ 20.80	$16.80	$ 1.48	$ 2.13
Soils High in P by Soil Test									
136-0-0	3318	1883	$ 94.15	$ 40.80	-	$ 53.35	-	$ 2.31	-
135-40-0	3450	2015	$100.75	$ 40.50	$ 10.00	$ 53.35	$-3.10 (less)	$ 2.31	$ 0.66

1/ Data supplied by Plan Costa (S.I.P.A., N.C. State University Mission, USAID/Perú) as part of survey of small and medium-sized operation farmers receiving supervised loans. Data summarized from 112 individual field observations in corn.

2/ Value of corn calculated @ U.S. $0.05 per kg.

3/ Cost of fertilizer calculated @ $0.30 per kg N, $0.25 per kg P_2O_5.

Table 7. Response of potatoes in Sierra of Peru to phosphorus fertilizer as a function of soil phosphorus level measured by soil test.[1/]

Rate of P applied	Yield of potatoes	Increase over check yield	Increase over check crop value[2/]	Cost of P	Net profit from P	Net return per dollar invested
kg/ha P_2O_5	kg/ha		U.S.$	U.S.$	U.S.$	
All Soils						
0	15,615	-	-	-	-	-
80	20,520	4,905	$ 98.10	$ 24.00	$ 74.10	$ 4.09
160	22,465	6,850	$137.00	$ 48.00	$ 89.00	$ 2.85
Soils Low in P by Soil Test						
0	10,930	-	-	-	-	-
80	19,640	8,710	$174.00	$ 24.00	$150.00	$ 7.25
160	22,830	11,900	$238.00	$ 48.00	$190.00	$ 4.96
Soils Med.-High in P by Soil Test						
0	20,300	-	-	-	-	-
80	21,400	1,100	$ 22.00	$ 24.00	$ -2.00	$ 0.91
160	22,100	1,800	$ 36.00	$ 48.00	$-12.00	$ 0.75

1/ Averages of 8 years of potato research carried out by S.I.P.A.-N.C. State University Mission in Peruvian Sierra.
2/ Potato value calculated at $0.02 per kg at field.
3/ Fertilizer cost calculated at $0.30 per kg P_2O_5 at field.

on the soils that were high in phosphorus. The next highest return was for phosphate on soils low in phosphorus. With the information gained from soil tests the farmers could do much better in selecting the fertilizers which would give them the greatest return for their investment.

Presented in Table 7 are data taken from eight years of research work with phosphorus studies on potatoes in the Sierra region of Perú. If 80 kg per hectare of phosphate is applied to all the soils, the average return per dollar invested is $4.09 but, if the fields are separated into the low and high classification, a much different picture is obtained. On the low phosphorus soils, a return of $7.25 was obtained for each $1.00 invested but only $.91 was returned on the high soils.

Making the right decision in the use of fertilizers not only is profitable to the farmer but can also have a marked influence on the economy of the country. This is illustrated in the calculations in Table 8. The preliminary summaries indicate that about 55 per cent of the land area of the Coastal Plain region and about 50 per cent in the Sierra region needs phosphorus for good crop production. If the fertilizer is applied to those soil areas which need it and not to fields which do not need it, the increase in crop production would have a value of about 14 million dollars. To acquire the needed information through soil analyses to permit the farmers to make the right decisions represents an investment of about $140,000. This calculation does not include the losses which are likely to occur from applying phosphate to soils already high in phosphorus. Neither does it include the increased effectiveness of nitrogen in crop production when used properly in relation to phosphorus. Moreover the proper use of lime and potassium would further increase the estimated total benefit from the proper use of fertilizer.

Table 8. Cost of a wrong decision in fertilizer use and how good soil tests can prevent it.

Statistic Under Evaluation	Corn Peruvian Coast	Potatoes Sierra Peru
Number hectares under cultivation	100,000	250,000
Per cent soils low in P (soil test summary of Peru)	55% (zones 1-7)	50% (zones 10,11,12)
Number hectares requiring high rate of P fertilization (soils low in P)	55,000	125,000
P fertilization recommended in low P soils	120 kg/ha	160 kg/ha
Total phosphorus needs: Tons P_2O_5	6,600	20,000
Cost of fertilizer (does not include maintenance P)	$1,650,000 (@ $0.25 kg)	$6,000,000 (@ $0.30 kg)
Return on fertilizer dollar: (from tables 2 and 3)		
Without regard to soil test	$1.58	$2.85
With soil test for P	$2.13	$4.96
Return on fertilizer investment P:		
Without regard to soil test	$2,607,000	$17,100,000
With soil test for P	$3,514,500	$29,760,000
Increase in return on investment in P when soil test recommendations employed	$907,500	$12,660,000
Cost of soil test (1 sample per 2.5 ha $1.00 per P test)	$40,000	$100,000
Increase in net return when soil test used = cost of wrong decision <u>if soil test not used</u>	$867,500	$12,560,000

Potassium Deficient Areas in the Coastal Region of Perú

The Coastal region of Perú is arid and most of the crop land is irrigated. The soils are not highly weathered and are very high in potassium. Potash fertilizers are not generally recommended for that part of the country. Soil tests identified an area in the Central Coastal region (Canete area) in which potassium is relatively low in the soils. The information has been called to the attention of the Canete Experiment Station and field trials will be initiated to study further the deficient area.

Secondary Nutrient Deficiencies in Costa Rica

Soil samples were collected from a pineapple producing area in Costa Rica that was experiencing poor plant growth. The samples were analyzed in the laboratory and potted plant studies initiated by Mr. John Mannix, following the guide outlined in Technical Bulletin No. 3, International Soil Testing Series. The tests indicated the soils were low not only in phosphorus and potassium, but in calcium, magnesium and sulfur too. In the potted plant studies, a response was obtained from application of phosphate and potash, but only after calcium, magnesium and sulfur were applied.

Extreme Phosphorus Deficiency in Rice Area of Guatemala

A national rice program in a new rice producing area of Guatemala is being developed through a cooperative program between the Ministry of Agriculture of Guatemala and the USAID Mission. Four soil series are involved in the region and 175 soil samples were taken to ascertain the fertility requirements. The results indicated that 98 per cent of the samples tested were very low in phosphorus and 26 per cent low in potassium. Five per cent were calcareous (pH above 7.5) but 14 per cent were acid (pH below 5.6) and needed liming.

The severe phosphorus deficiency in this new area was not anticipated but, thanks to soil analyses, proper fertilization and liming could be followed to assure good rice production. Cooperative soil fertility-rice variety trials were initiated in the area also to follow-up the information gained from the soil analyses.

Soil Fertility and Liming Requirements of Northwest Brazil

Fertility analyses of exploratory survey soil samples from the great land areas of interior tropical and subtropical Northwest Brazil have provided a good general appraisal of the fertility status and thus the potential fertilizer needs of the area. The need for phosphorus is extensive and often appears critical for crop production. Potassium need is widespread but generally not as critical as phosphorus. Lime needs are widespread and general but the quantities needed per hectare are not high. Other needs for secondary and micronutrients will need to be determined by detailed studies of specific crops in specified areas.

RESEARCH STUDIES

Correlation of Soil Test with Plant Growth

Primary and Secondary Nutrients: Soil fertility analyses (soil testing) is concerned largely with determining the plant availability in soil of phosphorus, potassium, calcium, magnesium and nitrogen. Therefore, greatest emphasis on correlation studies has been on relating the soil analyses results to responses in growth by the addition of these elements. Most of the calcium and magnesium studies have been made in relation to soil acidity and to overcoming the detrimental effect of exchangeable aluminum upon plant growth.

Soil scientists of several countries are engaged in conducting correlation studies. Most of the studies follow the procedures outlined in Technical Bulletin No. 3 of the International Soil Testing Series entitled "Soil Test Interpretation Studies: Laboratory and Potted Plant." Experiments are underway and at various stages of completion in Perú, Ecuador, Bolivia, Venezuela, Colombia, Brazil, Panamá, Costa Rica, El Salvador and Guatemala. Some experience and guidance are usually helpful in conducting good potted plant trials and the necessary techniques are being mastered in the various countries. The soil samples are first analyzed for nutrient levels, exchangeable acidity, and for phosphorus fixation. Soil treatments for potted plant and field experiments are based upon the results of soil analyses.

Brazil: Critical soil test levels for phosphorus (P) and potassium (K) have been tentatively established in Brazil and used uniformerly by the several laboratories cooperating in their National Soil Testing Program. Also lime recommendations are now largely based on a measure of soil acidity and exchangeable aluminum determined by the method outlined in Technical Bulletin No. 4 of the International Soil Testing Series. The P and K critical levels were first established in 1964 on the basis of an International Soil Testing analysis of several hundred field trials with a wide variety of crops and soils. Considerable variation was found when the results from these largely unreplicated trials by many organizations were plotted and studied by the Cate-Nelson method (Technical Bulletin No. 1 of the International Soil Testing Series). However, the resulting critical levels were nearly identical with the critical levels already accepted semi-intuitively by the leading Brazilian research institutions. Also the critical levels found in the study of old experiments were very close to those established by the use of similar soil

test methods in the Southeastern United States. (The critical levels are 10-11 ppm P and 45-46 ppm K using Mehlich's extractant with a 1:10 soil extracting solution ratio.) Since 1964, a number of scattered pot and field trials in various parts of Brazil have given no consistent indication that these critical levels vary appreciably among soils, climates or crops. However, in order to further verify and test the results from the older experiments and to delineate soil and crop situations which need further research attention, the institutions which are cooperating in the Brazilian National Soil Testing Program plan to carry out standardized nationwide pot experiments in 1968, using the procedure outlined in Technical Bulletin No. 3 of the International Soil Testing Series as a guide.

The results from a pot experiment conducted by the IPEANE Research Institute in Recife are shown in Figure 12 for greenhouse pot trials and in Figures 13 and 14 for field trials.

Perú: SIPA and the Agrarian University have cooperated in conducting correlation studies. A number have been completed by students for their thesis work. Some of the studies were reported in Technical Bulletin No. 3 of the International Soil Testing Series.

Patio for potted plant studies at La Molina, Perú. Dr. Quevedo and Ing. Velásquez inspect an NPK factorial experiment on bean fertility.

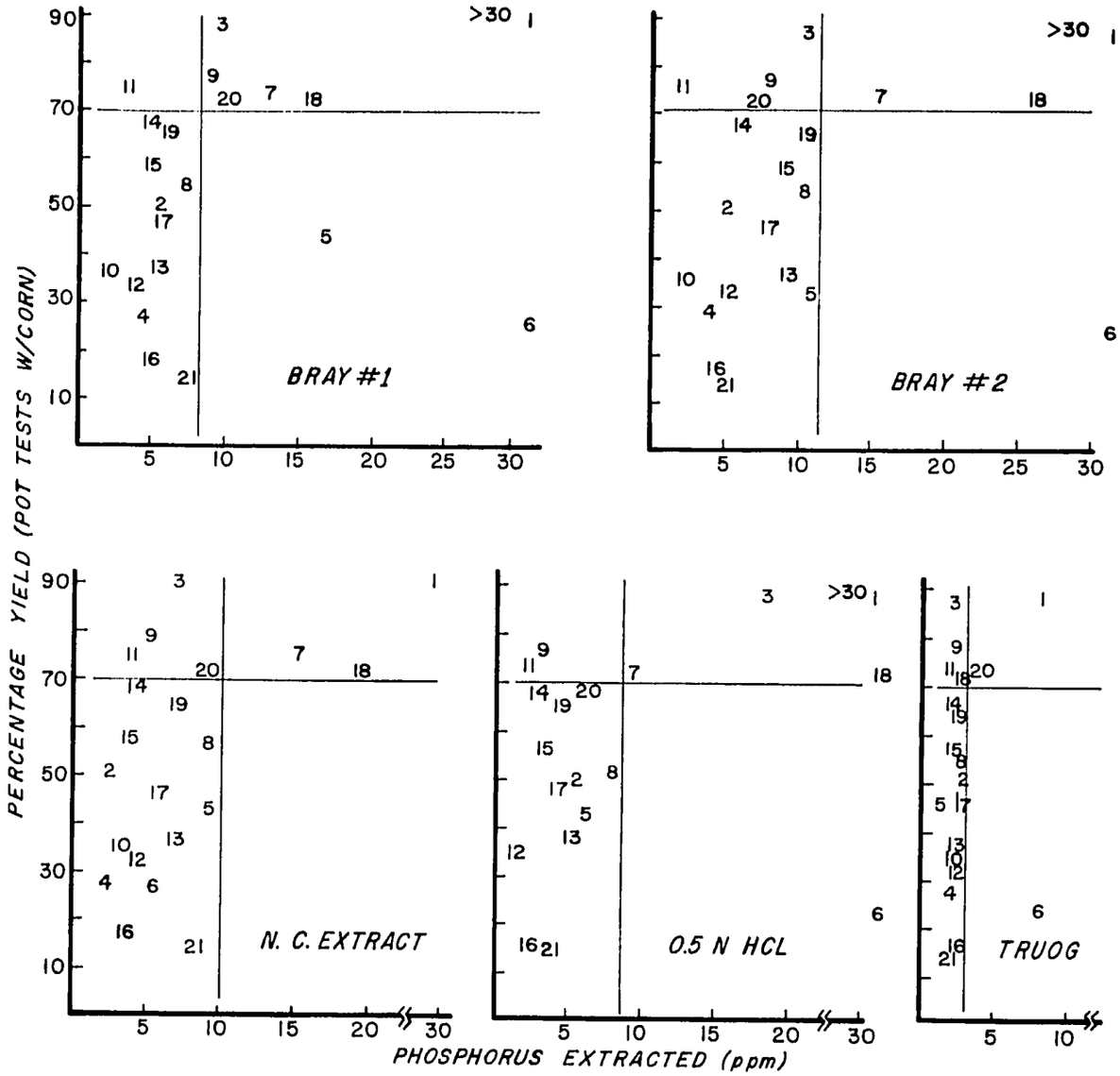


FIGURE 12. Comparison of greenhouse pot trials with five soil analyses methods (IPEANE, Recife, Brazil).

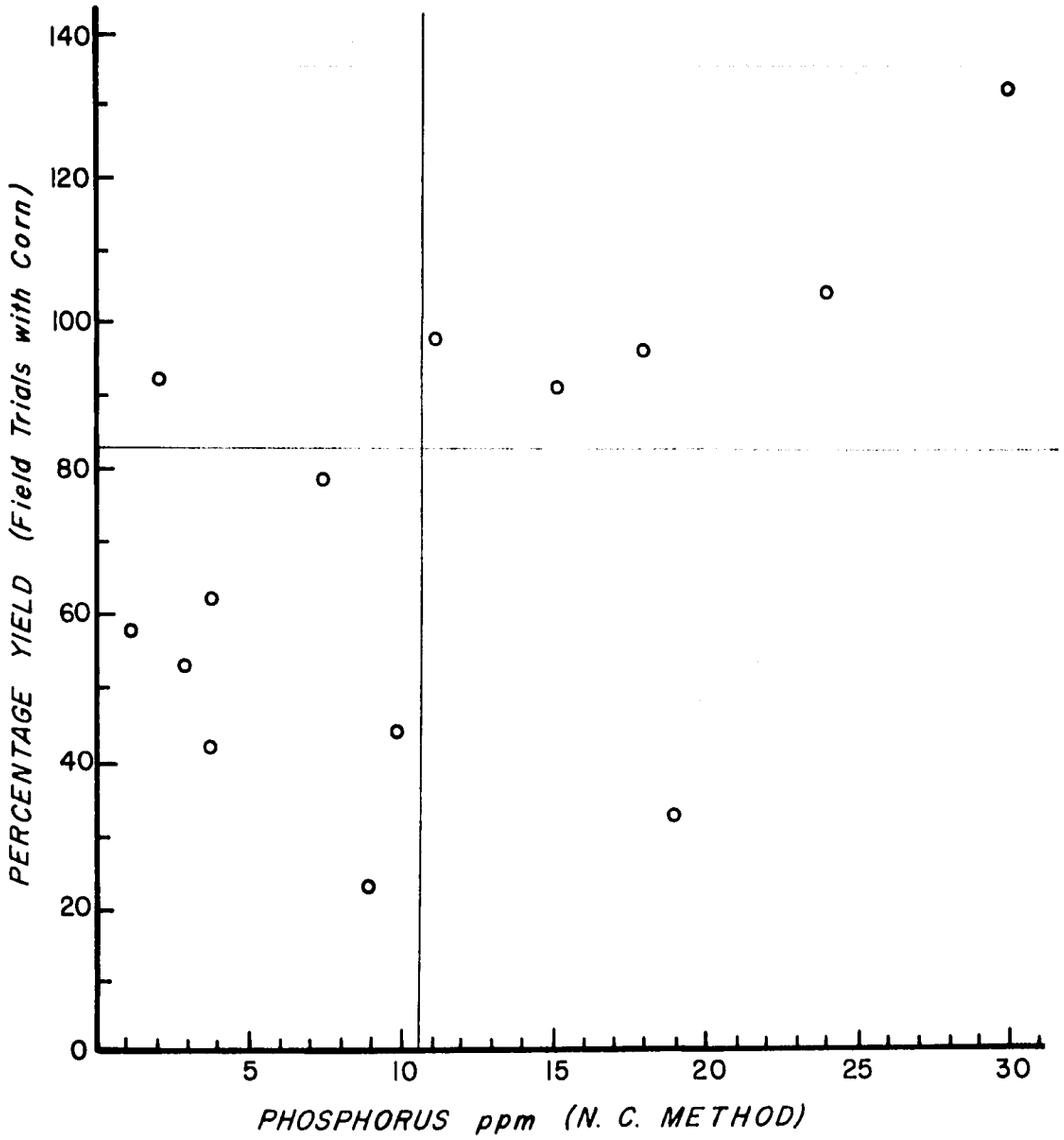
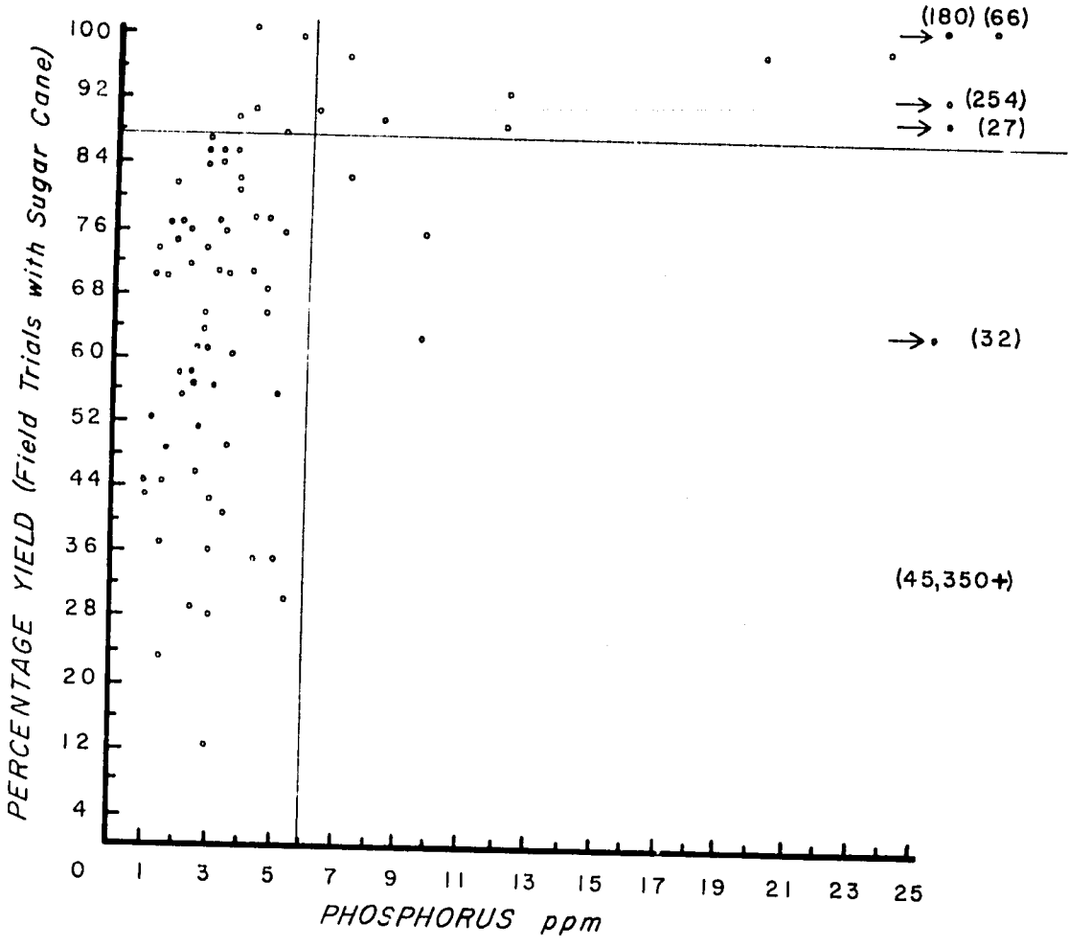


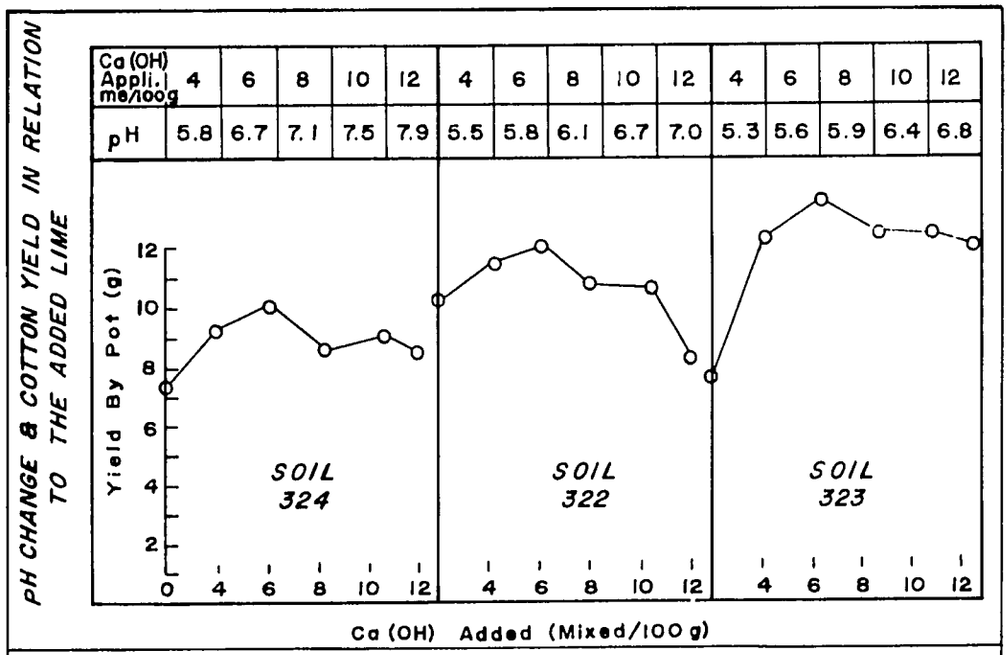
FIGURE 13. Calibration of soil test values with field response of corn to phosphate fertilizer



Source of Material: E. Strauss. 1951. Fertilizer Experiments in the Sugar Zone of Pernambuco. Annals of 3rd Brazilian Soil Science Congress, pp. 336-363

FIGURE 14. An analysis of sugar cane data by the method of Cate and Nelson

The results of four of the studies were presented in a paper entitled "Methods of Soil Analyses" as part of a Symposium held in Perú. The Symposium, "Evaluation of Methods to Determine Fertilizer Needs for Crops", was organized and sponsored by the Organization of American States. The data presented in the paper given by Dr. D. L. Waugh are shown in Figures 15, 16, 17 and 18. The best correlation for phosphorus analysis in the soils of Perú was obtained with the Olsen procedure (sodium bicarbonate). As would be anticipated the acid extractant used in the North Carolina procedure gave poor results. Good results were obtained with the four extractants

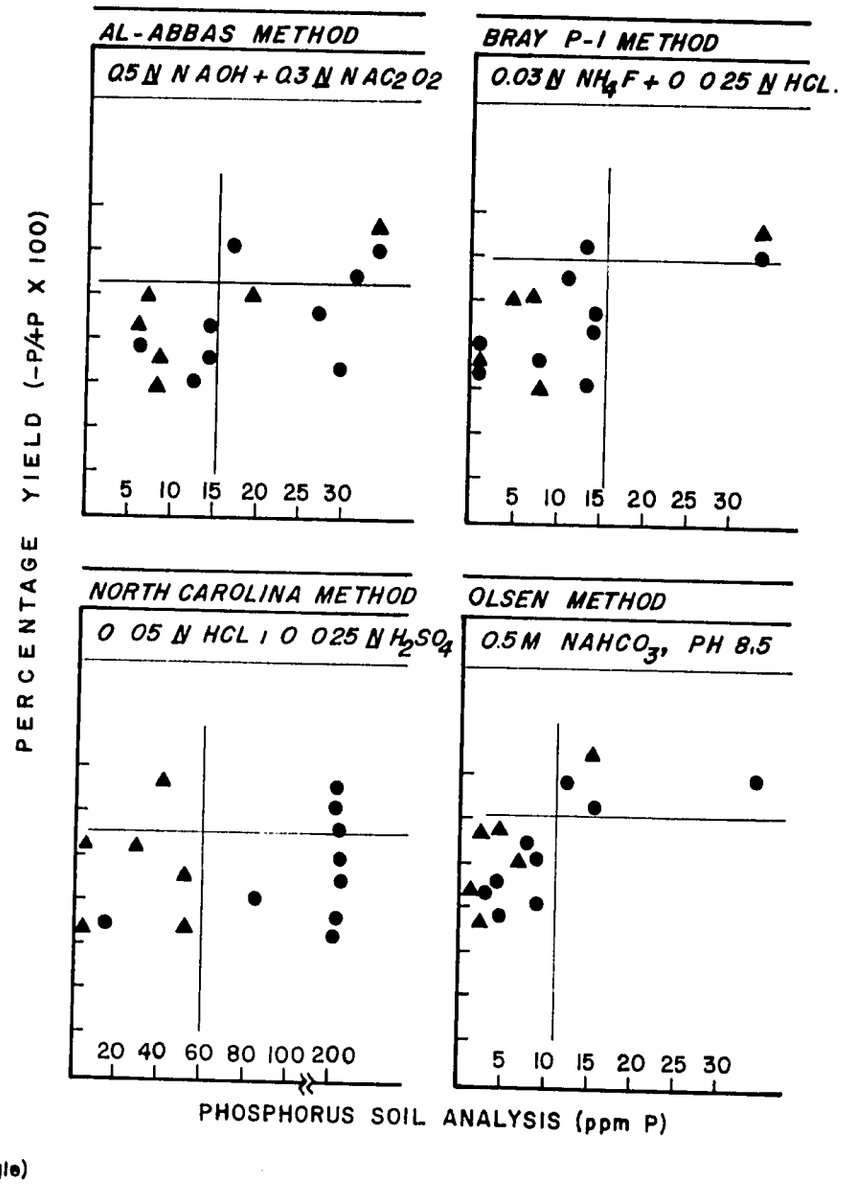


SOIL CHARACTER

SOIL No.	324	322	323
EXTR. AL (me/100 g)	3.5	4.6	5.0
Ca + Mg (me/100 g)	2.1	2.2	2.0
pH in Water	5.0	4.4	4.2

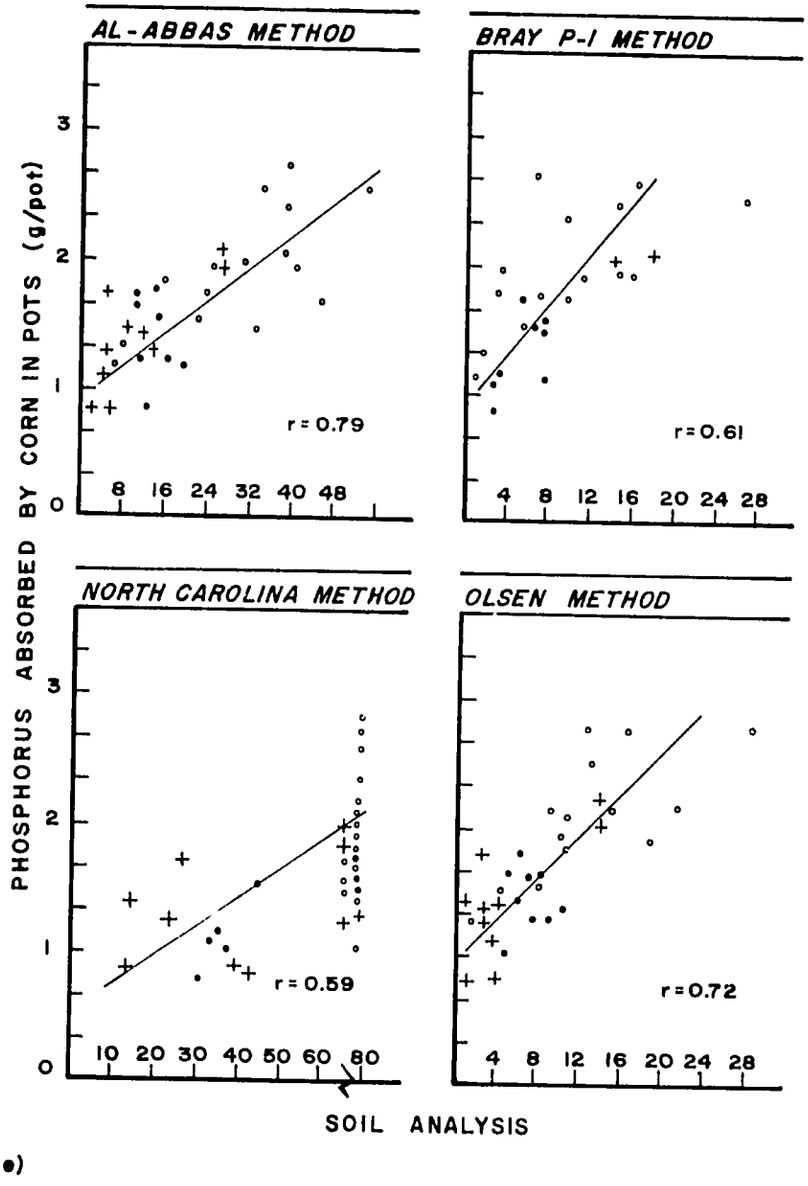
(Data from del Aguila's Thesis, Ing. Agrónomo, La Molina Agrarian University)

FIGURE 15. A study of the aluminum toxicity versus soil liming of the Peruvian Selva (jungle).



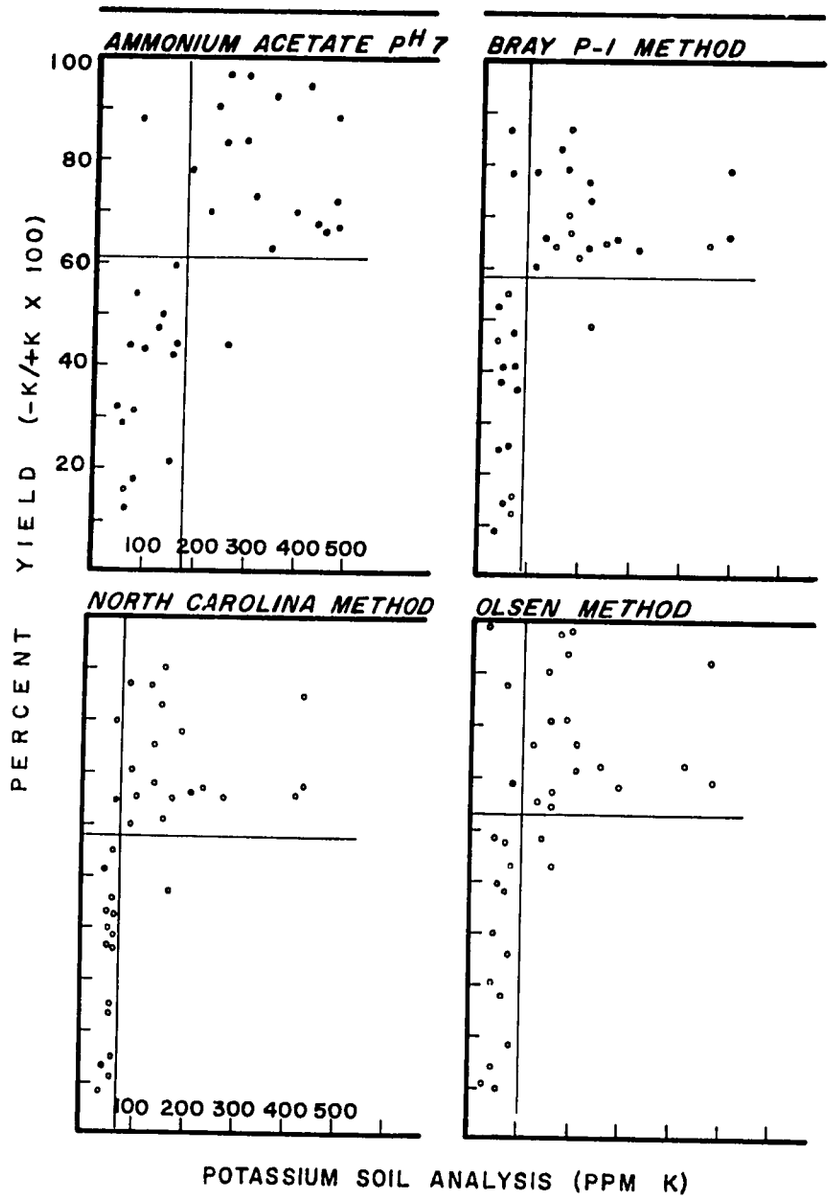
Data from Mueller's Thesis, Ing. Agrónomo, La Molina Agrarian University

FIGURE 16. Percentage of corn yield in pots versus P analysis by four methods in fifteen soils of the coast and the Selva (jungle) of Perú.



Data from Luna's Thesis, Ing. Agrónomo, La Molina Agrarian University

FIGURE 17. Correlations between soil analysis and Phosphorus absorption by corn in pots under intensive conditions in thirty-five soils of Perú.



Data from Duran's Thesis, Ing. Agrónomo, La Molina Agrarian University

FIGURE 18. Percentage of corn yield in pots versus K analysis by four methods in thirty-five soils of the coast, mountains, and Selva (jungle) of Perú

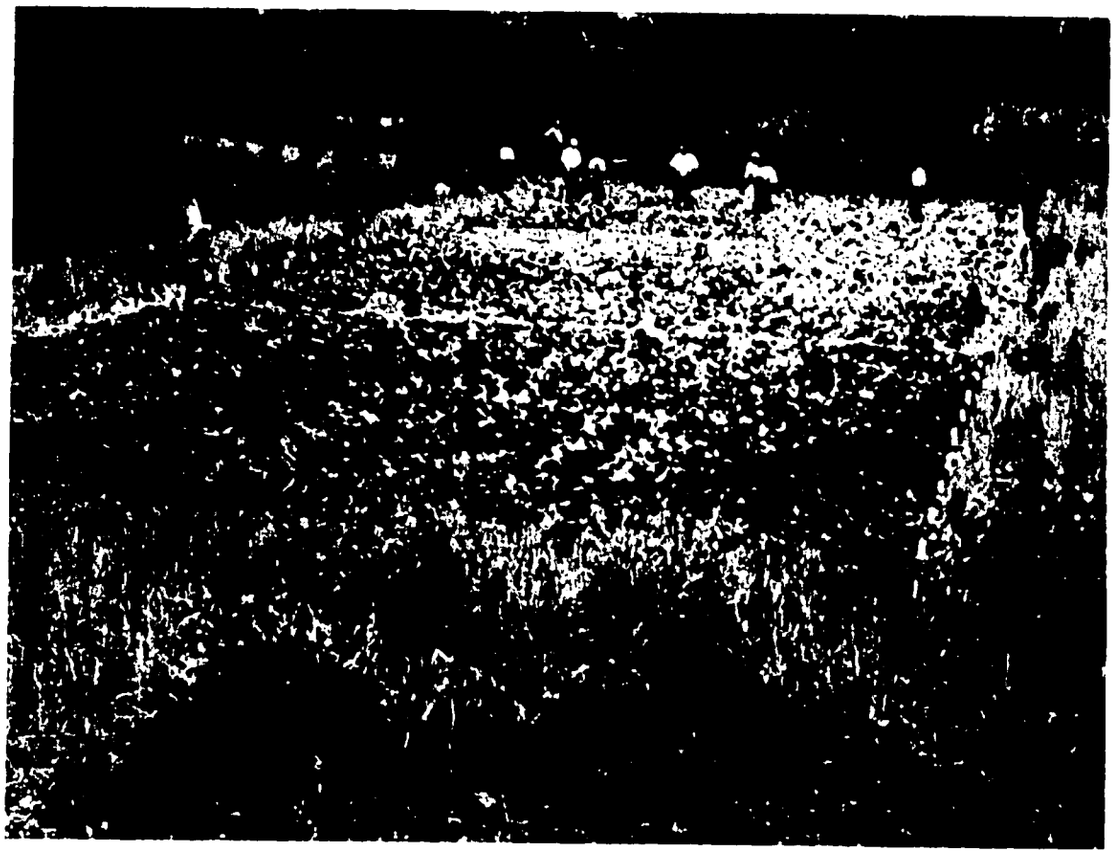
used for measuring exchangeable potassium for correlating with per cent yield. The ammonium acetate results which have been frequently regarded as the standard for extractants had a higher critical level than the other extractants, but was only slightly superior in the correct placement of the samples.

Adding sufficient lime to remove the exchangeable aluminum was found to be the optimum rate of liming in the study presented in Figure 18. The pH of the soil at the highest yield of cotton was less than 6.0 in two of the three soils. Liming the soils to neutrality resulted in marked decreases in yield in all of the soils.

Venezuela: Extensive correlation studies have been initiated in Venezuela by Ing. Agr. Rafael Gonzáles in cooperation with other members of the staff of the Sección de Suelos, M. A. C. - C.I.A., the Extension Service and I. V. P. (Instituto Venezalano de Petroquímica). Results will be available later in 1968 and will be used to provide a better base for a sound soil fertility analyses program.

Peanuts respond to phosphorus and calcium in Venezuela.

Greenhouse pot experiments to correlate soil test with crop responses to fertilizer in Venezuela. Ing. Agr. González inspects plant growth responses to added fertilizer materials.



Wheat fertility experiments in Bolivia will give information on crop responses to fertilizers and will provide data for correlating soil analyses with fertilizer needs. Twenty experimental sites for wheat were selected for the 1967-68 season on the basis of prior soil fertility analyses.

Ing. Menéndez and Dr. Walker make growth observations on potted plant study in El Salvador.

El Salvador: The results of a greenhouse pot experiment from El Salvador are plotted in Figure 18. The experimental work was done by Ing. J. R. Salazar of the Soils Department, Centro National de Agronomía, Ministerio de Agricultura.

Panamá: Some results from a phosphorus fixation and greenhouse pot experiment from Panamá are shown in Table 8. Although the soils retained varying proportions of the added phosphorus against subsequent extraction, there was no pronounced tendency in any of the four soils with the possible exception of Chiveco for severe phosphorus fixation. Factors other than P appeared to restrict the growth of the crop in some soils.

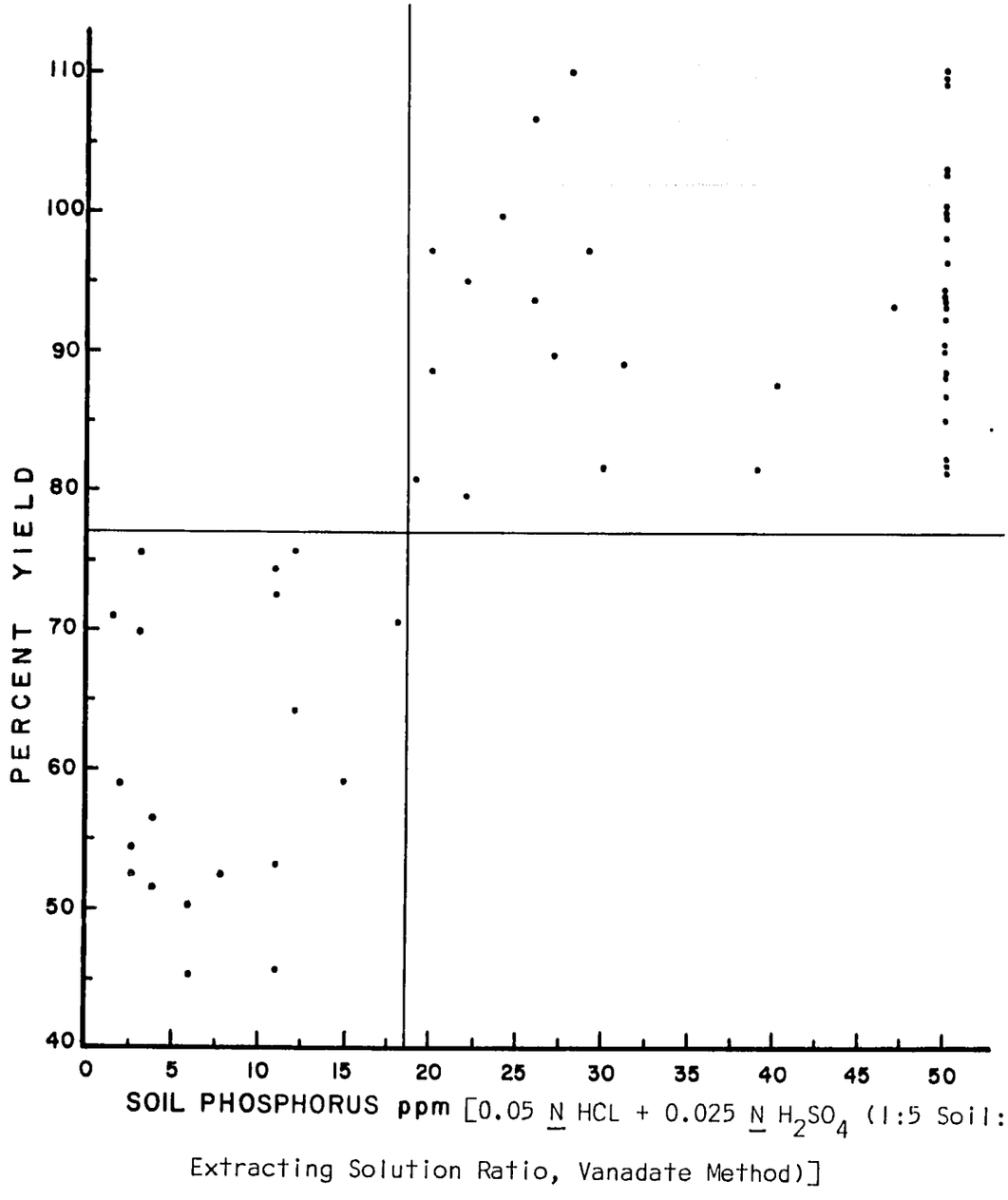


FIGURE 19. An analyses of potted plant data from El Salvador according to the method of Cate and Nelson

Table 8. The amount of phosphorus added to four soils of Panamá, amount of phosphorus extracted, yield, and per cent of maximum yield.

Soil	Phosphorus ppm added	Phosphorus ppm extracted	Yield	Per cent of Maximum Yield
Chiveco	0	0.2	19.4	53.6
	25	2.5	20.6	56.9
	50	5.8	36.2	100.0
	100	14.0	29.1	80.4
Chumico	0	0.2	24.4	34.3
	25	12.5	55.3	81.1
	50	24.8	68.2	100.0
	100	54.0	66.6	97.6
Est. Exp. de Chiriquí	0	9.0	40.9	47.0
	25	13.5	75.0	86.3
	50	18.5	83.3	95.8
	100	27.0	86.9	100.0
Cerro Punta	0	24.0	24.8	58.3
	25	31.5	36.8	86.5
	50	39.0	35.4	83.0
	100	57.0	42.5	100.0

No data at present are available from the other countries, but as the various studies are completed the results will be published by the research workers involved with the studies.

Micronutrients: A deficiency of micronutrients is likely to be more widespread in soils of tropical regions than in most areas of the United States. Interpreting soil and plant tests for micronutrients is difficult and much more research is needed. Some preliminary studies have been undertaken in Perú and Costa Rica in which the techniques outlined in Technical Bulletin No. 3, International Soil Testing Series, are utilized in studying both secondary elements and micronutrients. Elements under study include sulfur, zinc, and manganese. An atomic absorption instrument is utilized for the heavy metal determinations in Perú.

Srta. Carmen Torres operates the atomic absorption spectrophotometer at La Molina, Perú and makes the analyses for Ca, Mg, Mn, Zn, Cu, Fe, and Mo.

A special fertility study is underway in the Valley of Moquegua in southern Perú where chlorotic symptoms have been noted on plums and other fruit trees. Deficiency levels of iron, manganese and zinc have been observed and studies are underway to demonstrate response to these elements in potted plant studies as well as in the orchards.

Boron deficiency in cacao production has been uncovered by Ing. Lainez of the Pichelingue Experiment Station in Ecuador. The International Soil Testing Project is cooperating with Ing. Lainez by making plant analysis for boron.

Foliar Analysis

Information relative to nutrient uptake by plants is important in soil fertility programs. The Peruvian Laboratory now has available for its use a Perkin-Elmer 303 atomic absorption spectrophotometer. Good use is being made

Boron deficiencies in coffee are under study at INIAP Station, Pichilingue, Perú.

The causes for chlorosis in the leaves of plums and other fruits are under investigation in the Valley of Moquegua in Southern Perú. Leaf analyses with the use of the atomic absorption spectrophotometer will help detect deficiencies.

of this instrument in the analysis of plant material from the correlation studies. Nutrient uptake data are being obtained for phosphorus, potassium, calcium, magnesium, zinc and copper.

A survey of some of the citrus groves of Perú was also made to determine the levels of magnesium, calcium, zinc, copper and iron present in the leaves, in an effort to locate conditions and/or areas where deficiencies of these elements may exist.

In conducting the potted plant correlation studies, the plant material from the various treatments usually is analyzed to determine nutrient uptake. In the studies made in El Salvador some interesting relationships were found between nutrient uptake and soil test levels.

The analysis of fresh plant tissue is another source of information that can be utilized in determining nutrient deficiencies.

The wet tissue tests are particularly effective as a diagnostic technique to help in determining the causes of poor growth. Such tests show the level of a nutrient element in a certain part of the plant at a certain time during the growing period. Like soil tests, the tissue tests must be correlated with plant growth factors in order to be able to interpret the results correctly. Sampling the plant is particularly important. Several factors must be considered including the age of the plant, portion of plant, time of day, etc.

In order to acquaint the agronomists in Central America with tissue testing as a diagnostic tool and with techniques that should be followed, Dr. Al Plant of the American Potash Institute demonstrated tissue testing in field clinics in Guatemala, El Salvador, Honduras, Nicaragua and Costa Rica. The clinics were jointly sponsored by the Ministry of Agriculture of each of the countries, the International Soil Testing Project, and the American Potash

Institute and Foundation for International Potash Research. Each clinic had more than thirty agronomists in attendance.

The participants had opportunity to determine major and minor plant nutrient levels in the tissue of a large variety of plants growing on a number of the major soils of each country. Visual deficiency symptoms were examined in relation to the results of tissue testing.

Field Clinic on plant tissue testing in Honduras.

New Apparatus

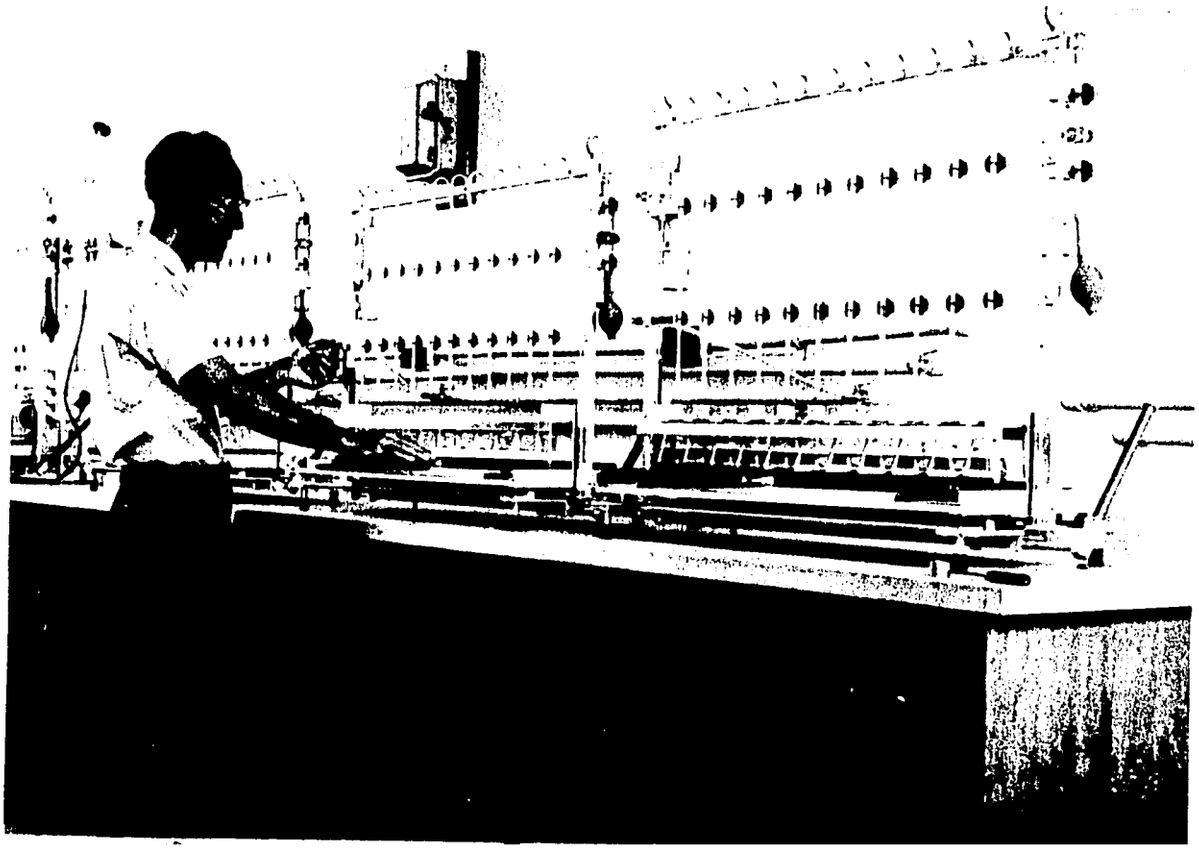
With the currently employed methods of soil analyses and apparatus so far developed, a reasonably efficient laboratory operation is possible in most of the countries. The same basic kinds of methods and equipment are employed at all locations. Some further improvements are possible and are under development. The limiting conditions differ in the several laboratories due in part to basic analytical instruments available and to laboratory organization and laboratory personnel. Roughly one-third of the total man hours of work in the testing laboratories is taken up by receiving and preparing samples for analyses including measuring and weighing subsamples into extraction containers. One-third of the total man hours is used in the analytical work and recording the results, and one third is taken up in reporting the results and making fertilizer suggestions or recommendations to farmers. To make the total laboratory operation more efficient, attention must be

Samples are measured instead of weighed in soil fertility analyses. Measuring is many times faster than weighing. Also when soil analyses are calibrated by measuring techniques, the results are equal or superior to the results from weighing since plants grow in volumes of soil and the roots contact surfaces of soil particles.

given to all three areas. Considerable efficiency could be effected by mechanizing the crushing, screening and mixing of the soil samples in preparation for subsampling. An undue amount of time is now occupied at all of the laboratories with this preparation function. In fact in some laboratories the soil preparation process constitutes the factor which limits the number of samples which can be handled each day.

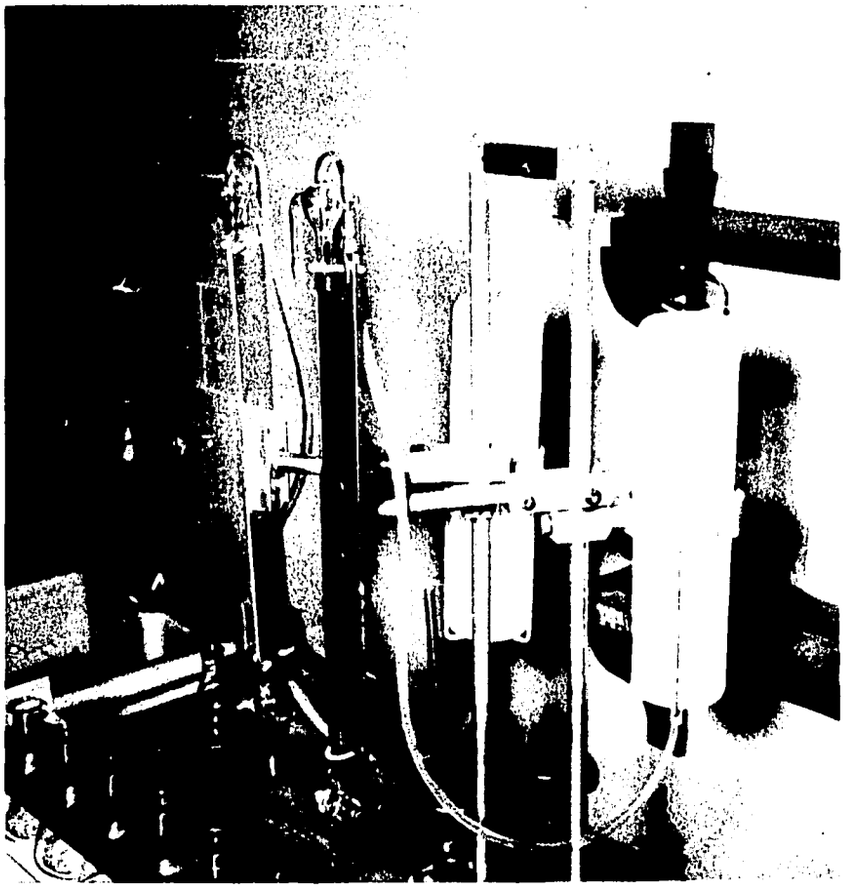
A soil crusher has been developed and is currently under test. This crusher has a sieve and screening mechanism to automatically reject rocks and other large objects which are normally excluded from the analytical procedures. If the crusher can be rapidly and adequately cleaned between samples, it will markedly speed up the preparation processes.

Multiple unit dispensing apparatus in use in Brazil. Mastre Juca supervises the construction and installation of these analytical units.

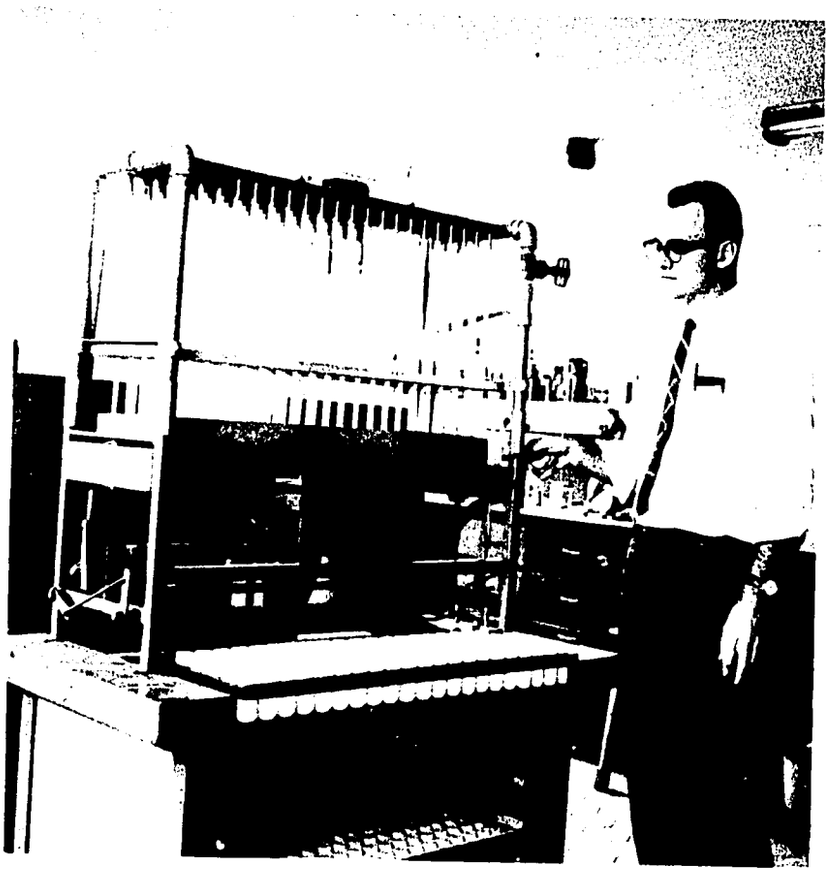


Dr. John T. Caldwell, Chancellor, North Carolina State University, examines a multiple unit stirrer in use at the soil fertility analyses laboratory at Tegucigalpa, Honduras.

Automatic pipette designed and constructed for use in the Brazilian laboratories in the determination of total acidity and exchangeable aluminum in soils.

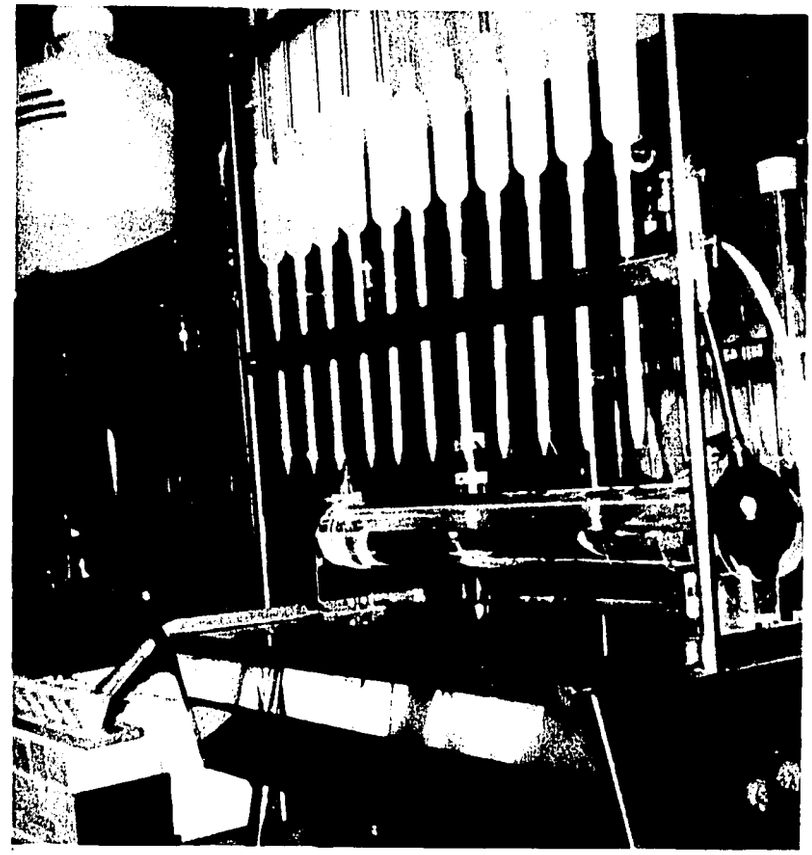


The multiple unit concept requires that several or even a large number of samples be handled together as a single operation. The first equipment developed had facilities for ten samples and one control sample in each group or tray. Ten or eleven samples in one tray was convenient because they could all be handled in one linear rack. Larger numbers of samples can be handled but the sample containers must then be arranged in a series of rows or racks.



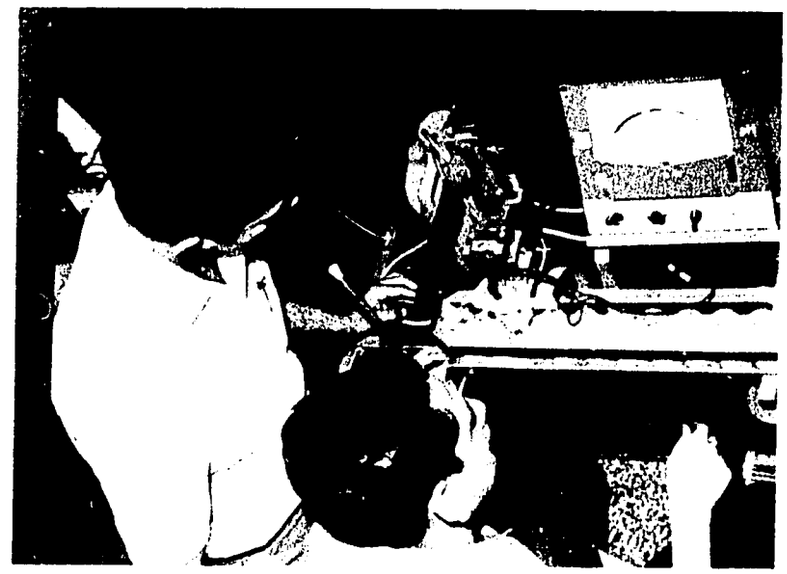
Dr. D. L. Waugh with the 100-unit dispensing apparatus in use in the soil fertility analysis laboratory at La Molina, Perú.

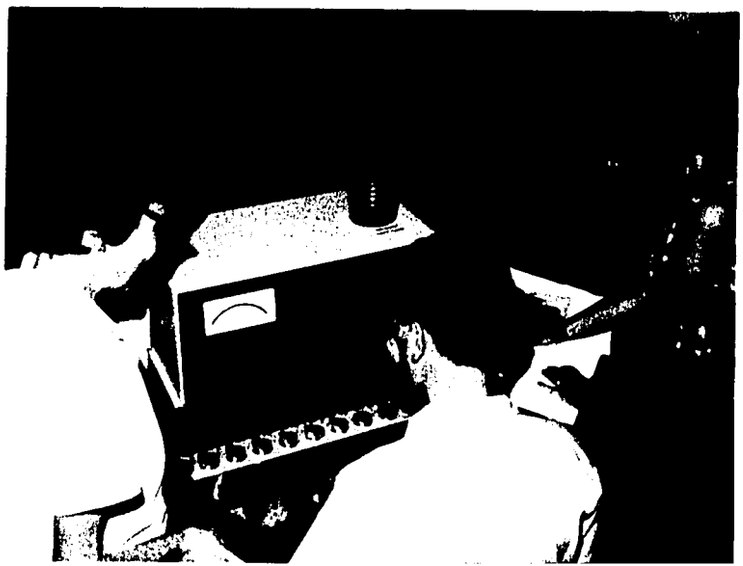
Multiple dispensing unit designed for use in the cooperating laboratories.



All operations including washing are done in multiple units. (Photo Sra. House in Honduras.)

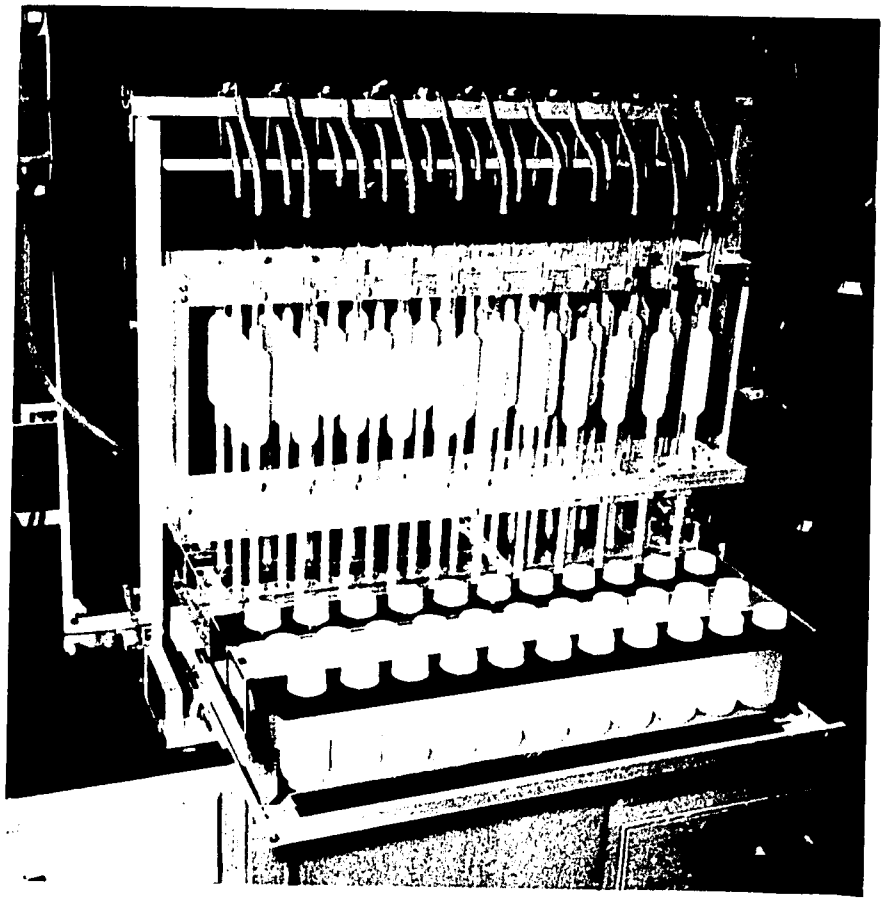
Apparatus designed by the International Soil Testing Project to speed up pH measurements by automatically changing samples and washing the electrodes in the change process.





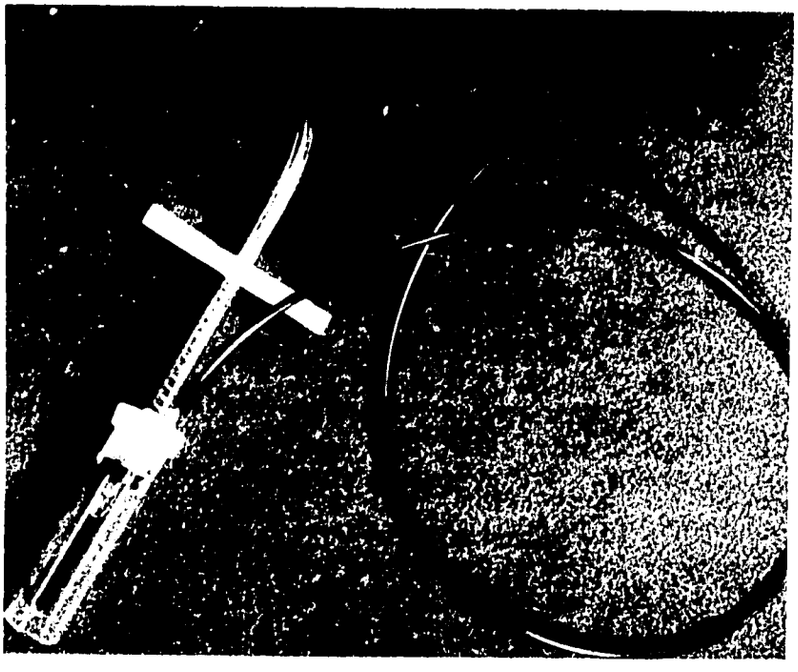
Solutions are presented at the Flame Photometer in multiple unit trays. Transfer from the tray to the instrument is made by a suction mechanism through a plastic tube.

The Control Laboratory at Raleigh has now constructed a dispenser to handle 33 samples at one time. This unit is likely to be more nearly adapted to the needs of most of the laboratories than is the 100 unit system. The stirrers employed at present also have a capacity of 33.

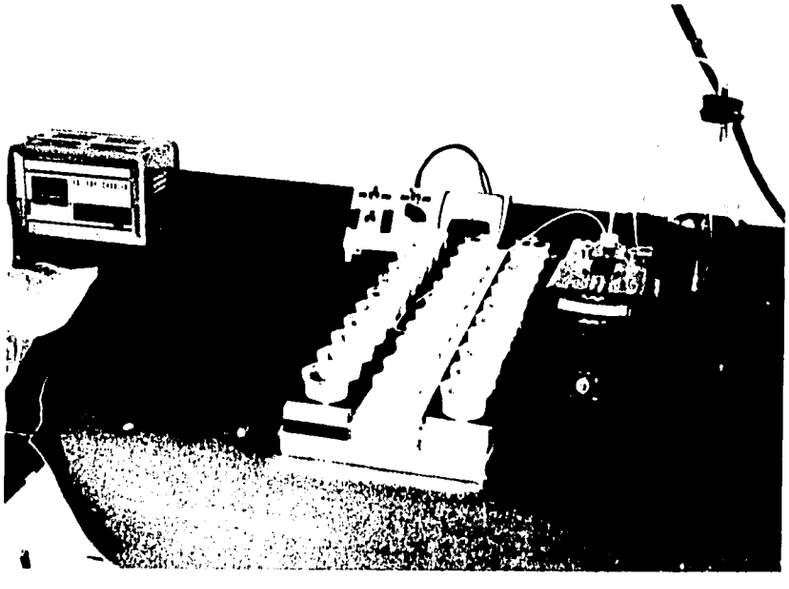


Multiple unit dispenser recently constructed to handle 33 samples at one time. It is specifically adapted to accommodate three 11-unit trays housed in an aluminum tray rack.

Other developments in the analytical field include an automatic sample changer for the flame photometer and for the atomic adsorption spectrophotometer. An apparatus is under consideration to quickly and accurately remove a specified volume of soil extract and simultaneously dilute it with other chemical solutions in preparation for phosphorus and potassium analyses. Basically it would perform two pipetting operations at one and the same time. This equipment would eliminate one handling operation in the determination of phosphorus, potassium, calcium and magnesium.



Changing samples in the Colorimeter is now accomplished by a suction method with the type of apparatus shown here. Suction is applied through the plastic plunger to draw the sample into the Colorimeter tube through the small diameter plastic tubing. To empty the Colorimeter tube, the plunger is pressed to the bottom. Distilled water is drawn through the system when there is a need to wash.



The sample changer shown here is adapted for use with a Cenco Photelometer. Such sample changing apparatus can be adapted to any colorimeter or photelometer. Moreover, the solution changer has a marked advantage in addition to speed of operation. It standardizes tube geometry and eliminates the need for matched colorimeter tubes.

Design of Cartons

The basic design and construction of soil sample cartons and the availability of such cartons and the accompanying information sheets and instructions can have marked impact on several aspects of a soil testing program. Obtaining good representative soil samples is basic to accurate and meaningful soil analyses and has been found to be one of the most difficult aspects of soil testing. Sampling is the greatest single source of error in determining nutrient deficiencies and therefore plant nutrient needs of farmers' fields. Impressing agricultural leaders and farmers with the importance of good samples is a continuing necessity. Instructions associated with the soil carton is one of the educational procedures which help to assure procurement of good samples. A sample box is shown in Figure 20. Instructions with illustrations for taking the sample are given on the side of the box. A field history questionnaire occurs on another side of the box. A place is also provided for identification of the field and for the mailing address of the farmer.

In the laboratory the box can furnish the information on the sample and also serve for a container to hold the sample during the analytical process. The size and shape of the carton in relation to the size of the tray used in the analytical procedures is important in the efficient operation of the laboratory. The sample cartons must fit into a tray in such a manner that each carton can be lined up with an extraction bottle held in an extraction tray. This permits rapid measurement of sample and reduces the incidence of error.

Both in Raleigh and in several of the countries, considerable attention was given to an optimum carton size with instructions and information blanks that would be best suited for use in most of the countries. Countries particularly interested in this phase of soil testing during the past six months included Venezuela, Colombia, Ecuador and Costa Rica.

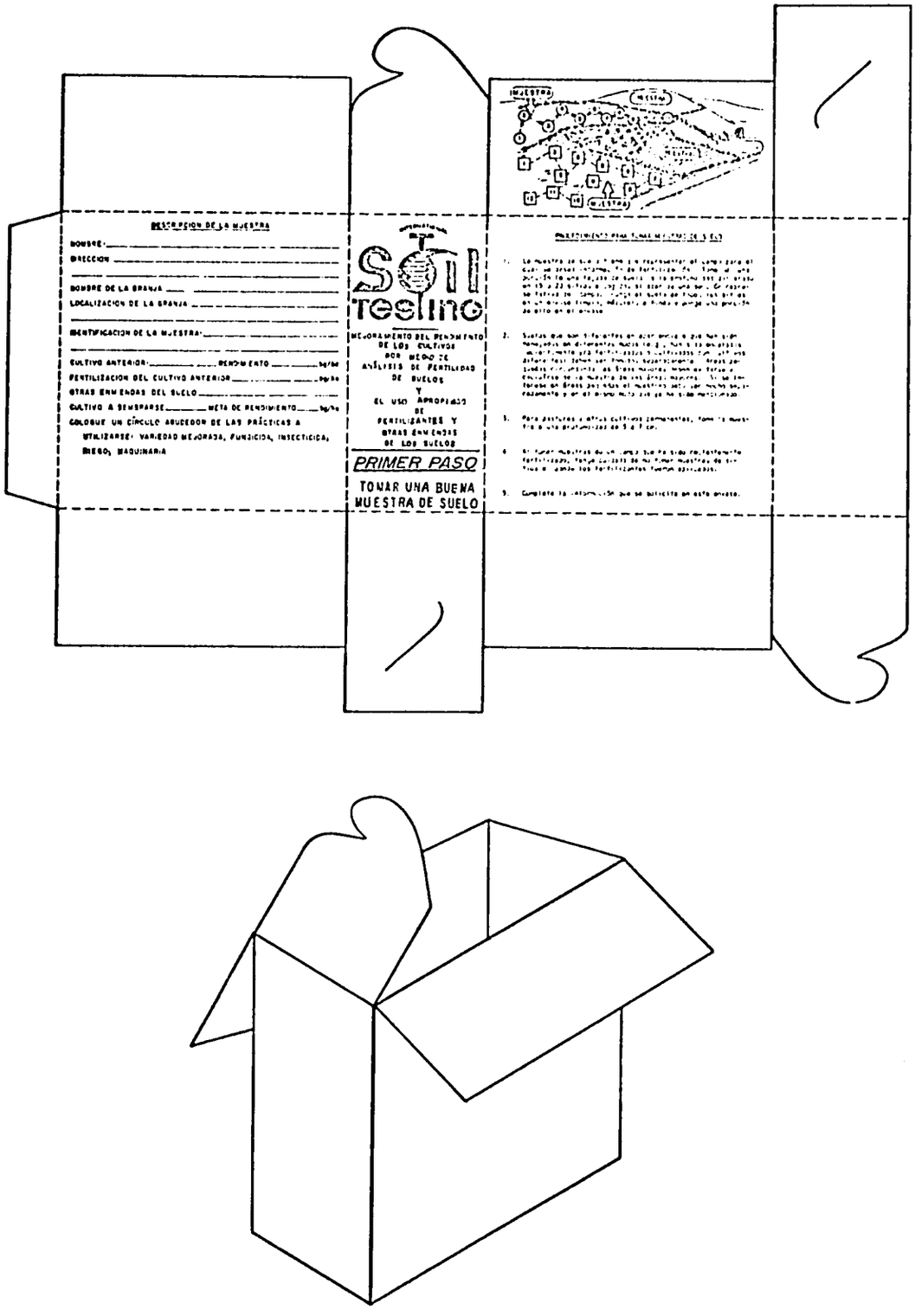


FIGURE 20. FORMAT OF THE SOIL SAMPLE CARTON SUGGESTED FOR USE IN LATIN AMERICA

Guide Sheets

Guide sheets are systematic tabulations of fertilizer suggestions for the many crops and soils of an area based upon the results of soil tests. The compilation of such guide sheets is necessary in order to make use of soil test information. The relationships between crop responses to fertilizers and soil analyses are the principal criteria employed in guide sheet compilation. In areas where this relationship has not been firmly established, fertilizer response data from other areas of similar climate and similar crops can be employed with considerable success. This adapting of information from other areas has been used extensively in Latin America in inaugurating soil analyses programs.

As the quantity of data on crop responses to fertilizer increases in an area is obtained through research, the guide sheets are reviewed and refined in the light of the new data. A number of years are generally required to have acquired sufficient data in any one area to make good fertilizer suggestions on all important crops by the use of soil tests.

In addition to soil analyses information, the fertilizer recommendations on the guide sheets must reflect the economics of fertilizer use. Soil tests provide information only on the probability of getting a reasonable magnitude of increase in crop growth by the use of fertilizers. The profitability of the use of fertilizer practices is dependent also upon the cost of the necessary fertilizer and the value of the crop to be grown. Local calculations of the latter factors are reflected in the guide sheets employed by the several laboratories making fertilizer recommendations from soil test information.

All of the laboratories now have programs designed to periodically modify and refine the recommendations. In Brazil this is done cooperatively through

the Brazilian National Soil Testing Project. In Perú it is done by periodic conferences by the research workers in fertility. In Central America, it has been done by both local and regional conferences called to review current work and experience with fertilizers.

The suggestions followed by the Brazilian laboratories are shown on pages 62 and 63.

All of the regions cooperating with the project continued to emphasize the preparation and alteration of guide sheets for the interpretation of soil test results and for making fertilizer suggestions. Of course more refinement will be needed and will be made as rapidly as data can be obtained. Prof. Cate has proposed a new approach to preparing fertilizer recommendations based upon soils containing an adequate and an inadequate amount of a given nutrient. Several field trials will be needed to thoroughly test the proposal.

Program Evaluation

Some periodic evaluations of the several parts of a soil analyses-fertilizer use program are essential for its success. This phase will be given increased attention as the programs in the several countries get established. In soil analyses programs soil samples and agronomic information are received from farmers and in turn analytical information and fertilizer recommendations are sent from the laboratory to the farmers.

The fertilizer recommendations made from soil analyses data are critically dependent upon securing good soil samples and to a lesser but important extent dependent upon getting good information about the fields from which the samples were taken. Moreover the quality of the soil fertility and land use summaries made from soil test information is determined by the extent and accuracy of the information obtained in association with the samples. Likewise

BRAZILIAN GENERAL FERTILIZER SUGGESTIONS are summarized on the next page. This guide is based on two tentative conclusions drawn from studies of several hundred Brazilian field trials with a variety of crops.

1. The chances of a large response to P or K are usually about four times greater when a soil test value is below the Cate-Nelson critical level[1/] than when it is above. Coincidentally, responses below the critical level also appear to average about four times larger than those above the critical level[2/].

2. A farmer who spends 10-20% of his expected gross income on NPK in the proper ratio will normally make a reasonable profit on his fertilizer investment, when operating within the limits of the table and when fertilizer-crop price relationships are similar to those currently prevailing in the United States and in south-central Brazil.

Modifications are naturally encouraged where adequate data warrant, but the essential philosophy of the present Brazilian system is that soil analyses should be utilized in choosing the NPK ratio, while expected gross income should be considered when estimating the amount of this ratio to be used.

Robert B. Cate, Jr., Regional Director (Brazil)
International Soil Testing Project

Leandro Vettori, Coordinator
Brazilian National Soil Testing Project

1/ Cate, Robert B., Jr. and Nelson, Larry A. "A Rapid Method for Correlation of Soil Test Analyses with Plant Response Data." Tech. Bul. No. 1, International Soil Testing Series. July 1965.

2/ Cate, Robert B., Jr. and Vettori, Leandro. "Fertilizer suggestions, Third Approximation." Presented at Congress of Brazilian Soil Science Society, Brasilia, July 1967.

BRAZILIAN GENERAL FERTILIZER SUGGESTIONS

SOIL ANALYSIS	SUGGESTED NPK RATIO	EXPECTED GROSS INCOME (US $/Ha)	SUGGESTED N(Kg/Ha)	SUGGESTED P_2O_5(Kg/Ha)	SUGGESTED K_2O(Kg/Ha)
Low P - Low K	2-4-4	$ 1000	100-200	200-400	200-400
" "	2-4-4	800	80-160	160-320	160-320
" "	2-4-4	600	60-120	120-240	120-240
" "	2-4-4	500	50-100	100-200	100-200
" "	2-4-4	400	40- 80	80-160	80-160
" "	2-4-4	300	30- 60	60-120	60-120
" "	2-4-4	200	20- 40	40- 80	40- 80
" "	2-4-4	100	10- 20	20- 40	20- 40
Low P - High K	2-4-1	$ 1000	120-200	240-400	60-100
" "	2-4-1	800	100-200	200-400	50-100
" "	2-4-1	600	70-140	140-280	35- 70
" "	2-4-1	500	50-100	100-200	25- 50
" "	2-4-1	400	40- 80	80-160	20- 40
" "	2-4-1	300	30- 60	60-120	15- 30
" "	2-4-1	200	20-40	40- 80	10- 20
" "	2-4-1	100	20- 20	20- 40	5- 10
High P - Low K	2-1-4	$ 1000	160-200	80-100	400
" "	2-1-4	800	120-200	60-100	240-400
" "	2-1-4	600	100-200	50-100	200-400
" "	2-1-4	500	80-160	40- 80	160-300
" "	2-1-4	400	60-120	30- 60	120-240
" "	2-1-4	300	50-100	25- 50	100-200
" "	2-1-4	200	40- 80	20- 40	80-160
" "	2-1-4	100	20- 40	10- 20	40- 80
High P - High K	2-1-1	$ 1000	200	100	100
" "	2-1-1	800	160-200	80-100	80-100
" "	2-1-1	600	120-200	60-100	60-100
" "	2-1-1	500	100-200	50-100	50-100
" "	2-1-1	400	80-160	40- 80	40- 80
" "	2-1-1	300	60-120	30- 60	30- 60
" "	2-1-1	200	40- 80	20- 40	20- 40
" "	2-1-1	100	20- 40	10- 20	10- 20

maximum economic benefit to the farmers and to the country comes through close adherence to the suggestions and recommendations made from the results of soil fertility analyses.

Periodic evaluation of the procedures employed to educate farmers and agriculturists on the importance of getting good samples is helpful in improving the program. Critical examination of the information questionnaires requested in association with the samples and with the processing and use of the information is also important. In addition the methods of transmitting the information back to the farmers and the degree to which it is accepted and followed should be continuously examined. How should soil analyses information be transmitted to farmers? How is it most readily understood? How many farmers are using the information and following the recommendations? What kind of results have farmers obtained where recommendations were followed? Information relative to these and other questions is needed to make the soil testing program most effective within each country. In Perú a student undertook a study for his thesis to obtain some information on "follow-up procedures." The study will be conducted in the Canete region of the Central Coastal Plains. It will include a review of the information submitted with the samples for analyses, how well the reports of the soil test analyses were understood, how far the recommendations were followed, and the results that were obtained.

SOIL TESTING--PROJECT ACTIVITIES

Soil Testing--Basis for Planning

Soil testing is an essential tool to determine precise fertility needs and to locate special soil conditions that may greatly influence crop production. Several cooperative programs are turning to soil testing as the first step in improved crop production. Some of these programs are cited below.

Improved Potato Production--Sierra Region of Perú: This is a joint project between SIPA of the Peruvian Government, the North Carolina Peruvian Mission, AID and the International Soil Testing Project. Several thousand samples of soil have been taken in the Sierra Region where an expected expenditure of almost $3,000,000 will be made for fertilizers and lime. The results of the analyses indicate that general fertilizer recommendations will fit only about 10 per cent of the samples tested. This is due to the wide variation in soil conditions. The goal of the project is to increase the potato yields by as much as 400 per cent. The proper use of fertilizer, based on soil tests, will play an important role in achieving this goal.

Improved Crop Production in Small Grain Area of Guatemala: An impact soil fertility program to increase crop production in the upland region of Guatemala was initiated in early 1967. The Wheat Growers Cooperative, the Ministry of Agriculture, social welfare organizations, private industry and the International Soil Testing Project are cooperating in the program. Plans were formulated to obtain about 7,500 soil samples from the region to serve as a basis for fertilizer and lime use. Field trials and demonstrations based upon the soil tests will be established by the Agricultural Experiment Station in cooperation with the Soil Fertility Section of the National Soil Fertility

Training in soil sampling techniques in connection with the Potato Impact Program in the Sierra Region of Perú.

A soil sampling training excursion in El Salvador.

A wheat fertility trial in the process of preparation in Bolivia. The site was selected on the basis of earlier soil analyses.

The fertility requirements of wheat are receiving increasing attention in Latin America. New varieties of semi-dwarf wheat which flourish in high fertility soils are being planted in ever increasing amounts. Knowledge of the precise fertility requirements of each field planted through experimentation and soil analyses is important if maximum use is to be made of the production potential of these new developments in wheat.

and Analysis Program. The Wheat Growers Cooperative agreed to give $5,000 to $7,000 annually to support the project.

Wheat Program in Bolivia: An impact program centered around wheat production is planned for Bolivia. Cooperating in the program are the Bolivian Ministry of Agriculture (Soils Department), the British Mission, USAID and the International Soil Testing Project. Each of the agencies will assume certain responsibilities for the program. Soil technicians that are located in the wheat producing areas will be trained in the various phases of soil testing, but the greatest emphasis will be on soil sampling. The information gained will be used in planning soil fertility and soil conservation practices.

National Corn Campaign in Costa Rica: The objective of this program is to increase corn yields. A large number of agencies, including several divisions of the Government of Costa Rica, are cooperating in the campaign. Soil testing will be used as a source of information in developing improved management practices.

Symposium: Economic Impact Through Soil and Plant Analysis

The Ministry of Natural Resources of Honduras and the International Soil Testing Project were co-hosts to a week long symposium entitled "Economic Impact Through Soil and Plant Analysis." This was the first regional meeting of the Central American Countries, Panamá and México in relation to soil-plant analyses as a guide to fertility practices. More than fifty persons registered for the symposium. Countries represented included: Colombia, Costa Rica, El Salvador, Guatemala, Honduras, México, Nicaragua and the United States. During the first two days of the program, emphasis was given to the economic impact that the proper use of fertilizers, lime and

High yields of corn can be grown even where hand operations are still employed in planting and harvesting.

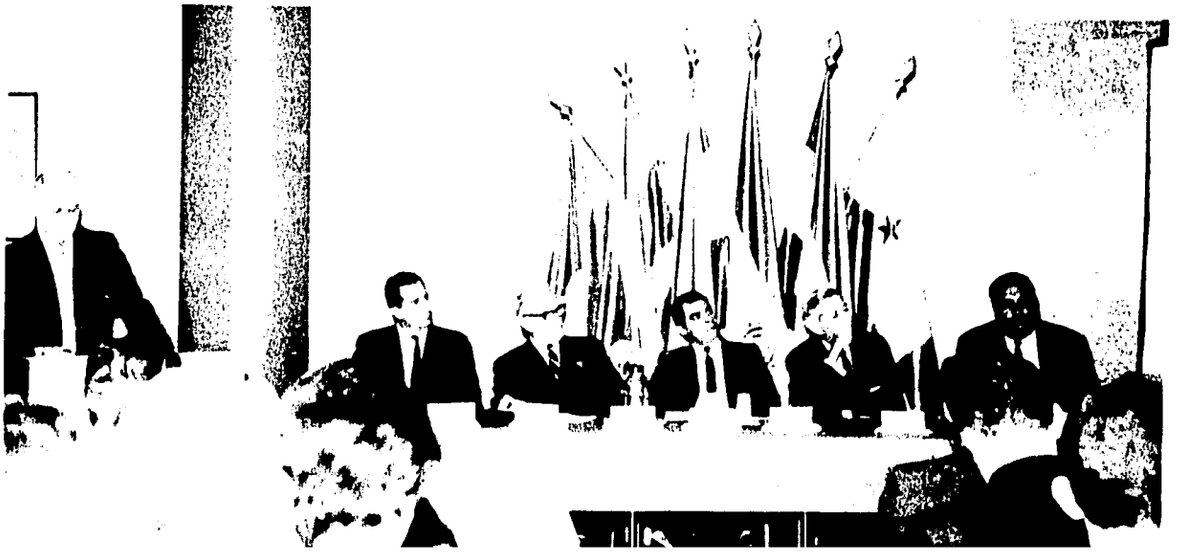
other soil amendments could have upon the countries. Speakers on the program included:

Mr. J. J. Jova	His Excellency, the Ambassador of the United States of America to Honduras
Dr. John T. Caldwell	Chancellor, North Carolina State University Raleigh, North Carolina, U.S.A.
Ing. Arturo R. Pino Navarro	Representing Director of Project Analysis Div. Interamerican Development Bank Washington, D. C., U.S.A.
Dr. S. E. Younts	Director for Latin America American Potash Institute and the Foundation for International Potash Research Decatur, Georgia, U.S.A.
Dr. J. M. Spain	Rockefeller Foundation Bogotá, Colombia
Mr. C. S. Simmons	Director FAO of the United Nations BANAFOM, Tegucigalpa, Honduras
Mr. R. Hughes	Representing Head Rural Development Division Office of Institutional Development Bureau for Latin America Department of State Washington, D. C., U.S.A.
Mr. R. J. Minges	Director, USAID/Honduras
Dr. J. W. Fitts	Director, International Soil Testing Project North Carolina State University Raleigh, North Carolina, U.S.A.
Ing. Oscar Alemán	Sub-Secretary of Natural Resources Tegucigalpa, Honduras

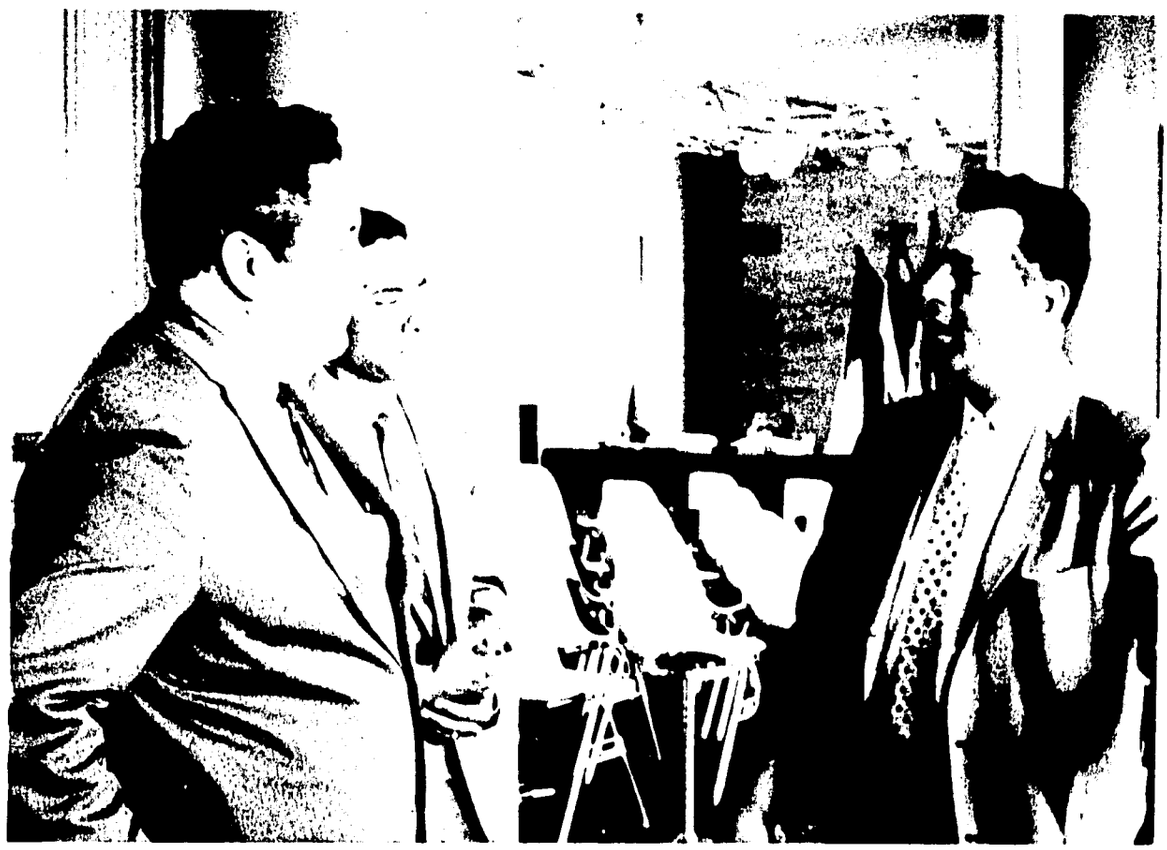
The last three and a half days were devoted to discussion of technical problems on soil analysis, fertilizer use and increased crop production in the several participating countries. During the last part of the program two committees were appointed among the technical representatives--one on research and another on operations. Resolutions were prepared by these committees and adopted by the participants. These committees and resolutions

Left to right: Ing. José Manuel Taráno, Director General Agricultural Research and Extension, Guatemala; Dr. John T. Caldwell, Chancellor North Carolina State University, Raleigh, North Carolina, U.S.A.; Ing. Oscar Aléman, Vice-Minister Natural Resources, Honduras; Mr. J.J. Jova, Ambassador, United States of America to Honduras; Ing. Hernán L. Tenorio, Director Government Planning Officer, El Salvador.

Dr. J. W. Fitts, Director International Soil Testing Project, addressing the Symposium.



The Symposium Program included a series of primary lectures giving emphasis to the economic importance to a country of effecting efficient systems of crop production and utilization. Included also in the program were discussions by small groups of the Symposium participants at which time specific technical problems were examined. Provided also in the program agenda were opportunities for individual participants to discuss topics of mutual interest and to exchange ideas and information.



Committee on Research

President	Ing. Miguel E. Menéndez, Ministry of Agriculture, El Salvador
Members	Dr. Flora Espinosa, Coffee Research Institute, El Salvador Dr. Bonifacio Ortíz V., Sugar Research Institute, Mexico Dr. José A. Martini, IICA-OAS, Costa Rica Ing. Jorge Díaz Zelaya, FFHA-FAO Nicaragua Ing, John Mannix, Ministry of Agriculture, Costa Rica Ing. Carlos Rivera H., Ministry of Natural Resources Honduras Lic. Oscar Ortíz, Ministry of Agriculture, Guatemala

Recommendations of the Research Committee

Considering that studies on soil fertility and plant nutrition are necessary for agricultural development, it is recommended that the International Soil Testing Project be continued and strengthened. The purpose of this project is to increase agricultural production through the efficient utilization of soil and plant analyses.

For the same reason the following specific recommendations are given:

1. Due to the fact that soil analyses frequently show low available phosphorus levels and that very high fixation capacities are observed in some important agricultural soils, such as latosols and those rich in amorphic material, investigations related to phosphorus fixation and calibration of analytical methods should be continued.

2. In the areas where soil analyses indicate adequate potash levels, potassium-magnesium interaction and crop response to application of potassium in the presence of adequate quantities of the other nutrients should be investigated. In the deficient areas, basic studies are justified.

3. In view of the fact that there are strong indications of sulphur deficiency in some agriculturally important areas in Central America, the delimitation of the areas and soils that respond to the application of this element should be undertaken as well as investigations on the use of sulphur-bearing fertilizers; the relationship of soil properties, yields, and the most reliable analytical methods to use should also be studied.

4. Because there is not sufficient local information for making lime recommendations, investigations on lime requirements in acid soils should be made.

5. Because of the importance of magnesium deficiencies in some coffee areas and the negative effect produced by magnesium application in other areas and with other crops, this nutrient should be studied; the relationship of this element with calcium and potassium should be investigated; routine analytical methods and the determination of critical levels through correlation with greenhouse and field studies is required.

6. In Central America we have neither enough studies nor sufficient basis to discard the determination of soil organic material; therefore, further study is recommended including the possibilities of simplifying the routine analytical methods. In areas where there are soil maps, soil color and texture may serve to indicate soil organic matter contents. The initiation of interpretation of the analytical data is also recommended.

7. Because the correct interpretation of soil analytical results depends upon establishing correlations through experiments in the laboratory, greenhouse and field, it is recommended that correlation studies be continued and intensified. Greenhouse studies should be the first phase when previously established field experiments are not available. It is also recommended that fertilizer trials not be initiated without first performing soil analyses.

8. Permanent files of soil samples from experimental fields should be established for future calibration of new methods.

9. Considering that the increasing quantity of data obtained by the soil analysis laboratories constitutes a valuable source for making maps, graphs and fertility summaries, and is of much value as guides for soil specialists, it is recommended that modern classification systems (Kardex or IBM) be used to tabulate these data.

10. In the National Soil Fertility and Analysis Programs, it is of great importance that all information, local, regional, and experimental, be used.

Committee on Operations

President	Ing. Jorge A. González, Ministry of Agriculture, Guatemala
Members	Ing. José Roberto Salazar, Ministry of Agriculture, El Salvador
	Ing. Vladimiro Castellanos, Ministry of Natural Resources Honduras
	Ing. Oscar Vargas, Ministry of Agriculture, Costa Rica
	Ing. Fabio Gómez Romero, National Agrarian Institute, Honduras

Recommendations of the Committee on Operations

Technical Considerations

The Committee recommends:

1. Exchanging: a) fertilization program designs and data; b) control samples; c) information and fertilizer guide sheets used in the laboratory.

2. A. Standardization and integration of: 1) research programs; 2) sampling methods; c) analytical methods in soil and plant analyses.

   B. Reporting the results of soil tests in parts per million (ppm), making the recommendations in terms of kilograms per hectare and attaching a table for conversion to other area units.

3. That, in view of the success obtained by the Coordinating Committee of the National Soil Fertility and Analysis Program of the Republic of Guatemala, a similar committee be formed in each of the participating countries. This committee has facilities to receive and manage funds donated by private industry. An objective of this committee is to assure efficient operation and remove budgetary problems which can paralyze the work of the National Soil Fertility and Analysis Programs.

4. That program results be published periodically, either annually or trimestrally.

Economic Considerations

The Committee recommends:

1. That the Ministries assign the funds necessary to provide continuity of programs and, where feasible, make no changes in annual budgets once they have been approved. Funding of annual budgets and yearly increases should not be delayed.

2. As members of the International Soil Testing Project, we should create in our soils budgets specific funds to enable sending yearly participants to the seminars offered by North Carolina State University. In one year's time the great impact of these seminars on the Soil Fertility and Analyses Programs has been demonstrated.

3. That the Coordinating Committees of the National Programs be allowed to accept donations from private businesses to be utilized strictly for studies recommended by the Committee.

4. That the creation of programs favoring conservation of natural resources is urgently needed. Due to bad management practices, irreparible losses seriously menacing forests, fauna and soil are occurring and affecting the potential productivity of these natural resources.

Cultural Considerations

1. That the unity between the laboratories established by the International Soil Testing Project be maintained and that a goal of regional planning at the Central American-Mexican-Panamanian level be established through: a) free exchange of data and information related to common problems;

b) mutual help in exchanging working materials; and c) holding of meetings between the heads and technicians of the soils departments and labs.

2. That, in accord with the agreement of the General Assembly and in addition to the International Soil Testing Program, because of the urgent need to unite ourselves extra-officially, the Soil Science Society, Central America, México and Panamá Chapter is formed. A President, Vice-President and two Secretaries, residing for 1967-68 in Costa Rica and Guatemala have been elected.*

3. That thanks be expressed to North Carolina State University and to the Ministry of Natural Resources of the Republic of Honduras for the magnificent idea of uniting us in the First Symposium. Without the material and technical direction and support they gave, this grand event would not have been possible, which today has produced its first fruit: the Society just founded. We ask the Governments to help this new organization so that it can, in turn, serve to resolve international problems in soil fertility analyses.

4. That the Ministers of Agriculture consider granting a Diploma to North Carolina State University in recognition of its meritorious collaboration in the México-Central America and Panamá region.

A Proceeding of the Symposium, including the principle presentations, is under preparation.

Inauguration of Laboratories in Guatemala, El Salvador and Honduras

A soil-plant analyses laboratory which is equipped with multiple unit apparatus is an impressive sight. An inauguration of a carefully planned and well equipped soil-plant analyses laboratory offers a concrete means of acquainting local administrators with a soil testing program as a method of increasing crop production. The administrators can be shown that they now have a means of analyzing samples rapidly and accurately, and that the laboratory can be used to test samples for farmers as well as conduct research.

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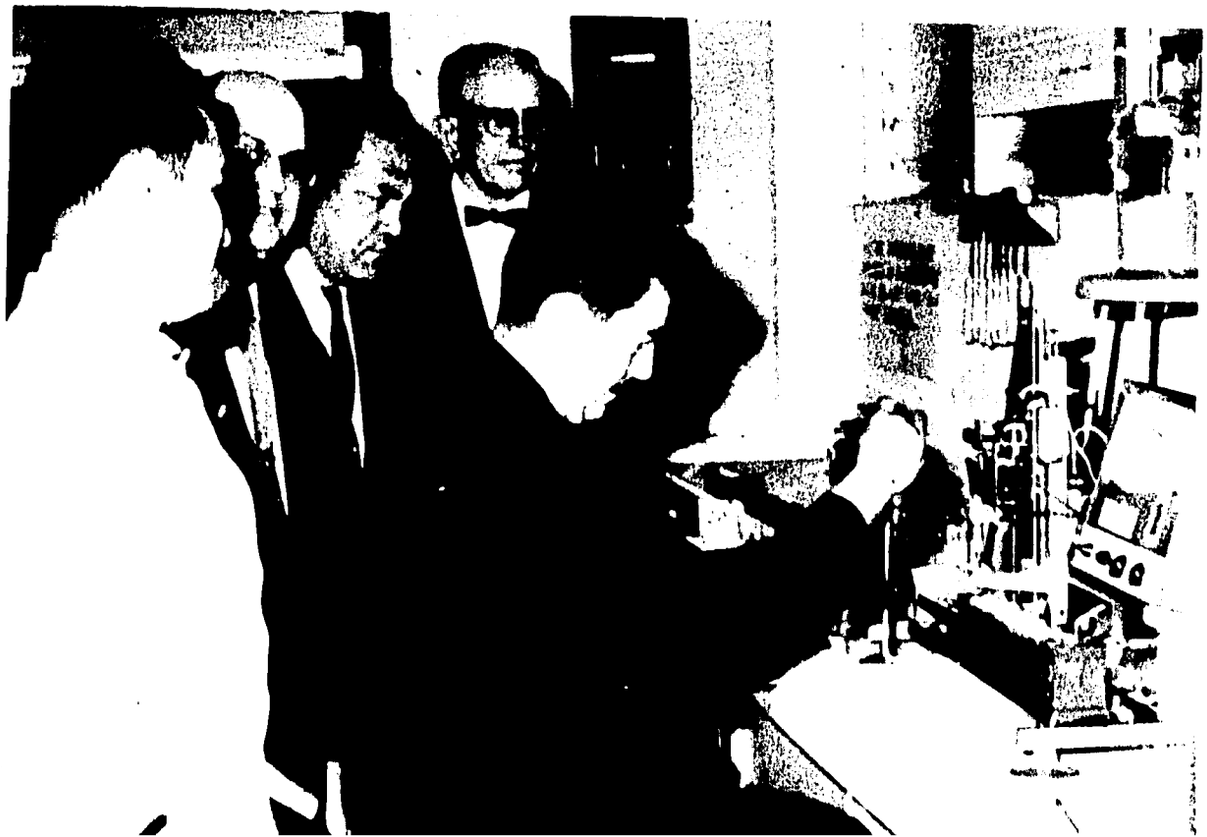
*Soil Science Society, Central America, México and Panamá Chapter--Results of election of General Assembly:

President	:	Dr. José A. Martini, IICA-OAS, Costa Rica
Vice-President	:	Dr. James L. Walker, International Soil Testing Project, N. C. State University-AID
Secretaries	:	Ing. Agr. John Mannix, Ministry of Agriculture, Costa Rica
		Ing. Agr. Jorge A. González, Ministry of Agriculture, Guatemala

Well organized displays of the use of greenhouse studies in making soil analyses-fertilizer use correlations were part of the Laboratory Inauguration in El Salvador.

A new semiautomatic apparatus for determining pH is inspected and operated at Santa Tecla by Ing. René David Escalante Orozco, Minister of Agriculture of El Salvador.



Well conducted greenhouse pot trials are an essential step in calibration of soil tests. The first step is to get good representative soil samples. Soil fertility analyses in the laboratory is the second step. Probable fertility needs are then established and greenhouse trials established to relate soil tests to growth responses to added plant nutrients. This research sequence was well illustrated by the greenhouse displays in El Salvador at the Laboratory Inauguration.

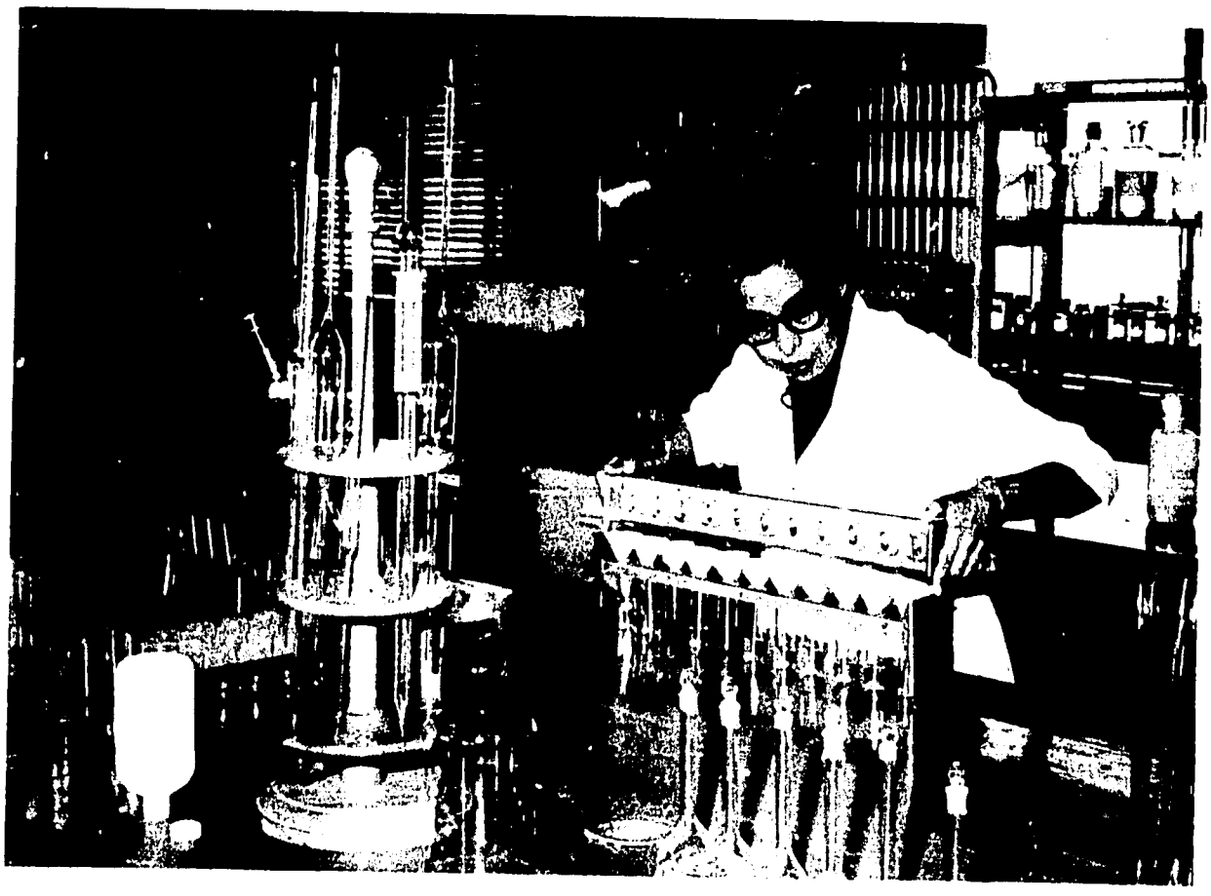
The soils laboratories in Guatemala, El Salvador and Honduras are fully operative and ready to handle almost any number of samples which are likely to be received. Inauguration ceremonies were held for the laboratories in Guatemala on May 3, in El Salvador on May 5, and in Honduras on May 8. The inauguration of the laboratory in Honduras was conducted as part of the Symposium on the Economic Impact Through Soil and Plant Analysis. All three programs lasted three to four hours and concluded with a tour of the laboratory facilities. From 50 to 100 persons attended each of the inauguration ceremonies.

Guatemala: The group was greeted by Ing. P. A. Héctor Cabarrús, Vice-Minister of Agriculture. Remarks relative to the soil testing program were made by Ing. José Manuel Tárano, Director General of Agriculture.

Many improvements have been made in the laboratory in Guatemala City and maximum use is now being made of the space available. The rooms were not designed originally for laboratory use but rearrangement of desks, etc. has been made to facilitate the handling and analyses of samples.

El Salvador: A new building has been constructed to house the soil-plant testing laboratory in Santa Tecla, El Salvador. It is an excellent laboratory and superior to most laboratories of similar nature in the United States. The laboratory was very well displayed during the inauguration. Small signs had been placed by each piece of apparatus or equipment which identified it and listed its use.

An excellent potted plant study, with appropriate signs, was on display in the greenhouse adjacent to the soil testing laboratory. Samples of soil from twenty soil types were included in the soil test correlation study. Techniques outlined in Technical Bulletin No. 3 of the International Soil Testing Series were being followed in this experiment.



Scenes from the well equipped laboratory in Honduras. Multiple analyses techniques are used in all the primary procedures.

Ing. René David Escalante Orozco, Minister of Agriculture, welcomed the group and then outlined the work of the Soil Testing Project in El Salvador. He was very complimentary of the program. Other administrators of the government of El Salvador who participated in the inauguration included: Ing. Luis Alonzo Vanagas, Vice-Minister of Agriculture; Sr. Ricardo Cabezas R., Director General, Agronomic Investigations; and Ing. Armando Alas López, Sub-Director General, Agronomic Investigations.

Honduras: Inauguration of the soil analyses laboratory in Honduras was held in conjunction with the Symposium Program "Economic Impact Through Soil and Plant Analysis". In attendance were the officials of the Ministry of Natural Resources in Honduras and the guests of the Symposium. The program of inauguration included a tour of the laboratories and displays of the new multiple analyses equipment. Visits to fertility research installations and reviews of research programs and program plans were also included in the inauguration schedule.

Research Seminar--Raleigh

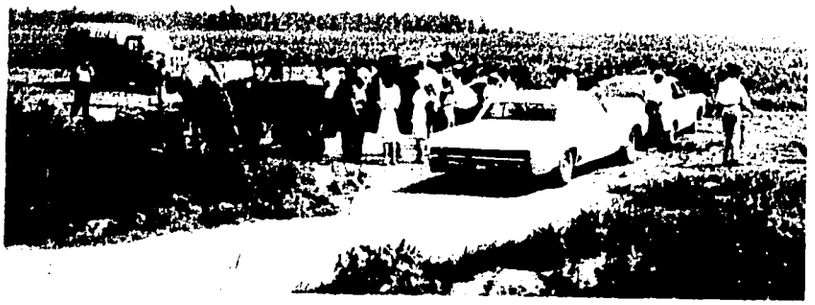
Observations made during the two seminars conducted in 1966 indicated that a longer period of time would be desirable for the seminars; therefore, a nine week seminar was undertaken in 1967. Twenty-five participants from nine countries attended the seminar. Latin American countries represented included: Brazil, Colombia, Ecuador, El Salvador, Paraguay, Perú, Uruguay, Venezuela and Bolivia. One representative was from Afghanistan. The participants and their respective countries are listed and shown on pages 84 and 85.

The seminar programs included: discussions of mutual problems and country programs; a lecture series on soil analyses principles and implementation programs; discussions of sampling, of laboratory techniques and organization,

and of calibration procedures and information; and field trips to observe programs in action. These several activities were fitted into a schedule of four periods per day. The first period, from 0815 to 1015 hours, was devoted to the primary lecture series. The second period, from 1045 to 1200 noon, was primarily for discussion groups organized and presented by the visiting participants. The afternoon periods, 1330 to 1500 hours and 1530 to 1700 hours, were occupied with research work by small groups, with special lectures and with construction of equipment and the preparation of reports and visual aids.

In addition to the staff of the International Soil Testing Project, the following members of the North Carolina State University faculty participated in the seminar programs:

Name	Title	Department
L. E. Aull	Research Assoc. - Soil Classification	Soil Science
Steve Barnes	Instructor - Soil Classification and Soil Management	Soil Science
M. G. Cook	Assoc. Professor - Soil Mineralogy	Soil Science
G. A. Cummings	Assoc. Professor - Soil Fertility	Soil Science
J. W. Gilliam	Asst. Professor - Soil Chemistry	Soil Science
E. J. Kamprath	Professor - Soil Fertility	Soil Science
L. A. Nelson	Associate Professor	Exp. Statistics
P. H. Reid	Prof. & Director, Soil Testing N. C. Dept. of Agriculture	Soil Science
R. J. Volk	Professor - Soil Chemistry	Soil Science
R. T. Troxler	Asst. Prof. - Industrial and Technical Education	Industrial Arts
Hal L. Reynolds	Associate Editor	Agricultural Information
Mrs. Ruth G. Sheehan	Assistant Editor	Agricultural Information



Field trips to see research in progress were an important seminar activity. Liquid fertilizer dispensing equipment (above) and soybean fertility plots (below) were observed in the course of the tours.

Fruit fertility research was observed at the Sandhills Research Station. The soil management research program currently in progress, including the need and use of fertilizers, was reviewed for the seminar group by Dr. G. A. Cummings of the North Carolina State University Soil Science Department. A pleasant part of the tour was the inspection and sampling of new varieties of peaches.

Also the following organizations outside of the University assisted in the seminar either by giving special lectures or by providing tours and demonstrations of their agricultural programs:

Program Cooperator	Address
American Potash Institute Al Plant	403 W. Ponce de Leon Ave. Decatur, Georgia
Agricultural Extension Service W. D. Lewis, County Ext. Chairman	Box 3027 Wilson, North Carolina
Agricultural Research Station William C. Allsbrook, Superintendent Central Crops Research Station	Box 303 Clayton, North Carolina
Clarence S. Black, Superintendent Sandhills Research Station	Jackson Springs North Carolina
Planters Industries, Inc. N. L. Sugg, Vice President Leroy Jackson, Agronomist In Charge of Sales	P.O. Box 912 Rocky Mount, North Carolina
The Sulphur Institute George R. Burns, Asst. to Director of Agr. Research	1725 K Street, Northwest Washington, D. C.
Texas Gulf Sulphur Corporation Earl Mason	Aurora, North Carolina

One of the special activities of the seminar was visits to private farms in Central and Eastern North Carolina. The following farms and farm operators played host to the seminar group and conducted tours of their farming operations and facilities:

Farms Visited

Marion Dilday Circle Grove Farm Belhaven, North Carolina	A. D. Swindell Swindell Farms Pantego, North Carolina
Welford L. Winstead Rocky Mount, North Carolina	Ralph R. Brake, Jr. Battleboro, North Carolina
Elsie Walston Wilson, North Carolina	Edgar Gardner Wilson, North Carolina

John Grimsley
Wilson, North Carolina

R.S. Griffin
Wilson, North Carolina

B. F. Glover
Wilson, North Carolina

Tom Reeves
Pittsboro, North Carolina

Excellent translation services made the meetings and tours proceed smoothly and plesantly. In addition to Mrs. Annette Cash, the bilingual secretary of the International Soil Testing Project, the following participated in the translation functions:

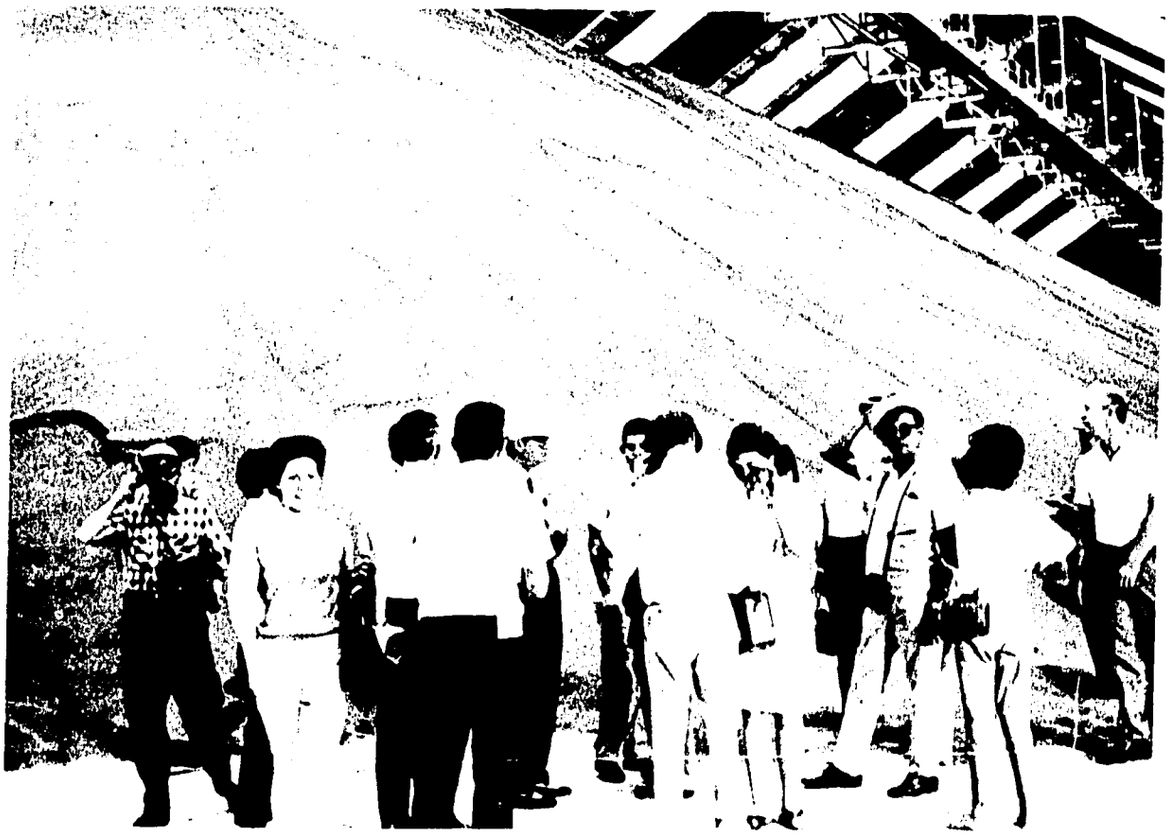
Mrs. Ofelia de Cano
Perú

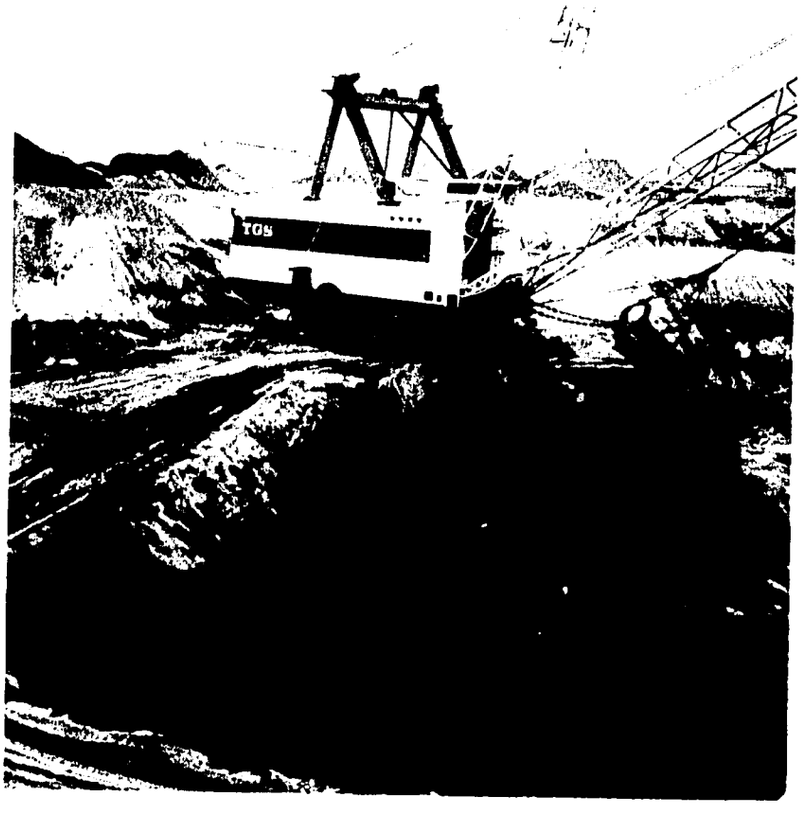
Arnaldo Gorrin Hernandez
Venezuela

Carlostadio Sanchez
Venezuela

German Segura
Venezuela

The visitors are dwarfed by the size of this pile of granulated phosphate in a storage shed at the Texas Gulf Sulfur Plant in Eastern North Carolina.



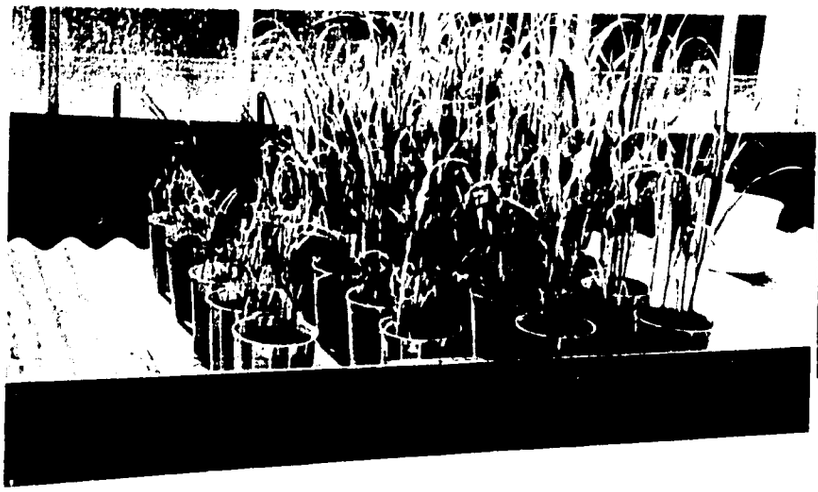


Fertilizer producing facilities were visited in the course of the field trips. The very large dredging crane makes the road grader in front appear as a toy. A large quantity of the phosphate bearing strata at the bottom of the excavation is brought to the surface with each scope of the dredge bucket.

The dark colored zone shown part way down the side of the pit is the phosphate bearing strata. It is overlain by varying thicknesses of surface sediments.

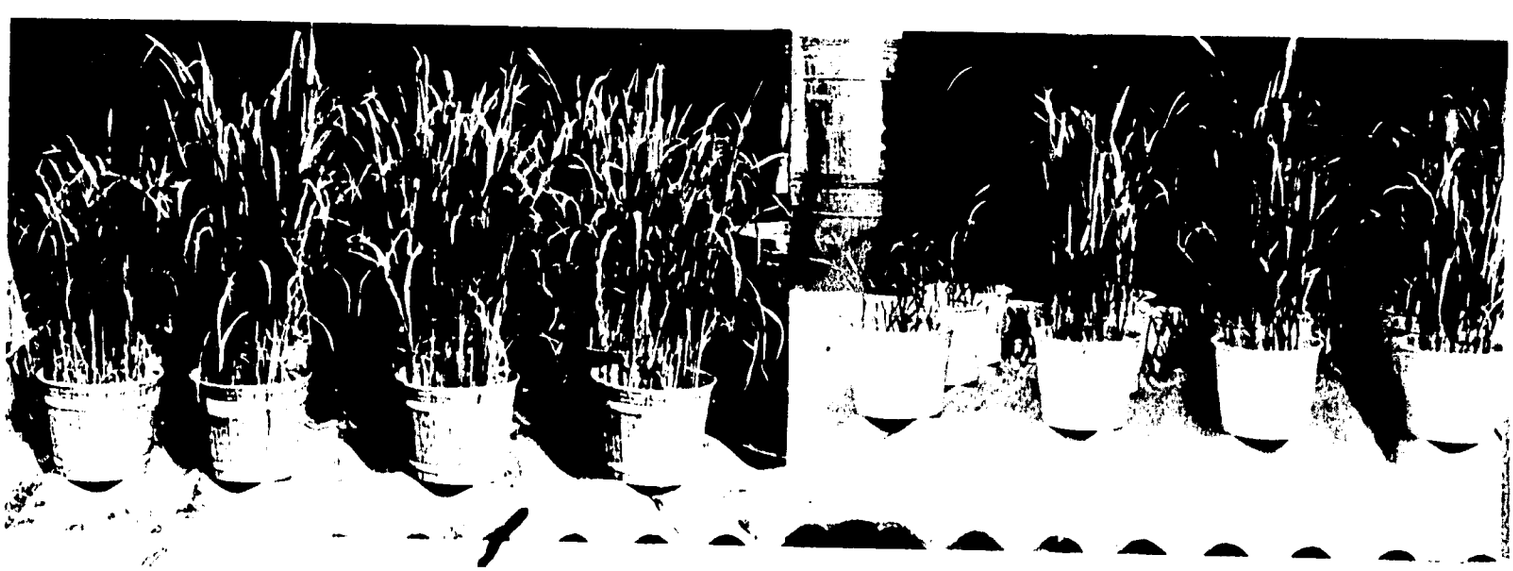
Exposed soil profiles were examined during the field trips. Here a site in Chatham County is inspected and studied.

Since taking good soil samples is such an important part of a soil fertility analyses program, the seminar participants examined this process in detail. A field trip to observe soil variation patterns and to examine methods and programs of sampling was included in the agenda. Samples taken were subsequently analyzed and the results were examined and discussed collectively by the seminar group.



Seminar participants reviewed and experimented with methods of correlating soil fertility analyses with crop needs for fertilizer. Greenhouse pot experiments are recommended to establish a measure of the probability of a particular crop responding to the addition of fertilizer.

The seminar participants were organized into groups for conducting experimental work. Each group selected a soil, made fertility analyses, decided probable fertility needs on the basis of the analytical results, outlined greenhouse pot trials to test the validity of their recommendations, and carried the tests to completion. The methods and procedures employed were later reviewed and evaluated in the light of the greenhouse results. The value of soil analyses and greenhouse pot tests were brought into better perspective by these research activities and a better appreciation of the use and value of soil fertility analyses in agricultural research and production programs was developed.



Follow-up and educational programs came under discussion by the seminar group. Here small groups are engaging in planned technical discussions as an aid in finding better ways of informing the general public of the results and importance of soil analyses programs. Some members assembled sets of colored 2 x 2 slides depicting the proper techniques in taking soil samples. Along with the slide sets they prepared and tape recorded narratives in their own languages to accompany the slides.

Sampling

Obtaining representative samples for either soil testing or plant analyses is one of the critical steps in the program. Samples not only must be accurately taken but distribution of number of samples throughout the year is important too. Organized sampling programs within given areas afford excellent opportunities for working with farmers in their soil fertility problems. Educational programs relative to sampling and follow-up can be established and efforts made to see that fertilizers, lime or other soil amendments needed in the area are available to the farmers.

Organized sampling programs have been initiated in several countries. The Altiplane area (high region) of Guatemala has organized to obtain 7,500 samples from cultivated areas. Several agencies and private organizations are cooperating in the project.

Much emphasis is being placed upon soil analyses in Nicaragua. The Agricultural Extension Service is closely coordinating their program with the soil testing laboratory. A goal of 4,000 samples per month was set for the country and this probably will be attained in 1968. Currently the laboratory is testing about half of that number.

The Peace Corps in the Ibarra region of Northern Ecuador is much interested in soil testing. A meeting was held in the region to organize a pilot testing program. Samples will be sent to the laboratory in Quito for analyses.

In the Improved Potato Production Program of Perú which is jointly sponsored by SIPA of the Peruvian Government and several agencies, a goal of 10,000 soil samples to be taken from 20,000 hectares was established.

Greater emphasis was also placed on getting representative samples in Brazil. Organizational meetings on sampling have been held and printed in-

Soil sampling clinic in Ecuador involving Peace Corps members and Extension Agents from the Ministry of Agriculture.

Terrain and undergrowth present peculiar problems in taking soil samples from some lowland areas of El Salvador.

structions developed. Most of these meetings were conducted by the Brazilian agricultural leaders.

Transportation of Samples

The total area which can be effectively served by a single soil analyses laboratory is directly related to the transportation services available for shipping the samples to the laboratory and in expediting the return of the analytical results and recommendations to the farmers. Soil analyses services are most economically operated per unit analysis when rather large numbers of samples are analyzed by a single laboratory unit each year (more than 50,000 per year). Rapid transportation, therefore, is a very important factor in the economy and efficiency of a soil analyses program.

Various transporting arrangements have been devised. Many of them closely linked to Agricultural Extension organizations and facilities. A unique system has been worked out in Perú where land travel is slow and erratic. Here an arrangement has been concluded with the Faucett Airlines to carry most of the soil samples to the laboratory by air freight. A map locating the collection stations is shown in Figure 21. A given number of samples is transported free each year. A nominal charge is made to the laboratory for numbers in excess of the maximum gratis quota.

Staff Conference

Periodic staff conferences are very essential to the success of the project. Problems are reviewed and plans of work for ensuing months discussed. A staff conference was held in Panamá during March. Preparation of soil test summaries, development of guide sheets, correlation studies and research in soil acidity and nitrogen availability were topics that were discussed in con-

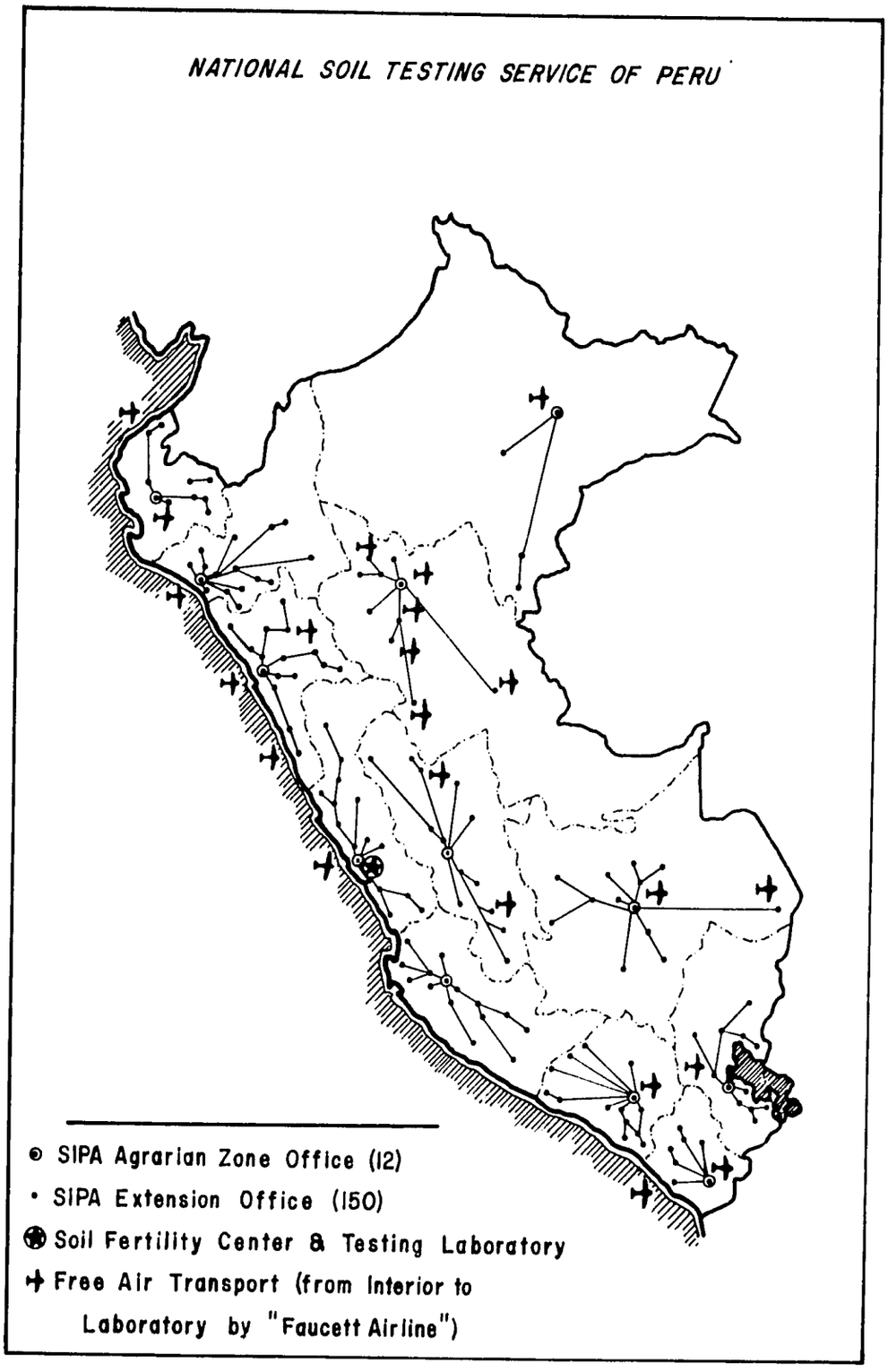


FIGURE 21. Location and distribution of SIPA Agrarian Zones Extension Offices and Airline Connections

Dr. J. W. Fitts, Director of the International Soil Testing Project, conducts Dr. H. Brooks James, Dean, School of Agriculture and Life Sciences, and Dr. R. L. Lovvorn, Director of Agricultural Research, North Carolina State University, on a tour of the Control Laboratory.

siderable detail. Administrative problems and details of project operation received attention also.

In October of 1967 a second conference was held in Raleigh in conjunction with a meeting of the United States Advisory Committee to the project. At this conference plans and preparations were made to summarize the soil analyses data available to date in the several cooperating countries.

United States Advisory Committee Meeting

Dr. H. Brooks James, Dean, School of Agriculture and Life Sciences at North Carolina State University, greeted the committee on behalf of the Uni-

The United States Advisory Committee meeting with staff in October 1967. Back row (left to right): Dr. C. B. McCants, Dr. J. L. Walker, Dr. E. J. Kamprath, Prof. C. P. Bickford, Dr. D. L. Waugh, Prof. R. B. Cate, Jr., Dr. A. D. Ayers, Dr. A. H. Hunter, and Dr. J. C. Engibous. Front row (left to right): Dr. W. H. Garman, Dr. S. E. Younts, Miss Dotty Goodson, Dr. R. W. Pearson, Dr. D. J. Lathwell, and Dr. J. W. Fitts.

versity and discussed the interest and problems of a university in projects such as the International Soil Testing Project. A review of project activities and progress was made to the committee by project personnel. After extensive discussions of the project in the light of project objectives, the committee in executive session made the following comments and recommendations relative to the project and its activities:

Recommendations of United States Advisory Committee
to
International Soil Testing Program
October 30-November 1, 1967

1. The United States Advisory Committee continues to be impressed with the progress being made in Latin America by the International Soil Testing program. The continued support of North Carolina State University at Raleigh is to be commended. The Advisory Committee is of the opinion that this project is now at the stage where maximum return may be realized, and thus it should be programmed on a long term basis so that its potentialities may be realized.

2. Recommendations made by the Advisory Committee in the two previous reports to the ISTP are still appropriate and applicable to its program in Latin America.

3. While continuing support by ISTP to existing soil testing laboratories in cooperating Latin American countries will be required, the Advisory Committee believes that the major research effort should be shifted from laboratory development and operation to soil test correlation studies. Although considerable effort has been made in these studies, increased effort should be expended in greenhouse and especially field studies. We realize that time will be required for substantial progress in collecting correlation data but we believe it it absolutely essential in solving the soil fertility problems of Latin America. In those areas where programs have not yet begun and laboratories are not available, the first logical step appears to be that of laboratory development.

4. With substantial numbers of soil samples now having been analyzed in several countries it should be possible to document the soil fertility requirements for increased crop production in much more detail than heretofor. Some progress has been made, but it now seems possible to summarize and publish formally the results of such studies. This research effort should be widely publicized and dissiminated to all public and private agencies in the various countries.

5. The Technical Report Series on pertinent research activities continues to be popular and fills an essential need as evidenced by the demand for these

publications both in the United States and abroad. The authors of these reports are to be commended. The Advisory Committee, however, is disappointed that the previously discussed report on laboratory equipment and design has not been prepared. The Committee strongly recommends that this publication as well as a proposed report on nitrogen be prepared and issued during the coming year.

6. Mutual cooperation with both public and private agencies should be encouraged at all levels to avoid duplication of effort in the field. The Program has proceeded to the point where ISTP should be recognized as providing leadership in the field for soil analysis programs. This leadership should be assumed at the field level in guiding the private fertilizer sector toward sound soil testing procedures and recommendations to farmers.

7. The Advisory Committee believes very strongly that the summer seminars for laboratory directors and technicians conducted at Raleigh the past two years have contributed significantly to the implementations of the ISTP program in Latin America. It is recommended that this training concept be continued at Raleigh as in the past. It is further urged that the seminar program be held in cooperating countries or regions as soon as practical. Due to its size and the great interest shown by its agronomists in past seminars, Brazil would perhaps be the logical area to initiate the field seminar approach.

8. At present or forseeable levels of support, emphasis should remain on the definition of soil fertility requirements for crop production in Latin America. While need in other developing areas of the world is real and urgent, dilution of effort in Latin America at this stage would reduce effectiveness. The completion of bulletins in preparation on laboratory equipment and procedures, field plot design and statistical treatment, and nitrogen, together with publications already released, can go far to meet the demand for assistance outside Latin America.

Soil Analyses Program Progress by Countries and Regions

Brazil: Brazil is developing the organizational structure and background information needed for a sound and efficient soil testing service. Owing to the size and agricultural complexity of the country, a soil fertility analysis service system must include a number of laboratories, extensive calibration research and programs (and/or administrative systems) to coordinate the activities of the several research service facilities contributing to the program.

In 1964 there were virtually no soil testing programs in Brazil of the type usually found in the United States, although 25 to 30 laboratories scat-

tered in various educational and research institutions were analyzing samples for farmers. The laboratories at that time were slow in producing results and the fertilizer recommendations were frequently considered unreliable.

There are now 13 efficient laboratories serving farmers throughout Brazil (Table 9). These are distributed in the highly developed coastal areas of Brazil (Figure 22). All of the laboratories are using the same or similar methods of analyses. The test calibrations are under the process of improvement and refinement by relating them to the results of an ever increasing number of greenhouse and fertility field experiments. Fertilizer suggestions based on soil tests should continue to be more precise because of the increase in field fertility trials with a wide variety of crops. Moreover a cooperative effort is currently underway to relate the fertilizer suggestions or recommendations made by the soil testing service to both soil test values and to the expected economic returns from the use of fertilizers. The latter is related to the monetary value of the crop as well as the expected increase in crop yield and quality from the proper use of fertilizers.

The results from the several efficient laboratories are considered reliable. The analytical procedures are checked by the consistent daily use of control samples. The service and the reporting of the results are rapid because of the advanced design and fabrication of equipment by the Ministry of Agriculture. All of the laboratories listed in Table 9 are equipped and staffed to receive and analyze in excess of 100 samples per day. With some additional staff and very little additional equipment, most of the laboratories could easily double or triple their daily output of service.

Lime recommendations are made by all the laboratories when the test results indicate a need. The recommendations are all made by the standard procedure

Table 9. Mechanized Soil Testing Laboratories in Brazil - Status as of June 30, 1967.

Location	Affiliation	Comments
Belém, Pará	Min. Agr. - IPEAN	functioning
Fortaleza, Ceará	Univ. Ceará (Arizona U.)	ordered
Recife, Pernambuco	Min. Agric. - IPEANE	functioning
(X) Recife, Pernambuco	Univ. Rural (N.C. State U.)	installed, but
Cruz das Almas, Bahia	Min. Agric. - IPEAL	functioning
Itabuna, Bahia	CEPLAC (cacao)	functioning
Seta Lagõas, Minas Gerais	Min. Agric. - IPEACO	functioning
Lavras, Minas Gerais	Sup. School of Agric.	functioning
Rio de Janeiro, Guanabara	Min. Agric. - DPFS	functioning
Km. 47, Estado do Rio	Min. Agric. - IPEACS	installed, but
Campinas, São Paulo	Secre. Agric. - Inst. Agron.	functioning
Londrina, Paraná	Min. Agric. - Exp. Stn.	installed, but
Curitiba, Paraná	Secr. Agric. - CERENA	under construction
Rio Negro, Paraná	Cia. Souza Cruz (tobacco)	functioning
(XX) Pôrto Alegre, R.G. do Sul	Univ. RGS (U. Wisconsin)	functioning
Pelotas, Rió Grande do Sul	Min. Agric. - IPEAS	functioning

(X) Raleigh-made equipment, primarily for research teaching.
(XX) Wisconsin-type equipment, primarily for research and teaching.

All of the above laboratories use similar methods, and their results are comparable.

At least ten non-mechanized labs are also operating. Most of these are believed to have adopted our analytical methods, but the reliability of the results is unknown.

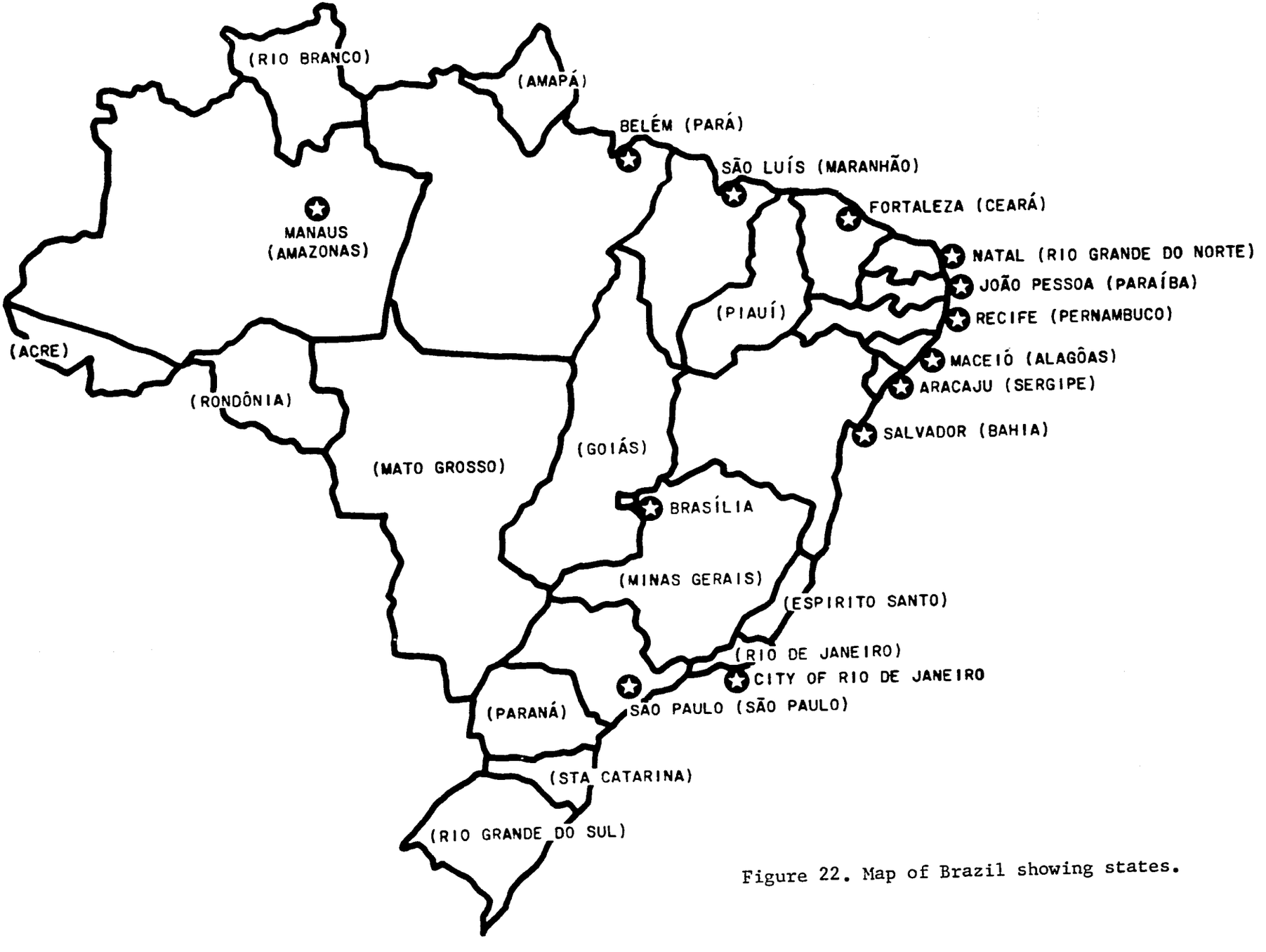


Figure 22. Map of Brazil showing states.

outlined in Technical Bulletin No. 3 of the International Soil Testing Series. Also the phosphorus and potassium fertilizer suggestions at all of the laboratories are based upon the national soil test critical levels. These critical levels for P and K were tentatively established in 1964 on the basis of an International Soil Testing Project analysis of several hundred field trials with a wide variety of crops and soils. Considerable scatter was found when these largely unreplicated trials by many organizations were plotted and studied by the Cate-Nelson method. However, the resulting critical levels were virtually identical with those already accepted semi-intuitively by the leading Brazilian research institutions, and were astonishingly close to those used in the Southeastern United States. (The levels are 10-11 ppm P and 45-46 ppm K, using Mehlich's extractant with a 1:10 soil-solution ratio.) Since 1965 several dozen scattered pot and field trials around the country have given no consistent indication that these critical levels vary appreciably among soils, climates or crops. However, in order to further verify these levels, and pinpoint possible exceptions that warrant research, the institutions cooperating in the Brazilian National Soil Testing Program have agreed to carry out standardized nationwide pot trials in 1968, using as a guide Technical Bulletin No. 3 of the International Soil Testing Series. Results of these trials, as well as field data, will be circulated informally among all laboratories.

To facilitate coordination of the soil testing activities in Brazil, the Pedology and Soil Fertility Division of the Ministry of Agriculture plans to create a staff of roving advisors headed by Dr. Leandro Vettori, Coordinator of the Brazilian National Soil Testing Project. As an aid to project coordinating in 1967, there were two general meetings held in Rio de Janeiro of representatives of the cooperating laboratories. Another coordinating meeting is scheduled for July 5, 1968.

The success of the coordinated efforts has been enhanced by the fact that a large proportion of the Brazilian workers in soil testing activities have participated in one of the International Soil Testing Seminars.

Rió Grande do Sul and Santa Catarina: The Ministry of Agriculture Research Institute at Pelotas has been active in soil fertility and soil testing for many years. During that time numerous field trials have been conducted. The results from the trials, however, were not translated into practical orientation for farmers through close correlation with soil testing methods. Thus, even though the laboratory in 1964 was the only semi-mechanized unit in Brazil, it was handling relatively few samples for farmers.

Potentially, the Pelotas laboratory is one of the most important in Brazil in that there is a great service to be performed. In 1967 two members of the laboratory staff attended the International Soil Testing Seminar. This and other developments should enhance the interest in soil fertility analyses as an aid to more efficient crop production. The University of Wisconsin AID contract group in Pôrto Alegre has established its own soil testing facilities at the local university. This laboratory is primarily for research and training purposes, but on two occasions it has participated in model county impact programs, each of which produced over 3,000 farmers samples in a matter of weeks. This indicates the possible demand. Part of the explanation for the low number of soil samples tested at Pelotas lies in the fact that Rió Grande do Sul also has a state soil testing laboratory and three or four private laboratories. All of these are small and test but few samples, thus tending to handicap acceptance of soil testing. What is needed is a coordinated, statewide program in soil fertility which would include promotion of a single efficient laboratory. The discussion above refers principally to Rió Grande do Sul.

Santa Catarina is a small state lying between Rió Grande do Sul and Paraná. Its farmers send soil samples to both states for analysis. However, the state also has its own soil testing laboratory, which it hopes to modernize and incorporate into the National Soil Testing Program. This will probably take place in 1968. In addition, the Souza Cruz Tobacco Company (British-American) operates a mechanized laboratory affiliated with the National Program. All samples are taken by its private extension staff. This organization serves about 30,000 farmers. The laboratory is actually located in Paraná but most of the samples come from Santa Catarina and Rió Grande do Sul. The man in charge of all research activity, including the laboratory, attended the first International Soil Testing Seminar in Raleigh.

A number of organizations are engaged in soil fertility research in these two states. However, data for immediate use in soil test calibration has not been abundant. In 1968 there are plans for International Soil Testing Project-oriented pot trials. The University of Wisconsin has done considerable useful work in conjunction with the State Secretariat of Agriculture, the Rice Institute, and IRI. Souza Cruz has an ambitious experimental program but the results are not available for general use. Some usable data should become available soon from a set of field trials organized by ANDA, an organization of fertilizer companies which will be discussed later under São Paulo. The Brazilian Potash Institute has a representative in Pôrto Alegre who has put out many field trials in the past several years, but little has been published and the program is being cut back.

<u>Paraná</u>: In addition to the Souza Cruz laboratory discussed above, there are two sets of Ministry of Agriculture soil testing equipment in this state. One of these is in Londrina and was originally destined for a proposed

Ministry experiment station. However, funds and personnel were not forthcoming so the apparatus has never been used. The other set of equipment is installed and functioning in Curitiba, under the direction of the State Secretariat of Agriculture.

Most of the soil fertility research in Paraná, as well as soil survey activity, is coordinated by CERENA, a state agency for the study of natural resources. The Technical Coordinator is Dr. Raul Kalckmann, former head of the Soil Fertility Section at Pelotas. CERENA has an ambitious program of its own in conjunction with IRI, ANDA and other organizations.

São Paulo: The Agronomic Institute at Campinas has the only modern soil testing laboratory operating in this state and it is by far the most active in Brazil, having analyzed over 18,000 samples in 1967 (vs. 12,000 in 1966 and 6,000 in 1965). During the rush season 165 samples are analyzed daily. Results usually are out within two weeks. One major customer (Phillips Petroleum's affiliate, Ultrafertil) has decided to install a similar laboratory of its own and this will relieve some of the pressure on Campinas. The only real bottleneck at Campinas is the secretarial work. Another large customer, ANDA, is expected to assist in resolving this problem in 1968. The Head of the Campinas laboratory is Dr. Hermano Gargantini. He attended the 1967 International Soil Testing Seminar in Raleigh.

Several organizations are active in soil fertility research in São Paulo. Some are briefly discussed here. The Instituto Agronómico has 15 crop divisions, all of which carry on field trials, usually in cooperatin with Dr. Gargantini who also has his own greenhouse program. The Agricultural School at Piracicaba (Escola Superior da Agricultura Luiz de Queiroz - ESALQ) has several divisions interested in soil fertility. Two faculty members attended

the 1967 International Soil Testing Seminar at Raleigh. Ohio State University has an AID contract with ESALQ but has not placed emphasis on soil fertility since the school is already strong in this field. The new organization of fertilizer companies, ANDA (Associação Nacional para Difusão de Adubos - National Association for Promotion of Fertilizers) financed and supervised several dozen field trials throughout Southern and Eastern Brazil in 1967. Results are not yet in but they should be very useful. The ANDA research program is expected to expand in 1968. The IRI Research Institute (formerly IBEC) has been active in the state for many years, and has produced much useful data. IRI has an all-Brazil AID contract to assist the Ministry of Agriculture in developing its research capability, with strong emphasis on soil fertility. The above mentioned fertilizer company, Ultrafertil, plans to install International Soil Testing-type pot trials at its fourteen service centers scattered throughout the state. The 25,000 member Japanese Farmers Cooperative, COTIA, has a continuing field research program primarily for its members. The Brazilian Potash Institute during the past few years has carried out over 100 field trials; however, little data are available from these trials.

Guanabara, Rio de Janeiro, and Espírito Santo: Until recently farmers samples from these states were channeled into the Ministry of Agriculture's original headquarters laboratory in the City of Rio (State of Guanabara). Now that the laboratory at the Regional Institute at Km. 47 in the State of Rio is operating, the headquarters laboratory will be working mainly on research and control samples plus "fertility" samples taken by the National Soil Survey. In the Ministry of Agriculture, soil survey and soil fertility are in the same division which greatly facilitates coordination.

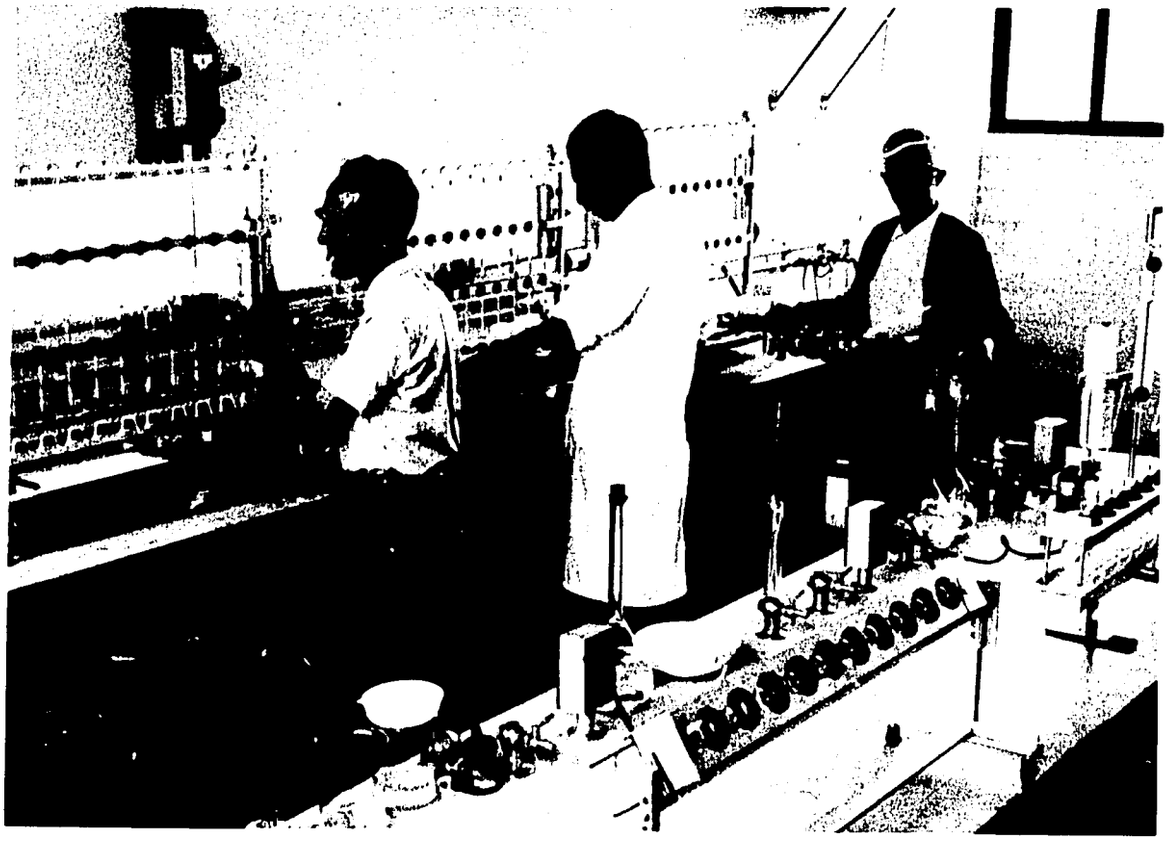
A fairly substantial amount of useful soil fertility work has been done in recent years by the Research Institute at Km. 47, some of which was in co-

operation with IRI. Not much has been accomplished at the neighboring Rural University but this may change now that a graduate program has been established under Dr. Abeillard de Castro, former Director of the Pedology and Soil Fertility Division of the Ministry. This division, itself, has never run any greenhouse or field trials but the new Director, Dr. Nathaniel Bloomfield, has promised to support in 1968 some potted plant fertility trials in the manner suggested by the International Soil Testing Project.

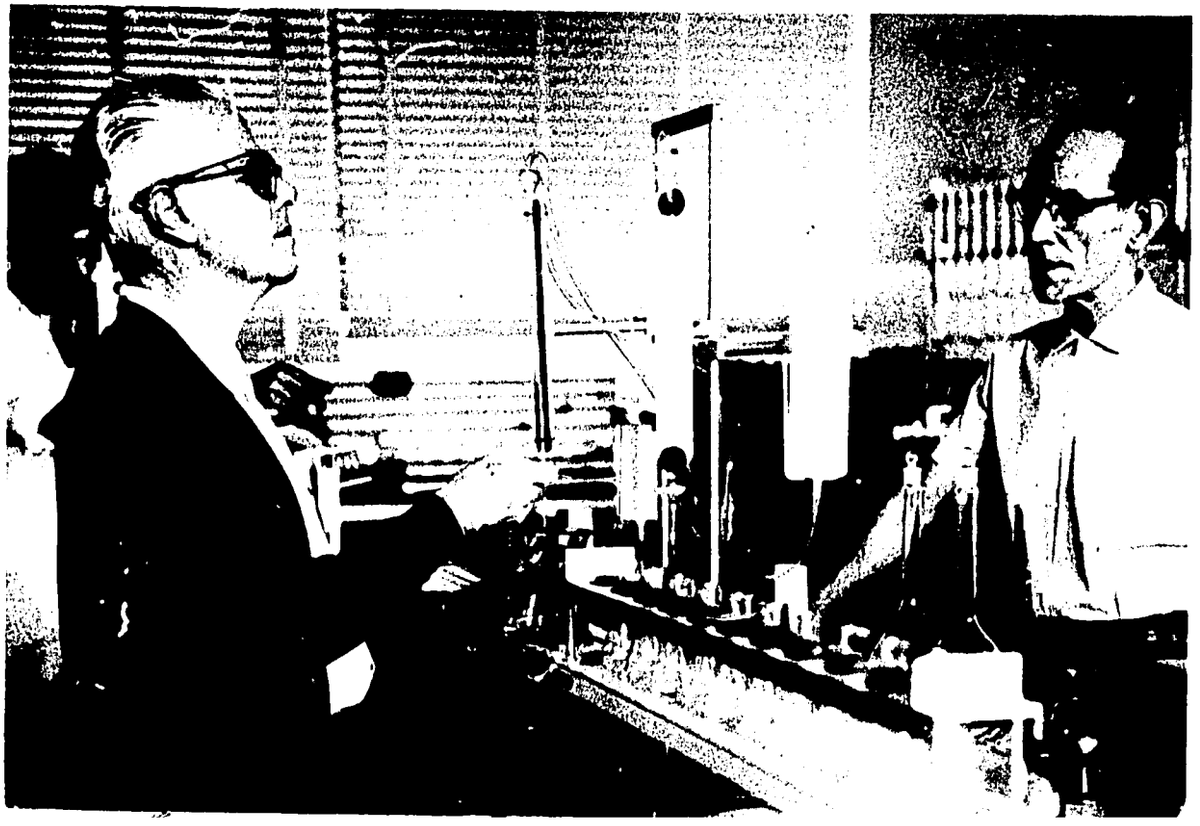
Minas Gerais: Two modern soil testing laboratories are operating in this state, one at the Ministry's Regional Institute in Sete Lagõas and the other at the Superior School of Agriculture in Lavras. The Purdue University AID contract at the state rural university (UREMG) would like to acquire Ministry of Agriculture mass production equipment for the UREMG Soils Department.

The three institutions named above are the principal agricultural research organizations in the state. A beginning has been made in soil fertility research in the state. In mid 1967 representatives of three institutions interested in soil fertility met with the International Soil Testing Project Regional Director and agreed to conduct jointly a series of International Soil Testing-type pot trials on 21 soils typical of the state. Two hundred kilo samples have since been collected, homogenized, and distributed. Subsamples are being distributed to all 14 cooperating laboratories in Brazil for comparison of analyses. The pot trials planned will test for NPK and lime needs. Preliminary analyses indicate that a wide range of nutrient levels are included in these 21 soils.

Bahia and Sergipe: Two sets of Ministry of Agriculture soil testing equipment are operating in the State of Bahia. One of these is at Itabuna, operated by CEPLAC, and the other is at the Ministry's Regional Institute in



Final adjustments and testing of multiple unit equipment by Dr. Vettori and Mestre Juca at the laboratory at Sete Lagõas, Minas Gerais, Brazil. This was the tenth laboratory in Brazil to be equipped with multiple-unit, automatic apparatus for soil analysis.



Cruz das Almas. CEPLAC is a semi-autonomous government organization for the development and diversification of the cacau zone in Southern Bahia. All samples are taken by CAPLAC's corps of extension agents. The Ministry laboratory at Cruz das Almas handles samples from the rest of the state and from Sergipe.

For the past three to four years CEPLAC and Cruz das Almas have cooperated in an extensive set of fertility trials. A high proportion of these trials have been of the "microparcela" type. Both organizations also have their own field and greenhouse research programs. IRI also has recently stationed a soil fertility man in Bahia as well as an agricultural economist. It is expected that some good data will result from the Bahia experiments in 1968. The Head of Cruz das Almas laboratory attended the 1967 International Soil Testing Seminar at Raleigh.

Alagõas, Pernambuco, Paraíba and Rio Grande do Norte: These states are served by the Ministry's Research Institute in Recife which has the second most active laboratory of the Brazilian National Soil Testing Program. About 6,500 samples were analyzed in 1967. Almost 2,000 samples were for pastures and forage crops.

Up until a few years ago, the only significant research on soil fertility in these states was related to sugarcane. About four years ago the Regional Planning Agency for the Northeast, SUDENE, began a series of trials on the infertile coastal tablelands using a variety of crops. Now that soil analyses are made in conjunction with field trials some useful conclusions are being reached. SUDENE has also sponsored two irrigation feasibility studies in the semi-arid interior. These have included soil fertility research. One project in the middle São Francisco Valley has been carried out by FAO; much useful

information has been derived from it. The other project in the Jaguaribe Valley of Ceará has been handled by the French Government. Soil analyses have been done in France and are not available for general use. SUDENE has also done a little fertility work in connection with an Israeli hybrid corn project in the São Francisco Valley and with a colonization project in Maranhão. Data from these projects have not become available. Several sugar estates have separately and cooperatively run field fertility trials in Alagõas and Pernambuco. The results have tended to confirm other data on sugarcane fertility. The Pernambuco State Agricultural Research Station has run a large number of field fertility trials in the past but only a very few have been usable due to lack of soil analyses.

Ceará and Piauí: These states are beginning to be served by the soil testing laboratory at the Agricultural School of the University of Ceará in Fortaleza where the University of Arizona has an AID contract. This laboratory is not yet equipped with mass production equipment but it can easily handle the present small flow of samples manually. The Ministry-fabricated equipment should be installed in early 1968.

Little soil fertility research has been done in this area. However, since the University of Arizona personnel are interested in soil fertility and a member of the laboratory staff attended the 1967 International Soil Testing Seminar at Raleigh, the future should see an increase in soil fertility research in their state.

Maranhão: This state is transitional to the Northern or Amazon region and farmers samples are currently being sent to the Ministry laboratory in Belém. Actually there is very little soil testing activity so far in the state but there are a number of development projects in progress in the state which could rapidly alter the need and demand for soil analyses.

Venezuela and Colombia: Substantial progress has taken place in each of these countries in the development of sound soil fertility analyses programs. Laboratories have been established and equipped and the necessary background research for calibration is under way. More detailed reports on country progress and plans for the future are found in the Appendix. (See Dr. McCants' report of Venezuela in the Appendix, page 135, and Dr. Kamprath's report of Colombia in the Appendix, page 131.)

Perú, Ecuador and Bolivia: Progress in Perú has been very good. An excellent laboratory is in operation in new building facilities with ample room for supplemental potted plant studies. The soil analyses data have been related to field responses of a number of important crops to the addition of fertilizers. The Extension Division is closely cooperating in the further development of soil analyses programs in Perú and they are using the test data in helping farmers improve the quality and yield of crops.

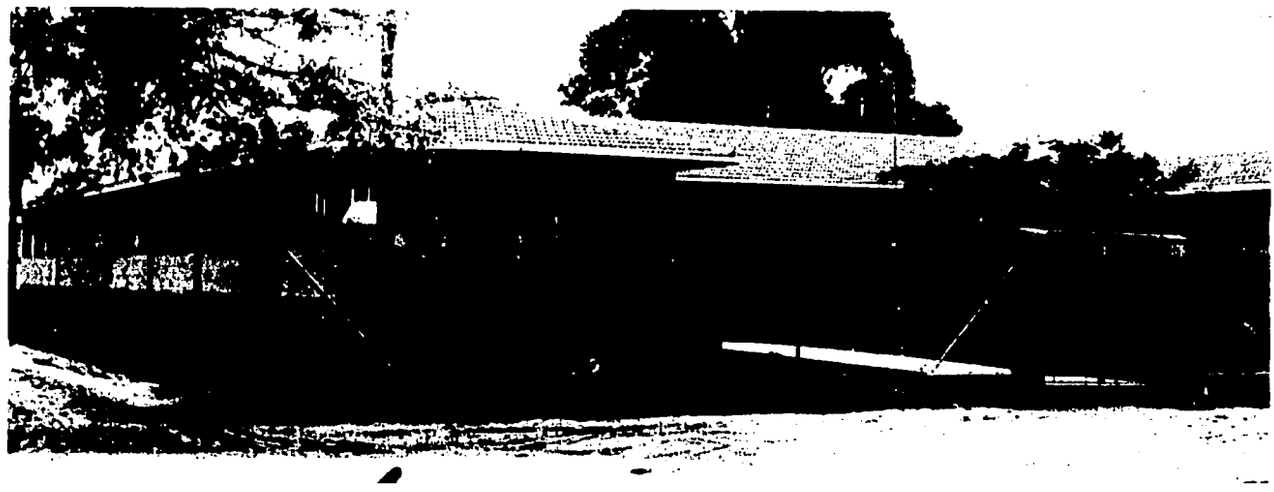
The programs are beginning to get under way in Ecuador and Bolivia. Laboratory facilities have been established and some of the needed correlation research is under way. The programs in these countries can be employed more effectively in facilitating improved crop production.

Nicaragua, Costa Rica, and Panamá: The cooperating laboratories in each of the countries are administered by a division of the Ministry of Agriculture. This organizational affiliation expedites coordination of the laboratory activities with other phases of a good soil testing program.

All of the laboratories have been equipped with multiple unit equipment such as dispensers, aliquoters, stirrers, trays, etc. which makes it possible for each to accurately and rapidly analyze in excess of 100 samples per day.

Newly constructed facilities (SIPA, La Molina) for soil and plant analyses (top) including enclosed patio (bottom) for potted plant experiments.

Recently completed laboratory at the Agricultural Center at Santa Cruz, Bolivia for soil analytical research and service.



The laboratories have had on hand or acquired from other sources electronic instruments such as pH meters, flame photometers, colorimeters, etc. so that the best methods of analysis can be utilized.

During 1967 each of the laboratories have had at least one period of time in which it was required that they analyze more than 100 samples per day in order to stay current with the numbers of samples received from the field. As a result they have demonstrated their capability and capacity to do so.

One of the real problems facing each of the laboratories at the present time is their lack of extra equipment, spare parts and stocks of required chemicals. Unfortunately, it is rather common at the present time that when a piece of equipment ceases to function properly and must be repaired and parts replaced, it requires from one to six months to obtain repairs. The length of time required to order and receive chemicals is also quite long.

Since soil testing programs are a public service and their success is so greatly dependent upon the promptness of the service, nothing can be more destructive to their success than to have long delays occur.

The final solution to these problems can only be achieved through proper understanding and cooperation of the officials who control the budgets. In the meantime, the International Soil Testing Project in times of emergency has been called on to supply needed replacements and chemicals to keep the laboratories in operation.

The director of the soil testing program and the head of the laboratory in Nicaragua have already participated in seminars held in Raleigh. Plans have been made for participants from Costa Rica and Panamá to attend in 1968.

Training of laboratory personnel in techniques of multiple analysis and in research procedures has been done locally by the regional director. At the present time each laboratory has a basic crew of trained personnel. Continued attention to training will have to be given due to changes in personnel.

Some training has been given to various groups who are involved in soil sampling. At present in Nicaragua and Panamá most of the soil samples are taken by extension agents whereas in Costa Rica most of the samples come from fertilizer companies and have been taken by their field representatives.

The samples received thus far probably give a biased view of the overall fertility of the areas since they generally are coming from farmers of better than average management levels. Also many more samples are coming from some cultivated areas than from others. As larger numbers of samples are received and the program is extended to other areas, this bias will gradually be decreased.

Originally only Panamá was interpreting for the farmer the results of the analysis and making specific recommendations for fertilizer use. Presently recommendations are being made in all three countries. These are based on the best research available to date. It is realized, however, that a greatly increased research program is needed for better interpretation of the results.

Some laboratory and greenhouse studies for correlation of soil tests with response to added fertilizers has been accomplished in all three countries.

However, progress in these countries has been slow due to a lack of trained personnel for doing the work, lack of funds and lack of support.

This phase of activity needs immediate and increased support.

Summaries of soil test results have been prepared in all three countries. These, of course, are of a preliminary nature since they do not involve a

sufficiently large number of samples to present an unbiased view of the true situation.

Guatemala, El Salvador and Honduras: A good cooperative working relationship exists not only between each of the soil testing programs in the countries and the International Soil Testing Project, but also between each other.

Much progress has been made in the past three years in each country toward establishing the soil testing program as an important and needed source of service and information for agricultural development.

Multiple analysis equipment has been installed in each of the cooperating laboratories and the number of samples being analyzed per day and per year has increased and is increasing very rapidly. The accuracy and efficiency in analyses has also been much improved through improved methods and by means of the interchange of standard samples among laboratories.

Each of the laboratories now has equipment such as multiple dispensers, stirrers, colorimeters, flame photometers, pH meters, etc. to permit rapid, accurate analyses. Some standby equipment is also on hand but more is needed in each laboratory in order to insure continued operation in case of malfunction of items now being used.

Training in new methods and in use of equipment has been a continuing function of the International Soil Testing Project.

The heads of the soil testing programs and the laboratories from each country have attended the seminar programs held in Raleigh, and all feel that it was a very helpful and worthwhile experience in assisting them to carry out their responsibilities.

Several soil sampling training sessions have been held which have resulted in obtaining more representative samples and larger number of samples. This

type of training needs to be continued. However, more and more of the responsibility for this is being taken by local leaders.

Research in methods and correlation studies has been initiated and has increased rapidly. The first studies of course have been primarily laboratory and greenhouse studies. Attention to this phase of the program will be much intensified in the future and increased activity in field studies will be stressed.

Guide sheets for recommendations for proper use of fertilizers and lime have been prepared in each country. These of course are based on the best information available to date and may be expected to change and be refined as quickly as more information is obtained in the research studies.

Sufficient data from research and farmers samples has been accumulated to permit preliminary surveys and summaries of the nutrient status of the soils to be prepared. A number of these summaries have already been prepared and are being used by the various agencies to some extent for planning purposes. A clearer indication of nutrient needs of course can only be obtained by more research and a larger number of samples being analyzed. These activities will receive continued attention.

México: México has a strong and well developed agricultural research program. In that program, however, only a minor emphasis has been given to soil testing. The project has continued liaison with the Ministry of Agriculture and an expanded soil analyses program is planned when adequate support can be obtained.

México has a rather good field research background upon which to base soil analyses interpretations. They also have well qualified scientists to organize and administer such a program.

The International Soil Testing Project is currently cooperating in the organization of a soil testing program in the Instituto para el Mejoramiento de la Producción de Azúcar. Dr. Bonifacio Ortíz Villanueva is in charge of the project for the sugar industry.

Argentina and Chile: The project has no current cooperative activities in either Argentina or Chile. A survey was made of soil testing facilities and activities in Argentina at the time of initiation of the project, but no cooperative arrangements were later concluded.

The project has had some inquiries from individuals and from organizations in Chile but no project activities in the country have developed.

Paraguay and Uruguay: A soil analyses-fertilizer use program has been started in Paraguay. Laboratory facilities have been established at the Department of Soils, Faculty of Agronomy, University of Asunción. Multiple unit equipment is at the laboratory and ready for installation and use.

Paraguay has several well trained soil fertility specialists who have knowledge of the importance of soil testing programs and how they are successfully organized and operated. The Ministry of Agriculture and Faculty of Agronomy have the experimental resources to develop the necessary fertility research to calibrate and support a good soil analyses program.

In Uruguay there is an interest in developing a soil testing program, but unsettled conditions in the country have prevented progress. A soil analyses laboratory is in operation but the samples analyzed have been largely for soil survey correlation. Multiple unit apparatus has not yet been acquired by Uruguay to modernize and upgrade the accuracy and efficiency of the laboratory operations.

Consultation in Countries Other Than Latin America

Most of the activities of the International Soil Testing Program are confined to Latin American countries since it is a regional project. On July 1, 1967, the contract for the project was amended to permit two man-months per year of consulting time in regions other than Latin America. Turkey and Afghanistan were particularly interested in obtaining some advice relative to soil testing programs. To furnish the consultation desired, a seven-week trip was arranged for the Project Director to review soil testing-soil fertility programs in Turkey, Afghanistan and India. Of course in such a short period of time, not all areas of each country could be covered and not all laboratories could be visited. Nevertheless, a cross section of the facilities and programs under way were reviewed. Reports of the observations made with suggestions for improving their programs were prepared for Turkey and Afghanistan. A resume of the reports is presented below.

Turkey: Increasing crop production is of utmost importance to Turkey, a country in which many of its fields have been in cultivation for several thousand years. A major effort is being undertaken jointly by the Turkish Government and USAID/Turkey to introduce improved wheat varieties since wheat is the major crop in Turkey. The wheat program is cognizant of the other factors influencing yield and steps are being taken to improve these factors also.

During the 1967-68 growing season the Turkish Government will distribute more than 60 million dollars worth of fertilizer to the farmers, almost all of which will be imported. This will be in the form of fertilizer materials--largely nitrogen and phosphorus but with some potash. Plans are already under way to construct fertilizer plants within the country to reduce the cost of importing fertilizers.

An indescriminate but wide distribution of fertilizer will result in increased yields on a considerable proportion of the cultivated soils of Turkey. No doubt a return of double the total investment can easily be obtained through such a practice. However, no return will be obtained on many fields and these farmers will have difficulty paying for the fertilizer. The question then becomes not one of will the increase in yields from the 60 million dollars worth of fertilizer be profitable, but how profitable? Is the Turkish Government willing to settle for double its money or a return of 120 million dollars for its investment, or would it prefer a return of four or five dollars for each dollar invested which means 240 to 300 million dollars in increased yields from the judicious use of fertilizers.

A strong soil testing program is imperative to furnish the information needed to obtain the greatest return from the use of fertilizers and other soil amendments.

Soil analyses are now being made by the Ministry of Agriculture, Topraksu and the Sugar Company laboratories, but most of the samples tested are not farmers samples; the analyses are largely for research purposes and for information to be used in soil survey reports.

Suggestions to improve the current soil testing program are listed below:

1) Establish a complete soil-plant analysis program to include: a) research; b) sampling; c) analysis; d) interpretation; e) recommendations; and f) educational follow-up.

2) Appoint a Director of the Soil Testing-Plant Analysis Program. This position should be at a sufficiently high level that all phases of a soil testing program can be coordinated.

3) Increase the capacity of three or four laboratories to test several hundred samples per day (excess of 50,000 samples per year).

4) Correlation studies with laboratory procedures and plant growth should be expanded to obtain more information on the interpretation of soil test results.

5) Guide sheets should be prepared for making recommendations on improved soil management practices including the use of fertilizers.

6) Sampling program should be initiated.

7) Much attention needs to be given to an educational follow-up program to be certain farmers understand the tests and are using fertilizers and other soil amendments as recommended.

8) The Sugar Institute Laboratory should continue to test samples from fields that are in a sugar beet rotation. Another agency should assume the responsibility for all other testing of farmers samples and for developing a soil-plant analysis program.

Afghanistan: Increasing the yield of wheat is a major program in Afghanistan since the current food deficit (250,000 tons of wheat alone in 1966) must be overcome. A scarcity of water is a major problem in corp production. Approximately 13 million acres are reported to be under irrigation in Afghanistan but only about 60 per cent of this area is cultivated each year. A little over 5 million acres are dry-farmed and most of this is seeded to small grains.

The Ministry of Agriculture and Irrigation of the Royal Government of Afghanistan is to be congratulated in its efforts to harness the waters of their country for use in irrigated farming. Water is very important to crop production. Likewise soil is very important in plant growth because soil is the reservoir to hold water for the plant and is also the source of nutrient elements which are essential for growth. As soon as water is delivered to the farm, soil management (which includes distribution of water in the soil profile) and soil fertility become very important. Therefore, soils should be afforded the same status and receive the same emphasis as water.

It is suggested that a strong soil science department be developed to include initially soil survey, soil fertility and soil management. The other disciplines of soil science, physics, chemistry and microbiology, can be added in the future. The soils department should serve both irrigated and dry farming regions. Many of the basic principles of soils will apply to both situations.

Soil analysis to furnish information about the soils is the first step in soil management. All six phases of a soil-plant analysis program will have to be developed in Afghanistan. Steps should be taken to obtain information relative to these six phases but launching a large program for soil testing farmers samples should be delayed until correlation data can be obtained and recommendations can be tested.

It is suggested that plans be developed for a modern soils laboratory with a capacity of more than 100 samples per day. Adequate space with standard facilities (hoods, etc.) should be made available. Multiple unit apparatus will permit testing a large number of samples without increasing the size of the staff. Supplies such as propane or butane will have to be available in sufficient quantities to permit continuous operations of the laboratory. The laboratory can serve soil fertility, soil management, and soil survey needs.

Only the determinations which can be interpreted and put into use should be made. The frequent use of control samples should be initiated to assure accuracy of results.

Although the laboratory can test farmers samples, the initial responsibility should be to service the experiment stations. Soil samples should be taken from fields and analyzed before establishing fertilizer trials. Time, methods and rates of application of fertilizers should be studied in conjunction with the soil tests in order to give background information for the recommendations to farmers.

Correlation studies will be needed to test critical levels of soil nutrients and to observe if they agree with results from other areas. After the critical levels are established they will have to be tested for the major crops produced.

In developing a soil science department and a soil testing program, a problem will be encountered in obtaining a sufficient number of trained persons. Kabul University will graduate eight persons this year who are majoring in crop production, but they will have no graduates in soil science. A few AID participants currently are in training in the United States and plans are under way to send more.

Although it will be difficult to obtain a sufficient number of trained soil scientists immediately, plans should be prepared with a time schedule for training the needed scientists.

India: No formal report was prepared relative to the observations in India. Since the time spent in India was rather short only a few laboratories were visited.

The number of soil testing laboratories in India has increased from 24 in 1961 to 43 in 1967. Apparently several of the laboratories were not testing many samples One of the more active soil testing programs was at Ludiana. The laboratory here is testing about 30,000 samples per year.

The most common complaint of the laboratories visited is the problem of maintenance of equipment. This is a common complaint in soil testing and having a large number of laboratories does not help the problem.

Several adverse soil conditions were observed in the vicinity of Coimbatore in Southern India where the University of Tennessee is conducting a

cooperative program. The adverse conditions included acid soils, alkaline soils, saline soils, sodium alkali soils and soils deficient in nutrient elements. Information from soil tests is very important for preparing a soil management program in this area.

APPENDIX

The Appendix contains several semi-detailed reports of major project activities. These reports resulted from research consultation activities in Latin America. They contained more detail than could be logically included in the general body of the Annual Report. However, they are included with the Report to expedite dissemination of the information to all interested parties and to assure the preservation of the reports in available and usable form. In general, these reports are self explanatory and need no preface to account for the origin or to amplify the contents of the reports.

NOTES ON SOILS AND SOIL TESTING IN COSTA RICA

R. J. McCracken

This is a report of observations during my visit to Costa Rica, January 18-21, 1967. Purposes of this visit were to consult with the Regional Director for the International Soil Testing Project, Dr. A. H. Hunter, and to study properties of Costa Rican soils and their distribution in relation to agriculture with special emphasis on fertilizer needs. This visit consisted of three phases:

1. Discussion and review of International Soil Testing Project activities in this region of Central America (with special attention to Costa Rica) with the Regional Director, Dr. A. H. Hunter. This phase also consisted of a discussion with AID Rural Development Officer, Mr. William Shafer.

2. Discussion of the use of soil information, land classification, and land resource development in Costa Rica with Mr. Calvo of ITCO. This agency is the natural resource development arm of the Costa Rican government.

3. Field trip to study the soils of the Pacific side of Costa Rica with emphasis on the need for soil maps and soil classification and on the potential of these soils for agricultural development.

Discussion and review of International Soil Testing Project activities for the region with Dr. Hunter brought out the point that a soil testing program is well under way for the Republic of Panamá and that work is progressing well in Nicaragua despite shortage of trained personnel and other problems. The Soil Testing Program in Costa Rica is beginning to take shape with the recent installation of the new multiple sample analysis soil testing equipment and with the arrival of a flame photometer. Commercial fertilizer companies, plantation managers, and farmers are taking a real interest in an intensive soil testing program. However, there are a number of problems connected with the further implementation of the soil testing and fertilizer advisory programs.

One of these is the lack of personnel with training specifically in soil testing methods and in interpretations of soil tests in a fertilizer advisory program. One or more people in the Ministry of Agriculture should receive this training as soon as possible. Another real need in the soil test-fertilizer advisory program is the need for field and greenhouse studies of the different types of Costa Rican soils with respect to correlation of soil test results (using various extraction methods) with response to fertilizers. With the greatly different kinds of soils and climate in Costa Rica, (with respect to rainfall especially), such studies need immediate attention. Tabulation of previously conducted studies on crop responses to fertilizers on different types of soils should also be completed as soon as possible.

The discussion with Mr. Calvo of ITCO was particularly interesting and informative. Mr. Calvo, Mr. Soto, and their associates have made very effective use of soils information in their land classification and natural resource studies of the Atlantic North region of Costa Rica. Their synthesis of soils, vegetation, climatic and geographic information into a very impressive set of natural resource and land classification maps is very impressive - one of the most complete and well-based land classification programs anywhere. Their regional natural resource proposed land use studies for the Atlantic North region is superior to most studies of this kind in the U.S.A. Additional soils information is badly needed to help them in their synthesis and analyses, as well as to provide "backstopping" information for the Soil Testing Program. Determination of the basic chemical, physical, and mineralogical properties of the main kinds of soil and interpretation of these in terms of agricultural potential is badly needed. The older soil classification and surveys of the Atlantic side (for example, those of the former United Fruit properties) need to be updated in terms of modern concepts and in terms of the new soil classification system in order to give these dynamic people in ITCO all possible assistance in their excellent program. It should also be pointed out that more basic information about the soils of the Atlantic side is needed to aid the soil testing and fertilizer advisory programs. Soils of the Atlantic side differ greatly from each other and in turn differ from the soils of the Pacific side of Costa Rica - in greater part due to the differences in rainfall distribution in these two parts of the country. Information is particularly needed on the red soils (Oxisols, as they would now be classed) and the extensive areas of alluvial and colluvial soils associated with them. It is recommended that a reconnaissance soil study be conducted in this area to update the soil studies previously made on the former United Fruit and Standard Fruit plantations and to extend these studies throughout the region, and to select a minimum of three sites for detailed sampling of the soil profiles and laboratory determinations of the basic properties of the soils. These three should include an Oxisol (red latosol) and an associated brown alluvial soil of the "Ridge Hill" landscape plus at least one sample site of those alluvial soils near the coast higher in organic matter.

Three days were spent in field studies of soils of the central area west of San José and of soils of the Pacific side. A number of impressions stand out from this field trip:

1. The apparent high agricultural potential of soils of the central plateau and of many soils of the Pacific side of Costa Rica and adjoining countries.

2. The central plateau area is an ideal one for study of the extensive areas of volcanic-ash derived soils which occur in much of Central America and indeed in parts of the Andean region of South America. These soils have unique and distinctive properties and need additional studies in order that their behavior under liming, fertilization, and management practices can be determined. For example, these soils apparently contain large amounts of amorphous clay-size minerals known as "allophane" which impart distinctive properties to the soils, such as very high phosphate fixation, very high

cation exchange capacity at higher pH values, and high 15-bar soil moisture percents. The dry season also influences the soil properties and causes them to be different from soils of the U.S.A. The Grecia soil near San José is a good example.

3. The soils of the Pacific side also possess distinctive properties, different in some respects from most soils of the U.S.A. because of the strong dry season with a wet season--all with warm weather. For example, red soils of the Nicoya peninsula seem to contain a most unusual (for the U.S.A.) combination of clay minerals in their clay-size fractions--apparently kaolinite with large amounts of montmorillonite and iron oxides, a most unusual combination which imparts unusual chemical and physical properties to them. Another example of a distinctive and unique kind of soil can be found near Canos. These soils have formed from a rhyolitic (silica-rich) tuff (a sediment derived from volcanic ash) which gives unusual properties. These soils occupy a belt through this section into Nicaragua. Detailed knowledge of these properties is necessary in order to assess accurately their potential for agricultural development, their response to fertilizers and lime, and the types of soil tests needed. I have not seen or heard of soils similar to this anywhere in the world.

It is urged that a general reconnaissance study of the location, extent, and properties of the main kinds of soils of the Pacific side be undertaken as soon as possible in order to:

(a) more accurately assess the true agricultural potential.

(b) determine those properties affecting response to fertilizer and lime as an important aid in the soil test and fertilizer advisory program.

(c) provide information for the ITCO natural resource classification for Costa Rica.

(d) develop information badly needed for the new world-wide soil classification systems being developed in the U.S.A. and by FAO for South and Central America.

Samples should be collected of the profiles of the main kinds of soils of the Pacific side in order that their chemical, mineralogical, and physical properties may be quantitatively determined in laboratory studies. The Soil Science Department of N. C. State University stands ready to assist in these programs of soil studies, though additional funding is needed for the detailed lab studies of the soil samples.

These types of soils on the central plateau and Pacific side should be included:

1. The Grecia soil of the central plateau--formed from volcanic ash.

2. The Aranjuez soil of the Pacific side--formed from conglomeratic alluvium on old marine terraces.

3. The soils formed from rhyolitic and vitric tuffs in the vicinity of Canos.

4. Sonsocuite soils--black Vertisols (clayey soils that shrink and swell) of the Nicoya Peninsula--formed from limestone materials. This soil is extensive in Central America and similar soils are common in South America and Puerto Rico.

5. The red soils formed from limestone and related parent materials in the Nicoya Peninsula area.

6. The red soils in the San Dimas area of the North Pacific area--formed under higher rainfall than those of the Nicoya area--formed from lutites and volcanic tuffs. These soils also appear to have distinctive properties and to have rather high agricultural potential where located on less steep slopes.

In summary, the present stage of agricultural development is a real credit to the people and the potential for futher agricultural development is impressive and exciting.

In order to attain this higher degree of agricultural development which appears possible, additional attention is recommended to these points:

1. Improvement and expansion of the soil testing and fertilizer advisory program, especially additional training for people to be working directly with the soil test laboratory and expansion of correlation of fertilizer field trials on the main soils of the country with soil test values.

2. Further inventory of the excellent soil resources of the country, especially identification of the main kinds of soil in the country and their location and extent, accompanied by analyses of the basic properties of these soils.

SOIL TESTING AND SOIL FERTILITY PROGRAMS IN COLOMBIA

E. J. Kamprath

A visit was made to Colombia, South America, from February 17 to March 8, 1967, to work with the soil testing and soil fertility program of the Instituto Colombiano Agropecuario. A number of meetings were held with personnel of ICA at Tibaitata and Palmira, the Instituto Geográfico in Bogotá, the Rural Development Group - AID in Bogotá, members of the University of Nebraska - AID party, and the Rockefeller Foundation, Bogotá.

MEETINGS AND CONFERENCES

1. Rural Development Group - AID - A meeting was held in Bogotá with Norman Ward, Rural Development Officer, Donald Dobson, and Dr. James Haynes. I discussed with them my program while in Colombia and the activities of the International Soil Testing Project. They briefed me on the agricultural situation in Colombia and the areas in which information on soil testing and soil fertility is needed. The Rural Development Group was very helpful in providing information and suggestions as to kinds of data needed to implement programs which will increase food production.

2. Soils Section, ICA at Tibaitata - Meetings were held with Dr. James Spain, Ramiro Guerro, Gilberto Rodríguez, Jaime Navas, and Gabriel Martínez. Discussions were held on the soil fertility and management problems of the Llanos soils and research needed, sampling procedures for taking soil samples of mountain fields, liming studies on mountain soils for optimum barley yields, kinds of experiments which should be used to evaluate the availability of phosphorus in rock phosphate from the new Colombian deposits.

3. Seminar at Tibaitata - I was asked to give a seminar on Soil Acidity and Response to Liming while I was at Tibaitata. The meeting was attended by people from the Soils Section, Agronomy, and about 25 agronomists working with rice who were attending a training session at Tibaitata.

4. Soils Group, Instituto Geográfico - Ramiro Guerro and I met with Víctor Vega, Francisco Silva, and Miss Melba López of the Soil Survey staff. We discussed Bulletin No. 3 of the ISTP series. They were very much interested in the approaches outlined in the bulletin since they are planning some greenhouse studies to evaluate some properties of the important soils being mapped in their soil survey. Miss López attended the first ISTP Seminar in Raleigh.

5. Public Relations Dept., Avianca - Dr. Spain and I met with the Director of the Public Relations Dept. of Avianca to discuss a film which Avianca would make showing the taking of a soil sample and some scenes of the Soil Testing Laboratory at Palmira. Avianca transports the soil samples received at the various experimental stations to the laboratory at Palmira. A special air freight rate is given for soil samples.

6. Soils Section, ICA, at Palmira - Meetings were held at Palmira with Gildardo Marín, Jairo Gómez, Alfredo León, and Dr. James Spain.

   Suggestions were made about changing the procedure of recording the soil test results which would eliminate copying the results from one sheet to another before being typed. Considerable time was spent revising and preparing soil test recommendation guide sheets for corn, sorghum, cotton, rice, beans, soybeans, and pasture.

   Plans were made in regard to relocating the drying and preparation rooms for the soil samples. This would require less handling of the soil samples and increase the number of samples that could be analyzed by the present staff.

7. Seminars at Palmira - I was asked to give two seminars while at Palmira. The first seminar was a discussion on the potassium fertilization of cotton as related to soil test levels. This was given to the Soils Section and six new agronomists of ICA who were at Palmira for training.

   The second seminar was a discussion of Soil Acidity and Response to Liming which was given to the agronomy students of the Facultad of Agronomy at Palmira.

8. Dr. W. E. Colwell and Dr. Elder, University of Nebraska - AID party - A meeting was held with Dr. Colwell and Dr. Elder in which the various aspects of the soil testing program were discussed.

9. Meetings also were held with Dr. U. J. Grant, Director of the Rockefeller Foundation in Colombia, Dr. Cardona, Director of Research for ICA, and Dr. A. Gartner, Director of Education, ICA.

SOIL TESTING PROGRAM

Present Status:

The Soil Testing Laboratory at Palmira is well equipped and well staffed. The present laboratory and staff should be able to test 200 samples per day without any difficulties. With additional personnel the laboratory could hand twice this many samples. A drier has been built which will facilitate the handling of wet samples. One of the big needs is a soil crusher or grinder. Currently this is being done by hand. If a large number of samples are received this could be a bottle neck.

The number of farmer soil samples analyzed is showing a steady increase. The number of farmer samples received was 843 in 1965, 1,983 in 1966, and 1,260 the first two months of 1967.

In cooperation with the University of Nebraska-AID Project, a number of leaflets on soil testing have been prepared which will be used in promotional campaigns and follow-up programs on soil testing. The Soils Section of ICA has been holding numerous training meetings for other agronomists in which the various phases of soil testing are explained.

Soil Test Summary:

A summary of the farmer samples analyzed by the Soil Testing Laboratory in 1966 is given in Table 5, page 20. Although in some areas the number of samples received are quite low, the summary gives an indication of the fertility problems. In general the soils are low in phosphorus. Many of the soils have a fair supply of potassium except for the Atlantic Coast, the lower Magdalena River Valley and the Llanos. A need for lime is indicated in the Mountains, Sabana de Bogotá, and the Llanos.

New Methods:

The need for lime on a soil is presently based on the pH of the soil. This leaves much to be desired. Studies will be started on the use of exchangeable aluminum as the criteria for determining whether a soil needs lime and also how much lime needs to be added. The procedures outlined in Technical Bulletin 4 will be followed to exchangeable aluminum on mineral soils with a pH of less than 5.5 and on soils with more than 10% organic matter which have a pH less than 5.

SOIL FERTILITY RESEARCH NEEDS

The Llanos Orientales (Eastern Plains), as was pointed last year, provides a tremendous potential for agricultural development. However, to realize the potential some soil fertility problems have to be answered. It appears that many of the soils have a high content of exchangeable aluminum in relation to exchangeable calcium and magnesium. Liming studies based on neutralization of the exchangeable aluminum should be conducted on the major soil series. At the same time studies can be made on the outgo of calcium and magnesium. Another problem is the amount of phosphorus required to build up and maintain a desirable level of available phosphorus. Since these soils are low in available potassium studies are needed on the levels of available K which can be economically maintained and the best way to maintain these levels. Another problem relates to the need for micronutrients. Dr. James Spain of the Rockefeller Foundation indicates that the soils of the Llanos can be divided into three broad groups; well drained, somewhat poorly drained and wet. Where possible the studies mentioned should be conducted on these soil groups.

A Progress Report on the Soil Testing Program in Venezuela

C. B. McCants

January 15, 1968

The International Soil Testing Project began its cooperative relationship with Venezuela in January, 1966. A résumé of the most recent trip by the ISTP representative and recommendations to strengthen the developing soil testing program are included in this report.

The period September 16-30, 1967 was spent in Venezuela for the following purposes:

a. To attend the meetings of ALAF (Asociación Latinoamericana de Fitotecnia), to present at those meetings a paper on the role of soil analysis and the International Soil Testing Project in contributing to improvements in crop production programs, and to discuss soil fertility and soil testing programs in Latin America with appropriate participants at the meeting.

b. To review the research and extension programs in Venezuela that are related to the objectives of the International Soil Testing Project.

c. To consult with interested parties on projects to obtain information for correlation of soil test values with crop response in Venezuela.

d. To recommend areas of work to strengthen and promote the use of soil testing as a guide to efficient fertilizer usage and soil management.

ALAF Meeting

This meeting was held at the Hotel Maracay during the period September 17 to 23. There were approximately 561 persons registered, with representatives from 22 countries in Central and South America. Various disciplines in plant science were represented including genetics, botany, crop management, and soil science. The number of people engaged in soil science was relatively small and, of these, only a few were involved with soil fertility research or other activities related to soil testing.

The relatively few reports on soil fertility that were presented at the ALAF meetings apparently is indicative of the limited amount of work that is in progress in Latin America on this subject. The general impression

obtained is that soil fertility programs in this area are not as well organized nor receive the prominence within a country as do other phases of soil and plant science. This situation could probably be corrected by the exercise of more dynamic and forceful leadership by persons engaged in this work, since the evidence is clear that there is a need for reliable information on which to make decisions on the usage of fertilizer and that this information could make a significant contribution to the economy of the various countries.

The audience response during and following the presentation of the paper at the ALAF meeting was quite satisfactory. There was considerable discussion with individuals after the session ended on details of specific soil testing programs and means by which assistance of the International Soil Testing Project could be obtained. The representatives from Chile are especially interested in securing the assistance of the International Soil Testing Project in establishing a soil testing program in that country. The names and addresses of the persons with whom discussions were held are: Mr. Elías Letelier, I.I.A., Estación Experimental La Platina, Santiago, Chile, and Mr. Hernań Tejeda, Estación Experimental Chillan, Casilla 426, Chillan, Chile. From discussions with these men, it appears that there is in Chile an excellent research and extension organization with which to implement a complete soil testing program. The evidence suggests that the International Soil Testing Project can make a valuable and significant contribution to the development of such a program. It is recommended that at the earliest occasion, this matter be given active consideration.

Research and Extension Programs on Soil Testing in Venezuela

Interest in and programs related to soil testing continues to grow in Venezuela. Since the first active involvement by the International Soil Testing Project in this country, there has been a progressive and encouraging improvement in attitudes, programs, and public interest in and support of soil testing as a means for improving the use of fertilizers. Among the organizations that are giving active support are the research and extension sections of the Ministry of Agriculture, the Shell service programs for the farmer, the fertilizer industry, and various crop producers associations.

Some of the major accomplishments that have occurred since the International Soil Testing Project became involved in the soil fertility research programs in Venezuela and which relate directly to the objectives of the Project are presented in the following discussion.

1. Preparation of the report "Resultados Experimentales de Abonamiento en Algunos Cultivos y Suelos de Venezuela." In this report is summarized the results of experiments conducted over about a fifteen-year period involving studies on response of various crops to nitrogen, phosphorus, and potassium applied to the major soils of the country. However, soil analyses are available

for only a few sites so a detailed correlation study cannot be made from the data. Some examples of the results reported are given in Tables 1 through 4. Phosphorus and potassium analyses were made on sodium acetate extracts from the soils. These data show the wide diversity of responses measured and indicate the difficulty of making meaningful broader interpretation from these studies. The results do provide some general information about the fertility properties of the soils and some indications of the magnitude of response that may be expected from the major elements. They do not provide a firm base upon which a sound soil testing program can be built. Thus, appropriate plant response-soil analyses data are needed for correlation purposes.

2. Initiation of correlation studies. Mr. Rafael González in cooperation with other members of the staff of the Sección de Suelos, M.A.C. - C.I.A., the Extension Service, and IVP (Instituto Venezolano de Petroquímica) has initiated experiments to provide data for correlation of soil analyses with plant response. The number and type of experiments are:

a. 26 greenhouse experiments with corn

b. 20 field experiments with corn

c. 4 field experiments with black beans

d. 2 field experiments with cotton

The field and greenhouse experiments were designed and the procedures developed in cooperation with the ISTP representative. Due to the amount of detailed work needed to analyze the samples representing the various soils on which the crops were grown, and the absence of a suitable arrangement for them to be analyzed in Venezuela, soil samples were brought to Raleigh for study. The analyses will be made by Mr. Manuel Bárcenas, a member of the faculty at the University of Zulia in Maracaibo but now on leave of absence for study leading to the Master of Science degree in Soil Science. The plant response data will be provided him for correlation analysis. The results from these studies should make a significant contribution to advancing a soundly-based soil testing program in the country. Additional studies of this type will be conducted in 1968 on other soil types and test plants.

3. Inauguration of soil fertility research in the llanos. Dr. Carlostadio Sánchez, at the Universidad de Oriente near Jusepin, has initiated a dynamic and comprehensive research program on soils in the state of Monagas, located in the llanos region of the country. The soils in this area have many desirable features for potential crop production, including favorable topography and good physical condition. The data in Table 5 through 8 show,

however, that substantial fertilizer phosphorus and nitrogen will be required to obtain satisfactory yields. The results in Figure 1 indicate the high phosphorus fixing capacity of these soils. The work of Dr. Sánchez will make an invaluable contribution to crop production in this region, when it becomes an area of economic importance. At the present time, it is sparsely settled and the amount and distribution of rainfall will likely impede its development.

4. Activities of IVP. The fertilizer section of IVP, which is the exclusive manufacturer and dealer of fertilizers in Venezuela, continues to demonstrate active interest in and to encourage support for the development of a complete soil testing program. Through the cooperative effort of their field agronomists, six on-the-farm tests, designed by the ISTP representative and involving various rates of N, P, and K were conducted in 1967 for demonstrational and data accumulation purposes. Plans have been developed to add additional agronomists to the staff of IVP and to provide an intensive educational program on procedures for obtaining soil samples and for the interpretation of chemical analyses of soil samples for fertilizer recommendation purposes. A request was made by IVP that the ISTP cooperate with them in arranging an intensive program of study in North Carolina in the summer of 1968 for two or more of their agronomists. This program would involve training on the practical aspects of implementing a soil testing program with particular emphasis on working with farmers and agriculturally oriented industries. This is an area of demonstrated weakness in the country and it is strongly recommended that ISTP assist in these arrangements to the fullest practical extent.

Estimates of local inputs into cooperative soil fertility--soil test studies associated with CSD-287

This information was requested of each of the countries in which ISTP is cooperating in a memorandum dated June 15 from Dr. A. D. Ayers to Dr. J. W. Fitts. The following estimates are based on personal observations and discussions with various people in Venezuela.

1. Central laboratory: None

2. Total number laboratories performing soil analysis: 5

3. Samples tested in 1967: 10,000

4. 1969 goal: 100,000

5. Office space: yes

6. Greenhouses: 5

7. Experimental field areas: 7

8. Cooperating demonstrations: yes

9. Professional personnel: 15

10. Sub-professional personnel: 10

11. Approximate budget: $175,000

Recommendations

A satisfactory beginning has been made toward developing a potentially successful soil testing program in Venezuela. The progress to date, however, should be viewed only as the catalyst to escalate both the scope and intensity of research and educational programs in soil sampling, soil analyses, and fertilizer recommendations.

The following specific recommendations are suggested as guides to aid in further development of this work.

1. Appoint a full-time, nationally recognized, coordinator for soil testing programs. It is increasingly apparent that the present system of soil fertility research and education is not providing an efficient and effective use of either personal or financial resources. Greater emphasis toward unified and coordinated soil fertility research programs, combined with reliable chemical analyses of the soils from the experimental sites, will contribute toward minimizing this problem. The scope of this work, however, is such that the full-time attention of a properly trained and dedicated person is needed.

2. Continue the plant growth-soil analysis correlation experiments in the greenhouse at the present level of activity.

3. Expand the field programs involving rates of N, P, and K to additional soil types and cropping systems. Use these field tests for on-the-site educational programs on responses to fertilizers.

4. Assimilate available information and experience into a form that can be used to prepare tentative guide sheets for the interpretation of soil analysis for fertilizer recommendations. It should be recognized that fertilizer recommendations based on soil analyses are not perfect even in countries that have had soil testing programs for many years. Hence, it is neither practical nor necessary to wait until recommendations can be made with absolute certainty before beginning to use soil testing as a guide in making fertilizer recommendations. It is expected that guidelines will be modified as frequently as information and experience justifies.

5. Establish a few strategically located laboratories in the country to perform the analysis for fertilizer recommendations. These must be organized and operated in a manner so that rapid and accurate analysis can be performed and the results and recommendations reported to the farmer with the minimum delay.

6. Make more effective use of technical and advisory committees recommended in the March 1966 report.

7. Inaugurate a national educational program to promote soil testing as a guide in crop production and soil management programs.

Table 1. Effect of N, P, and K fertilization on yield of corn. Maracay series.

Treatment, kg/ha			Experiment [a]			
N	P_2O_5	K_2O	60-1	65-3	65-4	65-7
0	0	0	5.73 [b]	5.12	4.63	4.62
0	100	50	-10 [c]			
50	100	50	18			
100	100	50	2	-3	-2	23
180	100	50		-3	5	19
50	0	50	- 7	-23	-6	6
50	50	50	1	-22	-10	12
50	100	50	-18			
50	50	0	-18	-5	-4	5
50	50	50	1	-22	-10	12

[a] Soil Analysis

Phosphorus, ppm	9	143	40	26
Potassium, ppm	29	1.02	26	41
Organic matter, %	2.0	1.9	3.1	3.2
pH	7.3	7.1	8.1	7.9

[b] Tons per ha

[c] % increase in yield calculated as follows:

$$100 - \frac{\text{yield from 0-0-0}}{\text{yield from } N_iP_iK_i} \times 100$$

Table 2. Effect of N, P, and K fertilization on yield of corn. Valencia series.

Treatments, kg/ha			Experiment [a]	
N	P_2O_5	K_2O	65-5	65-2
0	0	0	2.42 [b]	5.68
0	50	50	1 [c]	8
50	50	50	31	11
120	50	50	39	15
50	0	50	31	1
50	50	50	39	15
50	50	0	31	12
50	50	50	31	11

[a] Soil Analysis

Phosphorus, ppm	25	35
Potassium, ppm	225	132
Organic, %	5.6	6.1
pH	8.1	7.8

[b] Tons per ha

[c] % increase in yield calculated as follows:

$$100 - \frac{\text{yield from 0-0-0}}{\text{yield from } N_iP_iK_i} \times 100$$

Table 3. Effect of N, P, and K fertilization on yield of corn. Ocumare Series.

Treatments, kg/ha			Experiment [a]		
N	P_2O_5	K_2O	62-7	65-1	62-6
0	0	0	5.95 [b]	3.61	4.68
55	55	50	-21 [c]	18	21
120	55	50	4	9	13
55	0	50		12	
55	55	50	-21	18	21
55	110	50	- 7		16
55	110	0	-18		17
55	110	50	- 7		16
55	110	100	- 2		16

[a] Soil Analysis

Phosphorus, ppm	7.5	3.2	9.1
Potassium, ppm	20.5	23.5	30
Organic matter, %	1.7	1.2	1.8
pH	6.3	6.5	6.5

[b] Tons per ha

[c] % increase in yield calculated as follows:

$$100 - \frac{\text{yield from 0-0-0}}{\text{yield from } N_iP_iK_i} \times 100$$

Table 4. Effect of N, P, and K fertilization on yield [a] of sesame.

Treatment, kg/ha			Paez Series [b]			Acarigua Series		
N	P_2O_5	K_2O	58-1	58-2	58-3	58-1	59-1	59-2
30	70	25	269	452	741	660	278	366
50	70	25	333	455	757	934	416	487
50	0	25	280	380	535	855	251	447
50	70	25	333	455	757	934	416	487
50	100	25	422	520	680	690	271	400
50	70	0	311	560	749	884	317	487
50	70	25	337	406	711	904	318	467
50	70	45	308	450	720	854	343	495

a/kgs per ha

b/Soil Analysis

Phosphorus	2.2	2.0	6.4	3.0	0.8	2.2
Potassium	30	34	32	35	22	28
Organic matter	1.7	1.2	1.5	40	3.8	3.2
pH	4.7	5.4	6.0	5.5	5.4	5.5

Table 5. Effect of N and P fertilization on yield of sesame. Savannah soils, Monagas state.

N	P_2O_5, kg/ha			
kg/ha	0	80	160	Average
	Yield, kg/ha			
0	470	1050	1067	862
40	389	1156	1369	971
80	310	1112	1314	912
Average	389	1106	1250	

Table 6. Effect of P and K fertilization on yield of sesame. Savannah soils, Monagas state.

P_2O_5	K_2O, kg/ha		
kg/ha	0	80	Average
	Yield, kg/ha		
0	415	363	389
80	998	1215	1106
160	1195	1305	1250
Average	869	961	

Table 7. Effect of N and P fertilization on yield of peanuts. Savannah soils, Monagas state.

N kg/ha	P_2O_5, kg/ha				
	0	40	80	160	Average
	Yield, tons/ha				
0	0.75	2.73	3.10	3.38	2.49
80	0.79	2.75	3.27	3.38	2.55
Average	0.77	2.75	3.19	3.38	

Table 8. Effect of P and K fertilization on yield of peanuts. Savannah soils, Monagas state.

P_2O_5 kg/ha	K_2O, kg/ha		
	0	80	Average
	Yield, tons/ha		
0	0.70	0.84	0.77
40	2.72	2.77	2.75
80	2.95	3.42	3.19
160	3.07	3.69	3.38
Average	2.36	2.68	

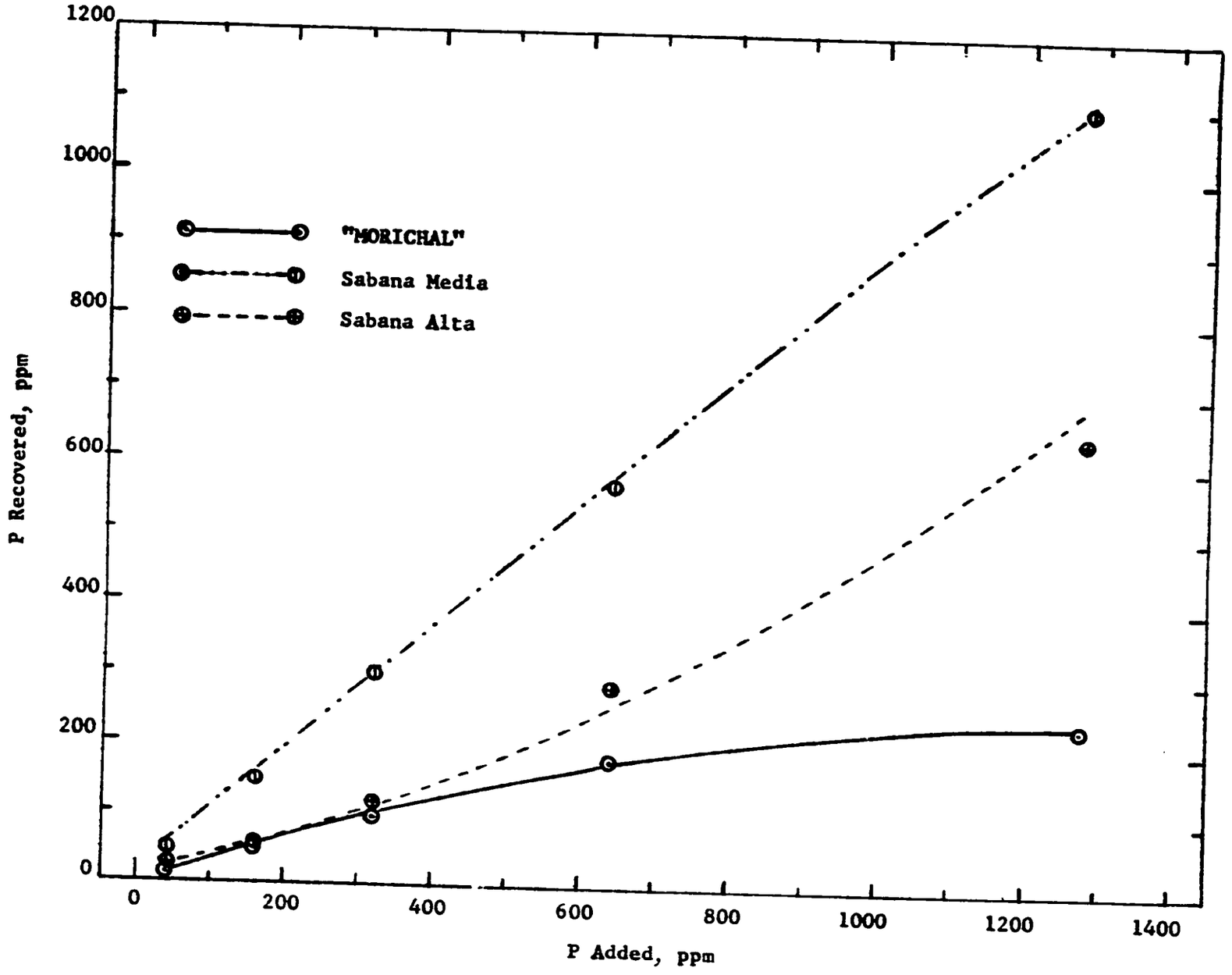


Figure 1. Phosphorus fixation by various soils of the llanos region of Venezuela

SOME OBSERVATIONS AND SUGGESTIONS ON SOIL AND FERTILIZER NITROGEN PROBLEMS IN SOUTHERN BRAZIL

W. V. Bartholomew

At the request of Professor Robert B. Cate, Jr., a short observation and consultation trip was arranged to Southern Brazil from March 16 to March 30, 1967. The purpose of the trip was to observe nitrogen problems in crop production and to review some of the nitrogen fixation studies conducted by Mrs. Dobereiner, soil microbiologist at the IPEACS, Km. 47 Research Station, near Río. Visits were made to the DPFS Laboratory, Guanabara, to the IPEACS Laboratory at Km. 47, State of Rio, and to the Experiment Station at Río Grande do Sul.

The observations and suggestions made here will largely be of a general nature. The problems are large in number and are often complex so that one does not become familiar with all phases in a short consulting visit. Moreover, the objectives and responsibilities of the International Soil Testing Project are limited to specific areas of nitrogen research. The comments and suggestions are made in the light of these limitations.

General Observations

An objective of the International Soil Testing Project is to encourage and expedite research which will provide the background information upon which to base recommendations relative to the profitable use of nitrogen fertilizer. Such research would include both field testing and chemical and biological studies of soil properties. Mr. Robert B. Cate, Jr., in surveying and reviewing the research accomplishments of the area, had indicated that field crop responses to the addition of nitrogen fertilizer had been generally small and/or insignificant. Since much of the presently cultivated area has been farmed for many years, greater general responses to nitrogen were expected.

Some soils of the western hemisphere had high fertility and a large natural supply of nitrogen when they were first put into cultivation from virgin conditions. With long continued cultivation, there is the tendency for the natural s pplies of organic matter to become exhausted to the extent that the soil can no longer supply the nitrogen needs for good crop production. Therefore, crop growth responses to the addition of nitrogen fertilizer would be expected to be greater on soils which had been under cultivation for many years than on soils recently placed under cultivation.

Low responses to the addition of nitrogen fertilizer may result from two general factors. They are:

1. The natural supplying processes in soil do not supply the nitrogen needs of the crop.

2. Fertility and/or productivity factors in the soil other than nitrogen limit crop growth and consequently the total need for nitrogen is low.

The Nitrogen Problem

In soil testing programs the making of proper and economically sound recommendations for the applications of nitrogen fertilizers is often difficult. The basis for the recommendation is a knowledge of:

1. The total and seasonal needs for nitrogen of the crop which is to be grown.

2. Quantities of nitrogen that may be supplied to the crop by natural supply processes (soil organic matter, non-symbiotic fixation, symbiotic fixation, rain, water, etc.).

3. The influence which the residue from the previous crop may have on nitrogen availability.

4. The probability that available nitrogen may be lost from the soil by leaching, etc.

With adequate information on these factors a reliable recommendation for the use of fertilizer nitrogen can be made for specific soil, crop, and management conditions.

The nitrogen needs of the crop (No. 1) depends on many factors. These include kind and variety of crop, climate, soil fertility and productivity and soil management including pest control and cultivation.

A knowledge of the nitrogen needs of a crop must be checked and verified by field experiments and crop production trials. It is the field experimentation that is slow and costly in terms of time and research resources. The high cost of such studies requires that they be well designed and that maximum use be made of the resulting data.

Information of the second factor (No. 2 - natural supplies) can come in some instances from soil test procedures and in other instances from general information and research experience in a given soil and crop area. Soil test procedures are generally designed to provide a measure of the nitrogen which can be supplied to the crop through the biological decomposition of organic nitrogen. Test procedures include measurements of total soil organic matter, easily extractable soil organic nitrogen, nitrogen release from organic matter by biological

processes during a short laboratory incubation and measurements of the accumulation of inorganic nitrogen (NO_3^- and NH_4^+) in soil. The particular test to be employed in soil testing must be determined by experimentation in the area where it is to be employed.

A short-coming of the soil test is that it may not always provide a total measure of the magnitude of the natural supply processes. Test procedures are limited in that they can be made to reflect the nitrogen supplying status of a soil sample at the time it is analyzed. The test analysis could not be easily made to measure additions of nitrogen to the soil by nitrogen fixation (symbiotic and non-symbiotic) or by rain water. Neither can the test procedure be made to measure nitrogen loss processes from the soil (No. 4) or the influences of residues from the previous crop on nitrogen available (No. 3). The influence of these latter processes on the natural supplies of nitrogen must be measured and evaluated separate from soil test procedures. Moreover, these supply altering processes may vary markedly from one area to another.

In summary then, in a soil testing program, the recommendations made to farmers or planters on the use of nitrogen fertilizer should be based not only on specific information about the soil, crop and management of the particular field and farm, but also on the general nature of the area soils and the prevailing climate. Soil test procedures can furnish only part of the needed knowledge. The remainder of the information must be acquired through general kinds of research in each area. In addition, laboratory procedures in soil testing must be calibrated and related to actual field fertility experiments.

Observations in Brazil

Background research in the areas visited, although extensive, has not progressed sufficiently to provide all of the needed information upon which to base sound nitrogen fertilizer recommendations for crop production at the present time, not to adequately assess the soil and natural nitrogen resources of the area. A number of nitrogen fertility trials have been conducted on several crops but the results apparently have not been adequately related to natural or analytical soil properties such that the results could be interpreted and extended to other areas for the purpose of predicting the need for nitrogen and the probable response of certain crops to the addition of nitrogen fertilizer.

Leguminous Crops

The use of leguminous crops for nitrogen, for forage and for other uses is receiving considerable attention. Soybeans for seed and oil as well as a number of tropical legumes for green manure and for forage are under investigation. Mrs. Dobereiner at the Instituto de Pesquisas e Experimentação has shown that symbiotic nitrogen fixation needs more research attention in the tropics. Temperature influences and some other soil conditions in the tropics result in the necessity to select new and specific strains of Rhizobia for the several legumes which are adapted and to determine the best soil and cultural conditions for plant growth, inoculation and nitrogen fixation.

A Case for Non-Symbiotic Nitrogen Fixation

An interesting and important case for according non-symbiotic nitrogen fixation an important role in some tropical soils has been developed by Mrs. Dobereiner. Her work has shown that some apparently well adapted non-symbiotic nitrogen fixing bacteria are abundant in soils of southern Brazil. Moreover, investigations have shown that the root zones or rhizospheres of sugar cane and Paspalum encourage the growth of these nitrogen fixing organisms to the partial exclusion of other organisms. Also, laboratory studies have shown that nitrogen can be fixed by the indigenous non-symbiotic bacteria when they are cultured on sugar cane and other plant residues.

Research which has been conducted on non-symbiotic nitrogen fixation has shown the fixation process to be growth regulated. By growth regulated is meant that nitrogen is fixed only in the process of growth of the organism. In other words, nitrogen fixation is accomplished by the organism only when nitrogen is needed in growth. Only growth regulated non-symbiotic nitrogen fixing systems have been heretofore observed. There has been speculation that other systems exist but they have yet to be demonstrated.

In non-growth regulated nitrogen fixing systems the organism or the nitrogen fixing biological system would fix atmosphere nitrogen in excess of the need of the organism for growth. The symbiotic nitrogen fixing systems are presumed to function in this manner. More nitrogen is fixed from the atmosphere than is needed or is used by the symbiotic bacteria.

Nitrogen fixation requires energy. In non-symbiotic nitrogen fixation the food energy supplies the energy for fixation. The amounts of fixation of atmospheric nitrogen depends on the amounts of food energy available to the fixing micro-organism and upon the efficiency of the organism in using this energy for growth purposes.

In symbiotic nitrogen fixing processes the energy is supplied by the host plant and both host and bacteria make some contribution to the nitrogen fixing processes. Here the amount of nitrogen fixed is not regulated by the growth of the micro-organism but is regulated by the growth of the legume and its need for nitrogen.

Another general observation of importance on nitrogen fixation is that both symbiotic and non-symbiotic nitrogen fixing systems are influenced by inorganic nitrogen. When inorganic nitrogen is available it will be used by both legumes and non-symbiotic nitrogen fixing bacteria in place of atmospheric nitrogen. Available nitrogen, therefore, replaces nitrogen fixation and if enough available nitrogen is present no fixation will take place.

The growth stimulation of non-symbiotic micro-organisms in the root zone of some crop plants in Southern Brazil suggests a close and possibly mutually beneficial association between the plants and the nitrogen fixing bacteria. Data show that the bacteria are benefitted. The benefit to the plant has yet to be demonstrated.

Many investigators have predicted that this is the kind of an association which would need to be established if non-symbiotic nitrogen fixation were to contribute significantly to the soil nitrogen supply. The presumptions made are that the plant supplies food energy to the bacteria and stimulates their prolification and growth. Competitive organisms are not stimulated in growth in the root zone to the extent that the non-symbiotic bacteria are stimulated. The selective stimulation may result from a high supply of carbohydrate food energy and a low supply of available nitrogen or other biological control factors may be operative. However, regardless of the factors bringing about the associations, that such associations have been shown to exist has renewed interest in the possibility that non-symbiotic nitrogen fixation may contribute significantly to the agricultural nitrogen resources in certain areas of the world.

Some Suggestions on Research Emphasis

In keeping with the specific interests of the International Soil Testing Project, namely; research to implement crop production through the efficient use of natural soil resources, fertilizer and lime, the following research areas concerned with nitrogen should be strengthened:

A. Examine soils from the several regions and soil type associations to determine the total nitrogen contents and the rates of release of the nitrogen for crop production. Such observations would be most meaningful if the samples were obtained at sites where field experiments were in progress, had been made, or could be made to determine the response of crops to nitrogen fertilizers. However, in the absence of field experimental data to associate with soil characteristics, soil properties as determined in the laboratory and in the greenhouses would be very helpful. Laboratory data should include: (1) soil nitrogen or soil organic matter; (2) some evaluation of the rate of nitrogen mineralization or release to available forms; (3) the general plant nutrient status of the soil; and (4) the pertinent physical properties of the sample.

B. Determine the nitrogen needs of specific crop plants in the several climatic areas and the supplemental nitrogen needs of each crop for profitable production. This information can be obtained by: (1) reviewing and examining field response data where nitrogen experiments have been conducted; and (2) conducting further field studies on nitrogen response where the survey indicates they are most needed. Any future field experiments should be preceded by an analysis of the soil from the site and then the treatments should be established in accord with the best estimates of the needs of the site and the crop to be grown.

C. Further investigate non-symbiotic nitrogen fixation as a possible important source of nitrogen for certain crops which encourage the growth of the fixing organisms. Important in this work is to determine the possible benefits to the crop plants and the specific circumstances under which benefits can occur. Owing to the extreme difficulty of evaluating the extent

of the nitrogen fixation with conventional techniques of nitrogen analyses, it would be most helpful if the experimenter could have access to the use of tracer nitrogen and to the necessary equipment for tracer analyses. Such techniques permit an evaluation of the sources and kinds of nitrogen which enter the plant.

The possibility that non-symbiotic nitrogen fixation may contribute an important part of the nitrogen needs of some crop plants is of sufficient importance to warrant a continued research effort in that field. The plant benefits should first be explored, if possible with tracer techniques, and then if significant nitrogen fixation is shown to occur, a subsequent investigation should be made of the soil and environmental conditions which result in a maximum benefit to the crop plants.

D. Legumes and/or other symbiotic nitrogen fixing associations should continue to receive attention. It is quite likely that for many years in the future the large part of the nitrogen supply for agricultural production will come from this source. Cultural practices as well as the symbiotic organisms and processes need further investigation in the tropical and semi-tropical regions.

DIAGNOSTIC TECHNIQUES AND RECOGNITION OF PROBLEMS IN THE FIELD

A. N. Plant

The United States Advisory Committee to the International Soil Testing Project recommended in 1966 that some attention be given to the use of diagnostic evaluations of nutrient deficiencies in crops growing under field conditions. As a result, Dr. S. E. Younts, Director for Latin America, Foundation for International Potash Research and the American Potash Institute and the author were requested to demonstrate diagnostic techniques and methods of recognizing problems in the field for the two research seminars which were conducted in Raleigh during the summer of 1966. Countries represented included Brasil, Bolivia, Perú, Ecuador, Colombia, Nicaragua, Honduras, El Salvador, Guatemala, and México.

The groups were very receptive to field diagnosis and tissue testing procedures for here were additional tools to help them accomplish their tasks.

On the requests of Dr. J. L. Walker and Dr. A. H. Hunter, International Soil Testing Project Regional Directors for El Salvador, Guatemala, Honduras, México and Panamá, Costa Rica, Nicaragua, respectively, the International Soil Testing Project requested me to demonstrate the techniques of field diagnosis and tissue testing utilizing crops grown on their experiment stations to the official Agriculturists of the following countries: Guatemala, El Salvador, Honduras, Nicaragua, and Costa Rica.

The trip was time to coincide with the inauguration of the soil testing laboratories in Guatemala, El Salvador, and Honduras as well as the Symposium on the Economic Impact Through Soil and Plant Analysis held in Tegucigalpa, Honduras, May 8-13, 1967.

The following visits and clinics were held:

1. Soil Testing Laboratory at Guatemala City
   Inauguration of the soil testing laboratory

2. Cuyuta Experiment Station
   Demonstrated field diagnostic techniques. On this station we observed corn in three stages of development; mature, tasseling and less than knee high. Rows were 1 meter wide and population was about 12-13 thousand plants per acre. The fields of tasseling and young corn had a severe out-grass problem as well as a moderate pigweed problem. Tissue tests showed the tasseling corn to be very high in nitrogen, low in phosphorus and low medium in potassium. If limiting factors were removed (weeds and stand) this field would very probably have responded to additional phosphorus and potassium. Tissue tests of the young

corn showed the crop to be low in nitrogen, phosphorus, and potassium. Visual phosphorus deficiency symptoms were present throughout this field. Tests of the nut-grass and pigweed showed these plants to contain over twice the concentration of phosphorus as the corn crop. It is doubtful if this field would respond to fertilization unless the nut-grass problem was eliminated.

3. Soil Testing Laboratory at Santa Tecla, El Salvador
   Inauguration of the soil testing laboratory

4. San Andrés Experiment Station
   Demonstrated field diagnostic techniques. On this excellently run station we again observed corn in various stages of growth. Two adjoining fields just beginning to tassel were selected for demonstration purposes. Stands in these two fields were approximately 25,000 plants per acre. Potassium deficiency symptoms were present on the lowermost leaves remaining (5-6 leaf) on scattered plants throughout the fields. Tissue tests showed the plants to be very low in nitrogen, low in phosphorus, and low medium in potassium, yet the plants had a fairly dark green color. Here was a perfect example of "Hidden Hunger"--the imbalance of one nutrient obscuring the deficiency of another element. This corn probably started firing within a few days after our visit.

   Visual symptoms indicated potassium deficiency sometime during the early part of the season, but tissue tests indicated a level of potassium higher than the deficiency symptoms would indicate. Questioning of the Experiment Station Supervisor gave the answer. The corn was planted and several rains got it off to a fast start. Then a period of drought occurred. The marginal level of potassium in the soil was not adequate to supply the plant under the low soil moisture level.

   The demonstration was repeated for the students of the Agricultural School of San Andrés.

5. Soil Testing Laboratory, Tegucigalpa, Honduras
   Inauguration of the soil testing laboratory

6. Banco Central
   Symposium--Economic Impact Through Soil and Plant Analysis

7. Experimental field, Tegucigalpa, Honduras
Demonstrated field diagnostic techniques. Due to the prolonged dry season most crops had not been planted. On this station we worked with Guatemala grass and Ramie. Deficiency symptoms of nitrogen and potassium were evident in both crops. Tissue tests showed both crops to be low in nitrogen, phosphorus, and potassium. On this station we were hard pressed to find a higher level of N, P, or K in any crop. Pigweed came through for us again and showed a strong medium level for phosphorus.

8. Soil Testing Laboratory, Managua, Nicaragua
Tour of facilities

9. Escuela Nacional de Agricultura, Managua, Nicaragua
Tour of facilities and lecture to the students and staff on field diagnosis and tissue testing

10. Experiment Station, Managua, Nicaragua
Demonstrated field diagnosis and tissue testing. On this station we observed corn, cotton, and forages. The place selected was the site of some earlier phosphorus rate studies. Tissue tests showed nitrogen to be high throughout the area. Phosphorus varied from spot to spot; however, it was interesting to note that any time the phosphorus level was medium, the potassium level dropped to low, otherwise the potassium was average medium to low medium. This was with a plant population of about 11,000 plants per acre. The reason for the low population was that they were trying to increase the seed corn from a promising selection. However, adequate populations in all probability would have shown potassium to be deficient.

11. Soil Testing Laboratory in San José, Costa Rica
Tour of facilities

12. Experiment Station at Alajuela, Costa Rica
Demonstration of field diagnosis and tissue testing. On this station we observed a large variety of crops. Corn, sugar cane, tomatoes, cucumbers, beans, etc. Corn was chosen for the indicator crop for tissue testing. Tissue test showed fields to be low in nitrogen, low medium in phosphorus and low in potassium. Sugar cane tested very low in N, P, and K. Tomatoes tested medium in nitrogen and potassium and high in phosphorus.

It is interesting to note that a standard statement in all of the countries was as follows: "Our soils are derived from volcanic materials and are all high in potash; therefore, you will not find any potash deficiency in any of our crops." Yet, tissue tests revealed potash deficiency on every experiment station visited. It was also observed that premature internal breakdown of the corn stalks was evident in all corn when it tasseled.

It is very probable that as soon as other factors limiting crop yields are removed potassium will become a limiting factor in many instances. As long as corn yields stay in the range of 15 to 30 bushels per acre, release of native potassium will be adequate to meet the needs of the crop.

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