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EVALUATION OF SOIL FERTILITY IN LATIN AMERICA: SOIL TESTING-PLANT ANALYSES 1965

INTERNATIONAL Soil Testing

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* * * * * * *

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J. W. Fitts

R. B. Cate, Jr.
A. H. Hunter
J. L. Walker
D. L. Waugh

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INTRODUCTION

Latin America is confronted with the task of doubling the agricultural output during the next twenty years in order to support general economic development. The increased output must be attained primarily by increased yields on lands now under cultivation. Many factors influence the crop yield (climate, crop, soil, management practices, etc.) that is obtained, but increased yields can only be attained when the supply of plant nutrients is adequate. Increasing the nutrient status of soils is generally accomplished by applying the proper chemical fertilizer containing one or more of the major nutrient elements, nitrogen, phosphorus, and potassium. The secondary elements, calcium, magnesium, and sulfur, as well as the micronutrients, iron, copper, zinc, boron, manganese, and molybdenum, must not be overlooked.

Fertilizers are not being used extensively in crop production in most of Latin America, yet the practice of fertilization can be accomplished without a large investment by the farmer in new machinery, etc. In fact, even the most primitive farmers can apply the required fertilizer by hand if need be. Of course, good seed and good management practices are necessary in order to obtain the greatest return from the fertilizer used.

Soil testing and plant analyses can furnish valuable information and provide an excellent guide for the use of fertilizers, lime, and other soil amendments in crop production. Experience in the United States and Europe shows that good soil testing is the best guide to soil fertility requirements. However, soil tests are not a "cure all" for crop production problems and do not assure a high return on fertilizers and lime used. All factors influencing plant growth must be considered in obtaining the most efficient production for the crop. Soil tests and plant analyses furnish the vital information needed in good fertilization practices.

There are several facets, or aspects, to a successful soil testing-plant analyses program which will furnish essential information in soil management. These include:

1. Obtaining representative samples: The largest source of error in soil testing and plant analyses is sampling. A poorly taken sample may even give erroneous results. In sampling soils for fertility purposes, interest should be in the layer or horizons which will be altered or improved by the application of fertilizer or other soil amendments. Since the plow zone is

the most variable layer in soils due to erosion or accumulation of plant and animal residues, a composite sample of several borings is desirable. This is in contrast to a soil survey sampling where the soil is studied vertically at a single site. In plant sampling, age of the plant tissue, portion of the plant sampled, and time of the day, are variables to be encountered.

2. Laboratory analyses: Analytical procedures to extract the various elements on which information is desired is very important. Total analyses of an element in soils offers no guide to the amount available to plants. The form in which the nutrients occur and the presence of other complexing factors influence the choice of the extractant that should be used. Employing techniques which permit analyzing many samples per day without sacrificing accuracy is also an important aspect in testing procedures.

3. Interpretation of results: After the analyses have been completed, the results must be interpreted. For the soil and plant tissue in question, should certain nutrient elements be added? Are there acid or alkaline conditions that need correcting before the full benefit can be obtained from fertilizers? Establishing guide lines for interpreting the data for the soil and plant analyses is very important.

4. Recommendations: After the analyses have been interpreted relative to the needs of fertilizers or soil amendments, then recommendation must be made relative to amount, time, method of application, and forms of materials to apply. Soils with high phosphorus fixation characteristics require more careful placement of phosphate fertilizers than low fixing soils. Likewise, on soils low in potassium, it is necessary to make frequent applications of potash fertilizers for crops which "luxury" consume this element. The economic aspects of fertilization cannot be ignored in making recommendations.

5. Research data: The more research data that is available for soils and crops for a given region, the more refined can be the interpretation and the recommendations of the soil and plant analyses. If no research data are available for a given crop under specific soil and other environmental conditions, then application of the results is difficult, if not impossible. Laboratory studies are needed to ascertain the properties of the soils to be encountered in a region. For interpretation of the analyses, both greenhouse and field trials are necessary.

6. Follow-up meetings: Although soil and plant analyses are excellent educational tools, they must be understood by the person wishing to make use of them. Follow-up meetings to help the farmer understand the analyses and reports and to ascertain the availability of recommended materials are very essential for a soil testing program.

7. Summaries: When a sufficient number of samples have been analyzed for a given region with respect to the kinds of soils and of the various crops grown, a meaningful summary can be prepared. Such summaries are of great value to administrative, educational and research agencies, and to commercial companies. The summaries can be related to soil associations, to ecological maps, etc.

THE INTERNATIONAL SOIL TESTING PROJECT

In June of 1963, North Carolina State University entered into a contractual agreement with the Agency for International Development (A.I.D.) to provide technical assistance in the study of soil fertility and fertilizer needs for the countries of Latin America. The first objectives of the project include:

A. To document the fertilizer and soil fertility requirements for increased crop production in Latin America.

B. To help cooperating governments and agencies develop and maintain improved soil testing programs (including all phases).

The first phase of the project was concerned with making a survey of the work being done in the soil and plant laboratories of Latin America relative to the six phases of a good soil testing program. It is difficult to make a complete survey since some analyses are made by laboratories primarily engaged in other activities. Some private laboratories engaged in analysis for their own use were omitted in the survey; also laboratories testing with "kits" were excluded.

The survey was conducted by the four regional directors of the International Soil Testing Project:

Regional Directors	Countries Surveyed
Robert B. Cate, Jr.	Brazil
Arvel H. Hunter	Argentina, Paraguay and Uruguay
James L. Walker	Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and Panama
Donovan L. Waugh	Bolivia, Ecuador and Peru

Surveys were not conducted in Venezuela, Colombia or Chile, but general information on the programs of these countries was obtained.

ACKNOWLEDGEMENTS

Many agencies, companies and persons were contacted in the completion of these surveys. To all participants, a sincere "thank you" is expressed for your help; without it, the surveys could not have been completed. A complete listing of all agencies and persons contacted directly, or who gave assistance indirectly, is difficult, since there are many changes in personnel from time to time. Therefore, a complete listing will not be undertaken. However, several agencies and individuals listed below have contributed so much that it would be remiss not to mention them.

Agencies

The Ministries of Agriculture and Natural Resources of all the countries who endorsed the project and who authorized their personnel to cooperate in completing the survey.

The staff of Soils or Agronomy Departments of the Ministries of Agriculture and of the National Universities.

The USAID Missions, especially the Rural Development and Agricultural Officers.

ROCAP of the Agency for International Development

The Food and Agriculture Organization of the United Nations (FAO)

The Natural Resources Units of the Interamerican Geodetic Survey

The Organization of American States (OAS)

The Rockefeller Foundation

The Esso Corporation and Fertica Corporation

The United Fruit Company

The British Mission to Bolivia

Individuals who were especially helpful:

Brazil:	Dr. Leandro Vettori, Dr. Homero Gargantini, and Dr. Raul Kalchmann
Argentina:	Ing. Jorge I. Bellati and Dr. Roberto V. Caravello
Paraguay:	Ing. Nelson de Barros and Ing. A. Bertoni
Uruguay:	Ing. H. Tobler Bottini and Dr. Ernest E. Reynaert

Costa Rica:	Ing. Oscar Vargas Vaglio, Ing. José F. Carvajal, Dr. Elmer Bornemisza and Dr. C. V. Plath (FAO)
El Salvador:	Ing. René Alvarado L., Dra. Flora M. Espinosa, Ing. Miguel E. Menéndez and Dr. W. C. Bourne (USAID)
Guatemala:	Ing. Mario Braeuner, Ing. Salvador Castillo O., Ing. Rodolfo Perdomo, Ing. Luis Solorzano, and Dr. C. H. H. ter Kuile (FAO)
Honduras:	Ing. Arturo Pinel, Ing. Jorge Díaz Zelaya, Ing. Vladimiro Castellanos, Dr. A. B. Awan, Ing. Héctor Lizarraga (FAO) and Dr. C. S. Simmons (FAO)
Mexico:	Dr. Rodolfo Moreno D., Ing. A. J. van der Sluis, Dr. B. Ortíz Villanueva, and Dr. E. J. Wellhausen (Rockefeller Foundation)
Nicaragua:	Ing. Orlando Lindo, Ing. Angel Salazar B., Ing. Ramiro Montes, and Ing. Antonio Prego
Panamá:	Dr. Reinmar Tejeira, Ing. Rodolfo E. Alemán, Ing. Ezequiel Espinosa, Ing. Darío Vallarino, and Dr. Pete Duisberg (National Resources Unit, I.A.G.S.)
Bolivia:	Ing. José Amurrio R. and Ing. Angel Cordero V.
Ecuador:	Dr. Julio Peña Herrera, Ing. Beatriz Hidalgo de Mena and Dr. Laura Iza G.
Perú:	Ing. Carlos Valverde S., and Ing. José Estrada

GENERAL SUMMARY OF SOIL AND PLANT ANALYSES SURVEY

Observations made in the United States and some countries of Europe indicate that a relationship exists between the number of soil samples tested and the amount of commercial fertilizers used. Farmers investing in fertilizers wish to obtain the greatest return for their investment and utilize soil tests as a guide in selecting fertilizers to use. In Latin America, to date, only relatively small amounts of commercial fertilizers have been and are being used; likewise, the number of soil and plant analyses is small. However, there is much interest in an increased use of commercial fertilizers and in the improvement of soil and plant analyses programs.

Most of the plant analyses have been with coffee but some work on other high return crops including sugar cane and bananas has been done also. Most of the coffee studies have been in Brazil, El Salvador, Costa Rica, Colombia and

Ecuador; the sugar cane studies in Mexico and the banana studies in Honduras. Much of the effort in plant analyses has been in research and relatively little has been done in analyzing samples routinely for farmers.

All of the countries surveyed have soil analyses laboratories but not all have laboratories that test samples for farmers. Some laboratories, such as the one in Uruguay, confine their analyses to soil survey samples. Very few laboratories test more than 2,000 samples per year and most of the samples tested are connected with research studies or soil survey. Brazil, Colombia, and Mexico are the leading countries in testing farmers' samples. Brazil and Colombia are testing about 30,000 samples a year for farmers; Mexico tests less than half of this number. In relation to the total area under cultivation in Latin America, the number of samples tested for farmers is indeed very low.

One of the greatest factors retarding soil testing for farmers is the long period of time required to obtain the results after a sample has been submitted to the laboratory. For a successful soil testing program, samples submitted to a laboratory must be analyzed and the results with recommendations returned to the sender within two weeks. Since soil sampling is seasonal (farmers usually take samples just previous to planting a crop), a laboratory must have a capacity for analyzing at least 100 samples per day in order to keep current with samples being submitted. The only laboratory surveyed that had a capacity of a hundred samples a day is in Colombia. A large majority of the laboratories analyze only 10 or 12 samples per day with a few approaching 20 per day.

With the exception of laboratories operated by commercial firms or associations (such as coffee or sugar cane associations), all of the laboratories are operated by research organizations or by soil survey divisions. In general, Agricultural Extension or Extension type agencies have very little if any connection with soil testing. Educational programs relative to obtaining soil samples and follow-up meetings to aid the farmers in interpreting and following the soil test results are almost non-existent. Such educational activities, of course, are very essential for a successful soil testing program.

Representative Soil Samples: Most of the laboratories were familiar with the use of small cartons or bags for submitting soil samples, but relatively few had them for distribution to farmers for use in getting samples. Since only a small number of samples were being analyzed for farmers, there was little demand for such containers. Mailing cartons were very rarely used for sending soil cartons to the laboratory.

Most of the laboratories testing samples for farmers had some type of instruction sheets for taking samples. Several, like those in Mexico, Guatemala and Panama, are nicely illustrated with cartoons. The instructions for taking the soil samples varied from country to country and even from laboratory to laboratory within a country; the greatest variation was in depth of sampling. Most laboratories recommend that farmers take composite samples for fertility tests.

Laboratory Analyses: In general, most of the laboratories were fairly well equipped to make the usual routine analyses such as pH, organic matter, exchangeable cations, total nitrogen, nitrate nitrogen, available phosphorus, and soluble salts. Also most of the laboratories were equipped to make texture analyses, using the hydrometer procedure. Almost all of the laboratories had a pH meter, one or two colorimeters, a flame photometer, conductivity bridge, and some type of Kjeldahl apparatus. Very few laboratories had spare equipment or parts. A breakdown in a piece of equipment usually results in a considerable delay in getting analyses made, since servicing the apparatus is a major problem. Several laboratories had equipment which was not suitable for the work to be done. Some apparatus may be good for research purposes, but would not operate successfully when used continuously in routine analyses. Likewise, some of the equipment was much more complicated than needed for the analyses desired; other equipment was accurate but too slow for use in a "high capacity" laboratory.

The laboratory in Palmira, Colombia (patterned after the North Carolina Laboratory) was the only laboratory found to be equipped with multiple units, such as dispensers and filtering apparatus, which permit handling 10 to 12 samples simultaneously. Such apparatus is indispensable for increasing the capacity of the laboratories.

Several extractants were being used by the various laboratories, but most of these are the same solutions used in the laboratories in the United States. Several studies on extractants, particularly for phosphorus, were under way in Colombia, Peru, Brazil and Mexico, and to a lesser extent in some of the other countries. In Mexico, the Bray No. 1 extractant was popular. For the reddish soils of South America, the North Carolina extractant is frequently used; on the neutral to calcareous soils, particularly in Peru, the Olsen-sodium bicarbonate procedure was employed. Some of the laboratories, especially in Central America, Panama, and Colombia, were using commercial

extractants (largely sodium acetate and acetic acid). In research trials in Brazil and Colombia, the Bray No. 2 (more strongly acid than No. 1) appeared good.

For exchangeable cations, particularly potassium, ammonium from ammonium acetate, sodium from sodium acetate, and hydrogen from hydrochloric sulfuric or acetic acids are generally being used. Potassium, sodium and frequently calcium are determined with a flame photometer in almost all of the laboratories. Since soil conditions vary so greatly in Latin America, no one extractant will be best for all situations. Nevertheless, the number of extractants that will be employed probably will be no more, if as many, as currently being used in the United States.

The quantity and quality of distilled water is a problem for many of the laboratories. Where large numbers of samples are analyzed daily an adequate supply of good distilled water must be available.

With the exception of the laboratory at Palmira in Colombia, the use of "control" samples was found to be almost non-existent. In fact, the idea of using control samples to assure accuracy of analyses and to eliminate error was new to a number of the laboratories. Several laboratories were using standard solutions for checking equipment but not control samples.

Interpretation of Results: Not many studies have been conducted in Latin America for the purpose of correlating soil tests. Dr. Enrique Ortega of Mexico has supervised fertility trials and soil test correlation studies for a number of years. Several studies have been conducted in Central Brazil, largely in the State of São Paulo, and the results are being prepared for publication. In Colombia, cooperative soil fertility studies have been conducted between the Governmental agencies and Rockefeller Foundation. Good field fertility trials have been undertaken for the past several years in Peru by SIPA and in Ecuador by INIAP, but they have not been correlated with soil tests. There are scattered studies in other countries too, but in general, field trials and demonstrations have not been conducted with the objective of using the data for correlating soil tests. Very few greenhouse or shadehouse studies have been made as yet for correlating soil tests. No publications on correlation data were found.

Recommendations: One of the important objectives of soil analyses is the increased efficiency in crop production through the proper use of fertilizer and other soil amendments. In making fertilizer recommendations, factors other than fertility must be considered. Guide sheets are very important in a soil testing program,

but none of the laboratories surveyed were found to have guide sheets prepared for their use. General fertilizer recommendations are available in several of the countries, but guide sheets with recommendations for specific situations revealed by soil tests are not available as yet.

Research: Most of the research that has been done in soil testing-soil fertility has been conducted in Brazil, Colombia, Mexico, and Peru, with lesser amounts in several other countries, particularly Ecuador, El Salvador, Panama, and Venezuela. But even in these countries, the major efforts in research have not been directed toward soil testing as related to soil fertility. Many field trials and demonstrations have been conducted without "supporting" laboratory analyses. Few studies have been made where the main objective has been some phase of soil testing.

The needs for further research are many. As additional research data becomes available, the soil and plant analyses can be refined and will be more meaningful. Soil sampling studies are needed relative to the variabilities of the surface soil, which in turn will influence the number of cores desirable per composite sample and the size of area to include in a sample. Research on the depth of sampling of soils in respect to the movement of fertilizers and lime should be investigated further. Of particular interest will be studies of seasonal influence on sampling; this will be especially important in relation to wet or dry seasons. Soil factors influencing availability and release of nutrient elements need attention, too. Of course, additional studies are needed on correlation in general, and on the response to fertilizer applications as well as the reduced availability of nutrient elements when applied to the soil.

Follow-up programs: Since little testing of samples has been done for farmers of Latin America, there has been little need for follow-up meetings. Educational programs relative to soil testing, including the use that can be made of the tests, how to use the fertilizer and lime recommended, etc., are greatly needed. Part of this phase of soil testing will be the development and use of visual aids.

Summaries: No country has a sufficient number of soil tests to warrant preparation of summaries for the country as a whole. There are scattered areas within countries, however, where there has been a sufficient number of samples tested to prepare summaries of the results. This is especially true where the information has been accumulated over a period of a few years. Publication of summaries will be encouraged whenever sufficient information is available.

REGIONAL SUMMARIES OF SURVEY

Inclusion of all the soil test-plant analyses questionnaires that were completed for Latin America would require such a voluminous publication that the information would not be readily accessible. The Regional Directors of the project have prepared summary statements from the surveys they made in the countries in which they work. The original survey reports are available in Raleigh, North Carolina for future reference.

Middle America Region

(Costa Rica, Guatemala, El Salvador, Honduras, Mexico, Nicaragua, and Panama)

J. L. Walker - Regional Director

Soil and Plant Analyses Laboratories Visited:

COSTA RICA

Laboratorio de Física y Química de Suelos, M.A.G., San José
Head: Ing. Oscar Vargas Vaglio - primarily service; soil chemical and physical analyses

Laboratorio de Investigaciones Agronómicas, Univ. Costa Rica, San José
Director: Ing. José F. Carvajal - primarily research; plant tissue and soil analyses

Laboratorio del Departamento de Suelo, Fac. Agron. Univ. Costa Rica
Director: Ing. Alberto Saenz M. - primarily research and teaching, soil chemical and physical analyses, mapping, agronomy

Soil Chemistry Laboratory, Nuclear Energy Project IICA, Turrialba
Head: Dr. Elmer Bernemisza - primarily research and graduate teaching; soil chemical analyses

Soil Science Department and Laboratory, IICA, Turrialba
Head: Dr. Frederick Hardy - primarily research and graduate teaching; soil science and agronomy

GUATEMALA

Laboratorio de Suelos, I.A.N., M.A.G., Guatemala
Head: Ing. Salvador Castillo O. - primarily service; soil chemical analyses for fertilizer recommendations

Laboratorio de Suelos, D.R.H., M.A.G., Guatemala

Head: Ing. Rodolfo Perdomo - primarily service; soil physical analyses and mapping related to irrigation purposes

Laboratorio de Suelos, Fac. Agron., Univ. San Carlos, Guatemala

Director: Ing. Mario Braeuner - primarily research and teaching; soil chemical and physical analyses, agronomy

HEMCO, Guatemala

Director: Mr. Richard Quast - private soil analyses and agronomic service

EL SALVADOR

Laboratorio de Análisis Rápidos de Suelos, D.G.I.A., M.A.G., Santa Tecla

Head: B.S.A. Eduardo Valiente H. - primarily service analyses of soil samples for fertilizer recommendations

Laboratorio para Caracterización de Perfiles, D.G.I.A., M.A.G., Santa Tecla

Head: Ing. Miguel E. Menéndez - primarily service and research; soil chemical and physical analyses related to soil classification, some research plant tissue analyses

Laboratorio de Químicos Agrícola, Instituto Salv. Investigación del Café, M.A.G., Santa Tecla

Head: Dra. Flora N. Espinosa - primarily service and research analyses of coffee plant tissue, some soil chemical analyses

HONDURAS

Laboratorio de Recursos Naturales, Depto. Suelos, M.R.N., El Picacho, Tegucigalpa

Head: Ing. Carlos Rivera House - primarily service; soil chemical and physical analyses

Soil Laboratory, Escuela Agrícola Panamaericana, El Zamorano

Head: Dr. Abdul Bari Awan - primarily research and teaching; soil chemistry and agronomy

Vining C. Dunlap Laboratory, United Fruit Co., La Lima

Head Soils Dept.: Dr. Charles E. Fulcher - primarily private research and service; soil chemical, soil physical and plant tissue analyses

MEXICO

Laboratorio Central de la D.G.A., S.A.G., Mexico, D. F.

Head: Ing. Alejandro E. Cárdenas - primarily service; analyses of soils, water and agricultural chemicals

Laboratorio de Análisis de Suelos y Plantas del Depto. de Suelos del Instituto Nacional de Investigaciones Agrícolas, S.A.G.

Head: Dept. of Soils - Dr. Rodolfo Moreno D.

Assoc. Head: Dr. Enrique Ortega T. - primarily research; analyses of soils, water, and plant tissue for improved soil use

Laboratorio Central "El Horno", Centro de Investigaciones Básicas (CEB) Chapingo, Mexico

Laboratorio Estación Agrícola Experimental, Mexicali, Baja California

Laboratorio, Centro de Investigaciones Agrícolas del Noroeste (CIANO) Ciudad Obregón, Sonora

Laboratorio, Centro de Investigaciones Agrícolas del Noreste (CIANE) Matamoros, Coahuila

Laboratorio, Estación Agrícola Experimental (CIANE) Río Bravo, Tamaulipas

Laboratorio de Suelos y Plantas del Instituto para el Mejoramiento de la Producción de Azúcar

Head: "Laboratorio Central" - Mexico, D.F., Dr. Bonifacio Ortíz Villanueva - primarily service and research analyses; plant tissue, soil chemical and physical characteristics, irrigation water, and agricultural chemicals of interest in the production of sugar

Regional Laboratories at:

Bellavista, Jalisco

El Carmen, Veracruz

El Mante, Tamaulipas

Matamoros, Puebla

Los Machis, Sinaloa

Navolato, Sinaloa

Tula, Jalisco

Tamazula, Jalisco

Xicotencatl, Tamaulipas

Departamento de Estudios Agrológicos, S.R.H., Mexico, D.F.

Head: Soil Survey - Ing. Mario Macías Villada

Laboratorio de Agrología, Tacubaya, D.F.

Head: Ing. Rafael Ortíz Monasterio - primarily service and research laboratories for soil investigations related to soil survey and irrigation work

Graduate School of the Escuela Nacional de Agricultura, S.A.G., Chapingo, Mexico - Laboratorio del Depto. de Suelos

Director: Soils Dept. - Dr. Ramón Fernández; primarily research and teaching, Soil Science

NICARAGUA

Laboratorio del Departamento de Química, Centro Experimental Agropecuario de "La Calera", M.A.G., Km. 12 - Carretera Norte, Managua

Head of the Dept: Ing. Ramiro Montes V. - primarily service and research; chemical analyses of soils, water and agricultural chemicals

Laboratorio de la Escuela Nacional de Agricultural, M.A.G.

School Director: Ing. Orlando Lindo

Head of Labs.: Ing. Noel Somarrila B. - primarily agricultural teaching and research laboratories

Laboratorio Médico Químico Dr. Bengoechea, Managua

Co-Director: Dr. J. Jaime Bengoechea - private analytical services, including soil and water analyses for consulting agronomists

Geotécnica, Managua

Director: Ing. J. Antonio Mora R. - private chemical and physical analytical service for agriculturalists, including agronomic advisory services

PANAMA

Laboratorio de Suelos, Asesoría de Agrología, M.A.C.I., Panamá

Director: Dr. Reinmar Tejeira - primarily chemical and physical analytical service and research analyses of soils and plant tissue

Laboratorio de Suelos, Escuela Agronomía, Univ. Panamá

Prof. of Soils: Dr. Reinmar Tejeira - primarily research and teaching laboratory in Soil Science

General Observations:

There are about forty laboratories performing soil and plant analyses in the Middle American Region. In addition, many small laboratories exist, generally associated with major distributors of fertilizers, in each of the seven countries. These small laboratories use mostly soil testing kits, which the users recognize are in many ways unsatisfactory. All commercial houses contacted expressed the desire to discontinue soil testing upon the initiation of governmental soil testing programs, which will enable customers to obtain soil test results and recommendations within two weeks after sending in their samples.

The 40 major laboratories of Middle America are distributed: 19 in Mexico, 4 in Guatemala, 3 in El Salvador, 3 in Honduras, 4 in Nicaragua, 5 in Costa Rica, and 2 in Panamá. Nearly all of the 40 laboratories, at least occasionally, analyze soil samples. The 40 major laboratories are operated by: Ministry or Secretaría of Agriculture and dependencies (including dependent agricultural schools), 17; Secretaría de Recursos Hidráulicos, 2; Universities and private agricultural schools, 4; International organizations (non commercial), 3; international organizations (commercial), 1; local commercial, 3; crop growers associations, 10.

In each of the seven countries, there is one governmental laboratory that is responsible for analyzing soil samples for the general public without restrictions concerning crops or areas within the country. Two to four laboratory technicians are employed in each laboratory. This excludes general helpers, often times university agronomy students, who work mostly on a part-time basis and whose number varies between 0 and 4. Inasmuch as all but one of the seven laboratories analyze other samples in addition to farmers' samples, it is difficult to assign a definite cost per analyses. However, since none of the laboratories has, on the basis of the past five-year period, an annual average greater than 5,000 analyses of all types, the cost per determination must be quite high. All of the laboratories operate independently rather than as part of a laboratory system. In addition to a central service laboratory, mobile laboratories on trailers are used in one country to provide service to agriculturists. All laboratories analyze soil samples both for purposes of making fertilizer recommendations and for obtaining research data; only two of the seven laboratories analyze solely soil samples. Of the other five laboratories, one each analyzes, in addition, either water or plant tissue samples; the remaining three laboratories have a multiplicity of additional analytical responsibilities ranging from the analyses of agricultural chemicals, including fertilizers, to foodstuffs.

Direct appropriations support all of the seven governmental laboratories. Two of the laboratories make nominal charges for analyzing farmers' samples, but the money derived is retained strictly for laboratory use by only one of these two laboratories.

During the past five years, all seven laboratories (one in each of the seven countries) have averaged analyzing less than 4,000 farmers' samples annually. Of the seven laboratories, one averaged about 4,000; two averaged between 1,500 and 2,000; two between 1,000 and 1,500; one between 500 and 1,000; and one less than 500 analyses of farmers' samples annually. Only one of the seven laboratories present a recommendation to a farmer within ten days of receiving his sample. The present maximum capacity for analyzing farmers' samples is 20 samples per day or less for all but two of the laboratories.

Obtaining representative samples and recording information about the soil samples:

All but one of the laboratories have printed instructions telling how to sample agricultural soils. Four laboratories recommend that soils be sampled annually, one recommends once every 3 to 5 years, and two that soils be sampled according to whether the crops being grown are annual, perennial, or pasture; these latter two laboratories also recommend the time to sample relative to the type of crop being grown. The other five laboratories recommend that samples be collected up to four weeks before planting. Three of the seven governmental service laboratories make definite recommendations limiting sampling according to the physical state (wetness or dryness) of the soil; of the three, one recommends taking the sample according to the conditions under which the crop will be grown.

Only two of the laboratories distribute containers suitable for farmers' soil samples. Both farmers and governmental agricultural agents collect the farmers' samples in all seven countries; in addition, six of the laboratories report the assistance of fertilizer company representatives, four report the assistance of laboratory and private agronomists, and two report the help of agricultural teachers in collecting farmers' samples. These samples are all sent or taken to the laboratory either by the person collecting the samples or by the government agricultural agents.

Most of the laboratories recommend sampling from 0 to 15 cm., one recommends sampling from 0 to 20 cm., but only one recommends sampling to plow depth ("color change"). In addition, four of the laboratories recommend taking a second sample to a depth of 30 to 50 cm., but the use to which data concerning this second sample are put is not clear. All the laboratories recommend taking

a composite sample, but in only two cases is the recommended maximum area represented by one composite less than four hectares. In the other cases, the maximum area recommended varies between six and fourteen hectares. The recommended minimum number of subsamples for making up one composite in two cases is only five, but the other five laboratories recommend taking from eight to twenty. The tools recommended for taking soil samples vary from machetes and spades to augers.

All of the laboratories require that more or less complete information sheets be filled out for each sample. Two of the laboratories report that the information sheets are adequately completed more than 50% of the time, but the other five laboratories report satisfactory completion in less than 40% of the cases.

In all cases, laboratory numbers are placed on the information sheets as well as on the samples. Two laboratories report that the information sheets accompany the samples and are also used for recording laboratory results. The other laboratories file the information sheets until analyses are completed, either as a safeguard against loss or to prevent the analysts knowing the area from which the sample came, an event which possibly would lead to biased results.

Only two laboratories report that training meetings have been held on the proper method of selecting soil samples.

Laboratory Facilities, Management and Procedures:

All of the laboratories give serial numbers to the farmers' samples when they arrive. Following this, the samples are air-dried at room temperature (in one laboratory the samples are dried at a temperature of about 30°C.) before being crushed and sieved. Three laboratories use a mortar and pestle, and four use a wooden rolling pin in crushing the dried sample. One laboratory also has a mechanical crusher which is occasionally used for preparing farmers' samples. None of the laboratories have blowers available for reducing dust while preparing the samples for analyses. In six of the laboratories the sample is crushed to pass a 2 mm. sieve; the other laboratory crushes its samples to pass a 0.5 mm. sieve. All of the laboratories discard resistant nodules, stones, and roots, but only one laboratory records the volume and nature of the discarded material. Two of the laboratories have storage racks with trays available for the samples awaiting analyses. In all of the laboratories, samples are often stored before testing, but this is either for drying them or because the pressure of other higher priority analytical work prevents their immediate analyses.

Four laboratories weigh the samples for analyses; the other three either weigh or measure the samples, depending upon the type of analyses to be performed. No laboratory, as yet, uses strictly a measured volume for all of its service analyses, even though all laboratories that make recommendations do so on the basis of applying fertilizer to a volume rather than to a weight of soil.

One laboratory uses only a leaching procedure and one either a leacing or equilibrium procedure in preparing soil extracts; the other laboratories adhere strictly to an equilibrium procedure. Of the five laboratories using an equilibrium procedure, four use activated carbon to decolorize the soil extracts; the other laboratory uses none. Control samples are used by only two laboratories in checking equipment and procedures; however, these control samples are not as yet used by either laboratory on a daily, systematic basis. All of the laboratories determine the texture of the farmers' samples; five by feel and two by hydrometer only. The five which determine texture by feel also occasionally check their results by using the hydrometer method.

Base saturation is not determined for farmers' samples by five of the laboratories. Each of the remaining laboratories determine base saturation in a somewhat different manner, one by using the sum of cations minus extractable H divided by N NH_4 Ac cation exchange capacity and multiplying by 100, the other by dividing the sum of cations minus H by the sum of cations plus H and multiplying by 100. In six of the laboratories the effects of soluble salts or free carbonates on the results of analyses of farmers' samples are not considered; the remaining laboratory uses a water leach before determining exchangeable cations in samples whose pH is greater than 8.5.

Seven of the laboratories routinely analyze farmers' samples for extractable N, NO_3, or NH_3, P, K, pH, and organic matter; five also analyze for Ca and Mg; two routinely determine cation exchange capacity, lime requirement and various other cations and anions. One laboratory analyzes, in addition for soluble salts and Al. Nearly all of the laboratories can perform all of the listed analyses, but do so, only, if specifically requested by either the farmer or the governmental agricultural agent.

In routine analyses of farmers' samples, the Morgan Universal extractant is used by four laboratories for N, NO_3 or NH_3, and K; by three laboratories for Ca and Mg; by two laboratories for P. Color charts are used in connection with this method by three of the laboratories for N, P, and K; by one laboratory

for N and P. The other laboratories using this method employ colorimeters. One laboratory uses the Spurway method with color charts for N, NO_3 or NH_3, P, K, Ca, and Mg determinations; another uses the LaMotte Universal method for N, NO_3 or NH_3, and K, and the LaMotte-Truog extract for P and uses color charts. Two laboratories use the Bray No. 1 extract in P determinations and one laboratory uses extraction with N NH_4 Ac for routine Ca, Mg, and CEC determinations. All seven governmental laboratories use the Walkley-Black method for organic matter determinations, six titrate, and one uses a color chart. Five laboratories use a 1:1 soil-water ratio in pH determinations; the other two use a 1:2 or a 1:2.5 soil water ratio. Six utilize pH meters in this determination, one uses bromcresol color charts. A variety of filter papers are used by the seven laboratories: Whatman #1, 2, 32, 40, 41, and 42; A. H. Thomas #2, and S & S #602H.

One laboratory has no electronic equipment, not even a pH meter. However, in the other six laboratories a wide variety of electronic equipment, more or less suited to routine analyses, is in use. Included in the equipment are flame photometers, colorimeters, pH meters and conductivity bridges. All of the laboratories have water distillation apparatus, in some cases inoperative much of the time. After analyses, the samples are held for periods ranging from 14 days to six months by all but one laboratory which discards the farmers' samples immediately after analyses.

Interpreting analytical results:

Little uniformity exists in the initial manner soil test results are reported, some laboratories report results as ppm or me/100 g. soil and others as Kg/hectare, pounds/hectare, pounds/acre, or pounds/manzana. However, excepting one, all laboratories report results to the farmer as high, medium, or low along with a figure such as Kg/hectare. Several laboratories make more than three divisions; for example, very low, low, medium, high and very high are often used; others make additional separations, and some make more or fewer divisions according to the element analyzed.

Apart from the laboratory results, other soil characteristics are not considered by six of the laboratories because of the dearth of information relating laboratory results with actual crop performance in the field. Where accounting for other factors that might affect yields is attempted, it is in all but one case on the basis of the personal experience of the technician making the interpretation, or, mostly, on the basis of the recommendations accompanying the soil test kits and bulletins.

Recommendations for use of fertilizer and other soil amendments:

Interpretations and recommendations are made by a number of persons; the Director of the laboratory, agronomists, Extension agents or the laboratory technicians who make the analyses. The desirability of having interpretations and recommendations made by trained agronomists, who also understand the meaning of the laboratory results, is universally recognized. However, experienced persons with this type of training are not readily availble for a number of reasons, the chief of which seems to be low budgets and low salaries.

In nearly all cases, written reports are sent to the farmers; if requested, copies are also sent to other persons who collected the samples. Only two of the laboratories report that a copy is automatically sent to another branch of the agricultural department, and, of these two laboratories, only one automatically sends a copy of the report to the local extension agent. Upon receipt of the report the agent is able to work with the farmer to be sure he understands the recommendation and can assist him in obtaining the proper materials. In general, in making recommendations the farmer's managerial ability is either not considered because of lack of information or assumed to be low. Some laboratories report that an "average" ability is assumed, but two report that it is assumed that any farmer who will go to the trouble of having his soil tested will have a high managerial ability; that is, he will use improved seed and other agricultural chemicals in addition to fertilizers to insure maximum production. Three of the laboratories state that the farmer's capital ability, if known, is definitely taken into account in making the fertilizer recommendations.

The amounts of fertilizer recommended are reported in a variety of ways, such as Kg/hectare or pounds/manzana N-P_2O_5-K_2O, quintales/manzana of a fertilizer grade or specific materials, or as pounds/hectare of a fertilizer grade.

Generally, the amounts of fertilizers recommended are hypothetically designed to overcome a deficiency and to either build the soil to a high nutrient level or to the level of most economical response. One laboratory assumes that the level of fertilizer recommended will lead to a profitable response.

Nitrogen is nearly always considered to be necessary, regardless of the soil test results. A majority of the laboratories make special recommendations concerning the source of nitrogen but the reasons for making the distinctions are quite varied. In one case the cheapest nitrogen source is recommended; in others, the sulfate form is avoided in soils having either a low or high pH. All of the laboratories make recommendations concerning time and method of

application of nitrogen fertilizers. For example, solubility is considered and for sandy soils a split application is recommended. There is, however, very little experimental evidence from field studies on which to base recommendations concerning the use of nitrogenous fertilizers. For the other plant nutrients, recommendations concerning methods of application are not made unless asked for in two of the laboratories, and one other laboratory recommends that the farmer consult his extension agent. Four of the laboratories do make recommendations concerning methods of application. These take into consideration soil conditions, especially for sandy soils, the time to apply the fertilizer, and how to apply it. For example, for phosphate fertilizers, one laboratory recommends applying the fertilizer with the seed; others recommend applying it in pockets or in bands. A majority of the laboratories consider phosphate fixation in making fertilizer recommendations; however, the basis for this consideration is hypothetical--it is generally according to soil pH. One of the laboratories assumes that all of the soils in its area have such high phosphate fixing capacity that building up of the soil phosphate levels will not be profitable. All of the laboratories that give consideration to phosphate fixation recommend the application of fertilizers either in handfulls or in bands. The two laboratories that consider potassium fixation suggest applying fertilizers in the same manner as recommended for soils considered to be phosphate fixers. No studies have been made by the soil testing laboratories to ascertain those soils which in actuality fix either phosphorus, potassium, or both. Most laboratories do not make lime recommendations; the three that do consider factors such as the crop, pH, and calcium contents of the soil in making their recommendations. One of the three laboratories making lime recommendations does so to overcome calcium deficiencies rather than for purposes of raising the pH. A variety of liming materials are recommended depending upon local availability. Of the three laboratories making lime recommendations, two recommend a maximum rate of liming; one recommends one ton per manzana, the other 500 pounds per acre maximum. One laboratory recommends that lime not be applied all in one application, that it not be mixed with the fertilizer, and that the last application be made at least thirty days before fertilizing.

Supplemental tests, such as visual deficiencies, are used whenever possible in making the fertilizer recommendations. One of the major problems in getting this kind of information is that personnel in the laboratories lack transportation to visit problem sites in the field. Four of the laboratories report that special recommendations are prepared for fertilizer applications on flowers, gardens,

lawns, or in greenhouses. These recommendations are usually prepared by allied departments, such as horticulture; however, special laboratory tests are not made on these kinds of samples.

Organic fertilizers are used so rarely in Middle America that little or no consideration is given to them, except for an occasional recommendation of organic materials to enhance the physical conditions of light textured soils.

There are very few guide sheets in use. Some have been prepared from data of local origin and are of specific crops in specific areas, but the majority of guide sheets in use have been prepared from information available in other countries which have quite different climatic and soil conditions.

The recommendations are sent by mail to the farmers and in some cases there is also a discussion between the laboratory personnel and the local agricultural agent; at other times, the farmers come directly to the laboratory to obtain the recommendations. In one case, a guide sheet is given the farmer requiring that he work out his own recommendations. Usually the laboratory recommendations refer directly to the farmers' samples.

Cooperative educational program for the agriculturalists:

Only one laboratory reports that special explanation sheets are enclosed with the fertilizer recommendations to encourage good management, proper application of fertilizers, hazards that might be encountered, or to explain the meanings of test results and recommendations, but several of the laboratories do write a special letter of explanation to accompany each report. Some literature that describes or encourages soil testing is available in three countries. No studies related to a soil testing program have been made on the most effective information sheets, directions for taking samples, report forms, visual aids, types of summaries, or methods of acquainting farmers with soil testing programs and how they can benefit from them.

Two laboratories state that meetings have been held to discuss the objectives of a soil testing program with extension agents, but no such meetings have been held with the farmers themselves, nor are any visual aids available to help explain the objectives of good soil testing programs.

No surveys have been made to see if farmers understand and are following the recommendations of the laboratories. Only two laboratories make periodic surveys to determine the kinds of fertilizer materials available.

Two laboratories report that soil test summaries have been made. In one case the summaries state the areas that have been sampled; in the other case

the summaries have been broken down according to crop grown, plant nutrient status, pH, and the location sampled. None of the data have been put on cards for machine processing.

Research for Supporting the Soil Testing Program

None of the laboratories have performed experiments on the best methods of collecting farmers' samples nor have any experiments been done to determine the best methods of handling farmers' samples in the laboratory. No studies have been made relative to the forms in which plant nutrients occur in soils nor to their rates of release. A few comparisons have been made of the merits of analytical procedures and equipment used in analyzing farmers' samples. There have been a few studies of phosphorus fixation and two studies concerning the clay mineralogy of a few of the soils of the region. However, a majority of the important agricultural soils in each country remain to be studied. Greenhouse studies have been largely neglected. Very few studies of plant response to fertilizers in relation to soils at varying plant nutrient levels have been made in the greenhouses for the purpose of correlating these studies with soil test results. Most of the field trials that have been performed for the primary purpose of calibrating soil tests have been made in Mexico. This is not to say that field trials with different crops have not been made, for thousands have; however, few attempts have been made to correlate the results of the field trials with the soil test results and thus obtain a basis for making fertilizer recommendations for particular crops on particular soils. For a few of the trials it may be possible to use data gathered for soils that have been tested to see if a relationship exists.

Many of the areas in Middle America have had soil surveys at various scales. Some 300 soil surveys have been made in Mexico; these cover the northern part of Mexico very well, but quite a bit of work remains to be done in southern Mexico. Soil surveys completed in Central America are listed in the Inventario de Estudios Básicos sobre Recursos Naturales de Centro América, Publicaciones de la Secretaría Permanente de Tratado General de Integración Económica Centroamericana, Guatemala, June 1964. Many of the agriculturally important areas in all but one Central American country have been recently surveyed. El Salvador has been especially well covered. Panama has had soil surveys covering most of its important agricultural areas. Some of the laboratories report that different soil profiles have

been examined chemically and that some soil test analyses for these characterized profiles are available; physical analyses have also been done for a number of the characterized profiles. All of these analyses were done in conjunction with soil survey work.

Argentina, Uruguay and Paraguay

Arvel H. Hunter - Regional Director

In Argentina, Uruguay, and Paraguay interest is beginning to be generated in soil testing programs among all the various groups concerned with agriculture production. Commercial fertilizer companies and the better farmers are especially interested in having this source of information available to them. In fact, some commercial companies have been considering the possibility of setting up their own laboratory facilities, but apparently, up to this time, are convinced that what is really needed is a program sponsored through a governmental agency rather than just a soil analytical service. That greater agriculture production obtained under economic conditions is urgently needed is not questioned. The problem, of course, is how to attain this objective. On cultivated land that has no history of fertilizer additions, it is generally found that the lack of at least one plant nutrient element is the first limiting factor in crop production. For this reason, it is expected that fertilizer use will increase rapidly within the next few years. The rate at which this increased use of fertilizer will take place is largely dependent on how wisely and efficiently the materials are used.

Soil and Plant Analyses Laboratories visited:

ARGENTINA

Farmers Samples Tested:

Soil Section - Estación Experimental de Agricultura - Tucumán
Ing. Agr. Franco Fogliata; Ing. Agr. Pedro Aso

Instituto Agrotécnico Económico de Misiones - Posadas
Ing. Agr. Alfredo N. Offerman; Ing. Quím. Ernesto Moll;
Dr. Ladislao Benedek

Soil Research Laboratories

Estación Experimental Agropecuaria de Misiones - Cerro Azul, Misiones
Ing. Agr. Santiago R. Lassere; Ing. Agr. Ethel N. E. de Lassere

Estación Experimental Agropecuaria Colonia Benítez - Resistencia
Ing. Agr. Miguel A. Rios

Estación Experimental Agropecuaria de Tucumán - Tucumán

Ing. Agr. Roberto F. de Ullivari; Ing. Agr. Guillermo Kenning

Estación Experimental Agropecuaria Villa Alberdi, Villa Alberdi - Tucumán

Ing. Agr. Jalil Elias; Ing. Agr. Dimas Morin

Facultad de Agronomía de Tucumán - Tucumán

Dr. Francisco Han; Ing. Agr. Raman Zuccardi; Ing. Agr. Guillermo Fadda

Estación Experimental Agropecuaria de Cerrillos, Cerrillos - Salto

Ing. Agr. Alberto Pequin; Ing. Agr. Arturo Rojo; Ing. Dario Ulivarri

Facultad de Ciencias Agrarias Mendoza - Mendoza

Ing. Agr. Leon Nijensohn; Ing. Agr. R. Olmos; Ing. Agr. Manuel Avellaneda

Estación Experimental Agropecuaria Pergamino - Pergamino

Ing. Agr. Juan C. Musto

Estación Experimental Agropecuaria Mendoza - Mendoza

Ing. Agr. Rolando H. Wilke Braun

Instituto Edafología - Univ. del Sur - Bahía Blanca

Dr. M. Techapek

Instituto de Suelos y Agrotecnia - Buenos Aires

Ing. Agr. Jorge I. Bellati; Dr. Roberto V. Caravello

PARAGUAY

Laboratorio de Suelos (STICA) - Asunción

Ing. Agr. A. Bertoni; Ing. Agr. Nelson de Barros

URUGUAY

Facultad de Agronomía - Montevideo

Ing. Agr. H. Tobler Bottini

Centro de Investigaciones Agrícolas Alberto Boergen - Colonia

Dr. Ernest E. Reynaert

Laboratorio Químico "Azucarita" - Paysandú

Ing. Agr. R. Braun

General Observations

In this region there is a total of five laboratories which analyze farmers' soil samples for the purpose of giving some guidance to the farmer concerning the use of fertilizer or other soil amendments. Four of these are located in Argentina and one in Paraguay. In addition, there are about ten laboratories in Argentina and three in Uruguay which do some soil analyses for research purposes only.

Of the laboratories analyzing farmers' samples in Argentina, one is operated by a sugar company; one by a private institute; and two by provincial government experiment stations. The laboratory in Paraguay is now operated through the School of Agriculture.

The research laboratories in Argentina are operated by the Instituto Nacional Tecnica Agropecuaria (INTA). In Uruguay, the Ministry of Agriculture, the Facultad de Agronomía, and a sugar company (Azucarita) each have a laboratory doing some type of research.

The INTA organization in Argentina is primarily responsible for applied agricultural research for the whole country. INTA has one or more agricultural experiment stations in each of the provinces. Soil fertility research is presently being done in the following places: Famailla, Villa Alberdi, Cerrillos, Saenz Peña, Resistencia, Cerro Azul, Mendoza, Pergamino, Santa Fé, and Buenos Aires. Some fertility work on potatoes has been done at Balcarce, but at present the emphasis at that station is placed on cattle nutritional disorders as related to soil nutrient supplies.

The Ministry of Agriculture of Uruguay operated for sometime a laboratory in Montevideo which analyzed farmers' soil samples for the purpose of determining the fertility status of the soils. During the past year the personnel and equipment have been transferred to the Facultad de Agronomía for use in the soil classification program. The laboratory will not, at present, analyze farmers' samples, but will be doing chemical and physical determinations on the samples from the classification program for the purpose of characterization.

This information will be useful for a future soil testing service program, but no such testing program is anticipated in the near future.

A laboratory for the analysis of soil samples for farmers and for research has been functioning for some time under the direction of STICA in Asunción, Paraguay. This laboratory has not been well equipped and less than 300 samples are analyzed annually. At the present time a new laboratory is being constructed in Asunción at the Facultad de Agronomía, and it is expected that the functions of the old laboratory will be assumed by the new. Basic equipment will be available in the new laboratory.

In the laboratories of the three countries the number of laboratory technicians is equally quite small, 2 to 5 in most laboratories, but the INTA Research Laboratory in Buenos Aires has about 30.

All laboratories testing farmers' samples operate independently. The research laboratories of Argentina are all INTA controlled.

The Institute laboratories in Posadas, Argentina analyze plant tissue and fertilizer samples. A few laboratories also do some water analyses. The Azucarita laboratory in Uruguay is starting to analyze sugar beet tissue samples.

Direct appropriations or grants furnish most of the financial support. The laboratories have a service charge which partially covers the cost of the analysis.

From 7 to 10 determinations per sample are usually made. Of the laboratories doing farmers' samples, the number of samples per year ranges from 20 to 300. In research laboratories the number ranges from 100 to 3,000 samples per year.

For farmers' samples, the results are seldom available in less than 15 days; sometimes it requires as much as two months. In general, the time required for the analysis of research samples is from one to six months. If many samples were submitted to any of these laboratories, the time required would greatly increase.

Sampling: There appears to be a well organized and operating extension service in Argentina and, with the cooperation of this group, there should be no large problem with respect to obtaining representative samples. At present, practically nothing is being done with respect to soil sampling problems, except perhaps in a few localized areas where soil analyses is being done for farmers.

Two laboratories issue sampling instructions; however, only two laboratories have sample containers available. These are heavy paper or plastic bags. The farmer gets the container at the laboratory. Usually the depth of sampling for farmers' samples varies from 15 to 30 centimeters; plow depth is most common. For research purposes, the subsoil or the entire profile is sampled. Composite samples are always recommended. The maximum suggested area from which a composite sample is collected varies considerably but, as a rule of thumb, it is about 3 to 5 hectares. All commonly used sampling tools are recommended. The spade is most often used because of its availability. Samples for research are usually taken by the person working on the project, and the method varies, depending on the study. Apparently no training meetings for taking soil samples have been held in any of the countries. Three to five years are usually recommended to repeat sampling a field, but, in most instances, annual sampling is felt to be preferable. Where attention is given to the time of sampling, then preplant is preferred.

Most of the laboratories fill in some type of information sheet; at least two laboratories require quite detailed information. Usually the information sheets are filled in at the laboratory since the farmer frequently brings his own soil sample to the laboratory.

Laboratories: Most of the laboratories are now using either the Morgan or the Bray method of extracting available P & K. Colorimeters, flame photometers, and pH meters are available in each of the laboratories. There apparently is no special equipment in use for doing analysis of more than one sample at a time; thus, the number of analyses per man hour is very small.

The person in charge of the laboratory usually receives the soil sample and aids in filling out the information sheet. In most instances the samples are given a serial number. Usually the samples are air-dried at the laboratory. Samples may be left in original container or transferred to another; both practices are common. No special storage racks for soil samples were seen in any of the laboratories surveyed. Most laboratories hold samples for at least two weeks after the analyses are completed. Some hold samples as long as a year. At present, the volume of testing is not large enough that this presents any problem. No equipment for reducing dust in the laboratory was observed.

Mortar and pestle and rolling pins are common for use in crushing soil samples; none of the laboratories had a machine for this purpose. Screen size for screening soil samples varies from 1 to 2 millimeters, but 2 millimeters is most common. Usually the samples are not stored before they are analyzed. All laboratories visited are at present weighing the samples very carefully. None of the laboratories visited analyzed the samples in groups; each sample is handled individually.

Both equilibrium and leaching procedures are used in the analyses. The time of shaking varies considerably between laboratories using the equilibrium technique. None of the laboratories testing farmers' samples use clarifying agents. Perhaps the reason for this is that these are difficult to obtain. Commonly, a true control sample is not used. One or two laboratories use a control sample in every 10 to 30 samples. The instruments are generally checked with some standard solutions. Soil texture is usually determined either by feel or more commonly by the hydrometer method. In laboratories testing farmers' samples the per cent base saturation is not generally calculated. The most noticeable thing about sample preparation and analytical procedures is that it is all done the hard and slow way. No automation or special labor-saving devices were observed anywhere.

Analytical Procedures:

Nitrogen	The Kjeldahl method is most common
Organic Matter	Walkley-Black method usually used
Phosphorus	Bray #1 is probably most common, but Morgan and Olsen extractions are also used
Potassium	Ammonium acetate or Morgan method most commo
Calcium and Magnesium	EDTA titration after extraction with water or K extracting solution
pH	Usually measured by glass electrodes using from 1:1 to 1:5 soil-water ratio
Lime Requirement	Usually obtained by addition of calcium carbonate in increments; equilibrated for a few hours and pH measured
Cation Exchange Capacity	Usually obtained by one normal ammonium acetate method
Soluble Salts	By Wheatstone bridge
Boron	By water extract
Aluminum	Not usually measured

All the laboratories seem to have the basic instruments necessary for a soil testing program. The major need is equipment for running samples in groups, such as automatic pipettes, trays, racks, etc. None of these items were found in any of the laboratories.

Interpretation of Results: At present in Paraguay, the interpretation of soil test results is performed by competent agronomists who base their interpretation on data from both local agricultural experiment stations and from other areas of similar soils. Of the laboratories in Argentina and Uruguay which are analyzing farmers' soil samples, the interpretations given to the farmers are based largely on experimental results obtained in other countries or areas where the methods are in common use. This, of course, is necessary where there is a lack of local data. It may be that the information from other areas is directly applicable to the local situation but more work is needed to be sure of this.

Results are generally reported in me. 100/g., but some are reported as percentage of dry soil. On the report to farmers the results usually are given as low, medium or high, or normal. Three to four separations are usually made relative to the fertility status of the soils. Usually some fertilizer is recommended even at high levels; this is a maintenance application. Crop differences and other soil properties are considered in the recommendations but more in a haphazard way than by a systematic consideration.

Recommendations: The person in charge of the laboratory usually makes the recommendations. When the recommendations are written, a copy goes to the farmer and a copy to the file. Copies of the recommendations are available to fertilizer companies upon request. In making the recommendations it is generally assumed that the farmer has average managerial ability. The common practice in recommending fertilizers is kilograms per hectare of a certain material which is available in the area.

Fertilizer recommendations are aimed at overcoming deficiencies and then maintenance applications. In making fertilizer recommendations, phosphorus fixation is considered only in a general way because not much has been done to determine phosphorus fixation of the soils. No guide sheets for interpreting the laboratory results and for making recommendations were seen in any of the laboratories. Sources of fertilizers are often specified because of a lack of knowledge by farmers of fertilizer materials. Recommendations for time and method of application are frequently included with the reports. No supplemental tests in addition to soil tests are made to aid in preparing fertilizer or lime recommendations; a general knowledge of the area, however, is brought into consideration. No special recommendations are made for specialty crops.

Follow-up Educational programs: At the present time there is little or no planned follow-up educational program for farmers or extension personnel with respect to soil fertility.

The person in charge of the soil testing laboratory is usually well aware of what fertilizer and liming materials are available. However, he is not always well informed as to their value as a fertilizer. For instance, where new products of questionable quality are placed on the market, the person making recommendations would not be familiar with their value as a fertilizer since no research has been done in the area on these materials.

There is no local literature available relative to soil testing. Although there is much interest in "visuals" for use in educational programs in soil testing-soil fertility, none are available at present.

The number of soil samples tested is so small, no summary has been prepared of the results.

Research: In Argentina the facilities for soil fertility research are mostly quite adequate. The real problem and barrier for increasing this work is the lack of trained personnel.

INTA presently has about six soil analytical laboratories which are doing analysis connected with soil research studies. The large laboratory at the Agricultural Research Station in Buenos Aires is concerned primarily with soil analyses for characterizing the soils chemically for the soil classification program. The laboratory at Resistencia will also be used primarily for chemical characterization of soils. The laboratories at Mendoza, Villa Alberdi, Cerro Azul, and Resistencia are engaged in analysis related to soil fertility problems.

Most of the fertility work has been originated within the last 3 to 4 years at both INTA and the Provincial Stations. Very little of the soil fertility research being done has been specifically designed for the purpose of correlation with chemical analysis of soils, but, of course, the data will be useful for recommendations.

Argentina and Uruguay now have a rather ambitious program for soil survey and classification. Chemical analyses for characterization of the soils is being done in these two countries. In Paraguay, a general survey has been made with the soils being classified into the great soil groups.

An INTA group in Buenos Aires has recently started to classify and map the agricultural soils of Argentina. This project will require considerable time but is progressing well. A cooperative INTA and FAO project is presently making a land use classification map of some areas near Resistencia. There is also a chemical characterization of agricultural soils near Tucumán being done by a group at the University of Tucumán.

Recently, with the help of Iowa State University, The Facultad de Agronomía in Uruguay began a program of classification and mapping of the soils of the country. This program is making good progress and, when completed, will furnish a very helpful inventory of soil resources of the country.

A number of field fertility trials have been conducted in Argentina on such crops as potatoes, wheat, and corn, and some trials are in progress on a few other crops. In Paraguay a few fertility trials have been run at the Experiment Station; none have been done off the station. In Uruguay some field trials on wheat and soybeans have recently been conducted.

In Uruguay very little soil fertility research has been done in the past. At present some work is being done at the Experiment Station at La Estanzuela mostly on wheat. The Plan Agropecuario group is doing some studies on the fertilizer requirements for establishing improved pastures. A few experiments related to fertility requirements have been done at the Facultad de Agronomía.

A limited amount of soil fertility studies have been carried on in Paraguay for the past several years. Those fertility experiments have been carried out on the Experiment Station at Cascupe which apparently has soils that would be similar to much of the area now being cultivated in the country. The fertility experiments which have been done appear to be well planned and conducted so as to give reliable data. Since no research has been carried out in other parts of the country, it is not known how representative the data may be for the soils in general. No specific work was being done on soil sampling in any of the countries. Most of the laboratory studies were in the form of plans for future work.

A few publications relating to some of the seven phases of a soil testing program have been prepared in Argentina but very few are available in Uruguay and Paraguay.

Very few greenhouse studies have been made in any of the three countries since greenhouse facilities are not readily available.

No studies have been made relative to cost of operating a soil testing laboratory.

Very little attention has been given to training of any kind in connection with soil testing. There is a very definite shortage of trained people for doing soils research and also funds for this work are in very short supply.

Brazil

Robert B. Cate, Jr. - Regional Director

It is difficult to present an up-to-date picture of the status of soil testing in Brazil because the country is so large and complex, and because the situation is constantly changing. The rate of change has been accelerated by the mere attempt to gather the following data, since the pointed questions used have provoked innovations. However, this summary probably reflects fairly accurately the situation as it existed at the end of 1964.

Soil and Plant Analyses Laboratories visited:

About 31 soils laboratories exist in Brazil, most of which test farmers' samples at least occasionally. These laboratories are distributed as follows:

SOUTH

1. Instituto de Pesquisas o Estudios Agropecuários do Sul, (IPEAS) Pelotas, Rio Grande do Sul
2. Secretaria de Agricultura, Porto Alegre, Rio Grande do Sul
3. Instituto Rio Grandense de Arroz, Porto Alegre, Rio Grande do Sul

4. Companhia Rio Grandense de Adubos, Porto Alegre, Rio Grande do Sul
5. Companhia Cervejaria Brahma, Porto Alegre, Rio Grande do Sul
6. Secretaria de Agricultura, Florianópolia, Santa Catarina
7. Secretaria de Agricultura, Suritiba, Paraná
8. Secretaria de Agricultura, Jacarézinho, Paraná
9. Escola de Agricultura, Apucarana, Paraná

CENTER SOUTH

10. Instituto de Pesquisas o Estudos Agropecuários de Centro Sul (IPEACS) Kilometer 47, Estado do Rio de Janeiro
11. Instituto Agronómico (Setor de Análise de Terra), Campinas São Paulo
12. Instituto Agronómico (Setor de Agrogeologia), Campinas, São Paulo
13. Escola de Agronomia Luiz de Queiros, Piracicaba, São Paulo
14. Edaphos Laboratório Agrotécnico, Parque Dom Pedro Segundo, 1092, São Paulo, SP
15. Cooperative Agrícola de Cotia, Rua Cardeal Arcoverde, 2539, São Paulo, SP
16. Instituto de Pesquisas IRI, Fazenda Boa Vista, Matão, São Paulo
17. Cooperativa dos Usineiros de Oeste do Estado de São Paulo, Caixa Postal 695, Ribeirão Preto, São Paulo
18. Divisão de Pedologia e Fertilidade do Solo, DPEA, Ministério de Agricultura, Rua Jardim Botanico, 1024, Rio de Janeiro
19. Secretaria de Agricultura, Industria e Comércio, Alameda São Boaventura, 770, Niterói, Estado do Rio de Janeiro

CENTER WEST

20. Instituto de Pesquisas e Estudos Agropecuários de Centro Oeste (IPEACO) Sete Lagoas, Minas Gerais
21. Secretaria de Agricultura, Belo Horizonte, Minas Gerais
22. Universidade Rural de Estado de Minas Gerais, Giçosa, Minas Gerais
23. Instituto de Química John H. Wheelock, Escola Superior de Agricultura de Lavras, Lavras - Minas Gerais
24. Secretaria de Agricultura, Goiania, Goiás

EAST

25. Instituto de Pesquisas e Estudos Agropecuários de Leste (IPEAL) Cruz das Almas, Bahia

NORTHEAST

26. Instituto de Pesquisas e Estudos Agropecuários de Nordeste (IPEANE) Recife, Pernambuco
27. Grupo de Irrigacão de São Francisco, SUDENE, Jozaeiro, Bahia
28. Secretaria de Agricultura, Recife, Pernambuco
29. Departamento Nacional de Obras Contra Secas, Sousa, Paraíba
30. Escola de Agronomía, Fortaleza Ceará

NORTH

31. Instituto de Pesquisas e Estudos Agropecuários do Norte (IPEAN), Belém, Pará

There are several other laboratories in Brazil which are either nascent or dormant, but it is believed the above list comprises all laboratories currently active in soil analysis.

A summary of these laboratories with approximate cultivated areas is:

South (Rio Grande do Sul, Santa Catarina, Paraná)	- 9	(8.3)*
Center-South (São Paulo, Estado do Rio, Guarabara)	10	(5.6)
Center-West (Minas Gerais, Goias, Mato Grosso)	- 5	(5.1)
East (Bahia, Sergipe)	- 1	(2.5)
Northeast (Algoas, Pernambuco, Paraiba, Rio Grande do Norte, Ceará, Piauí, Maranhão)	- 5	(6.8)
South (Pará, Amazonas, and the Territories)	- 1	(0.4)

These 31 laboratories are operated by the following entities:

Ministry of Agriculture (DPEA)	7
Universities	3
Commercial concerns	3
Cooperatives	3
State Secretaries of Agriculture	10
School of Agriculture	2
Miscellaneous (SUDENE, DNOCS, IRI)	3

General Observations

The number of laboratory technicians employed varies from two to sixteen. These two extreme cases analyze about the same number of samples annually.

*The figures in parentheses represent rough estimates of the amount of cultivated land in each region, in millions of hectares (based on 1960 census data).

Since labor is the principal expense in soil testing laboratories, it can be seen how the cost per sample varies greatly. Incidentally, both of these laboratories analyze primarily farmers' samples; the one with only two technicians is a commercial operation, which charges for its services, while the other is a state laboratory which does not charge.

With the exception of the Ministry of Agriculture's net of seven, most of the laboratories operate independently.

Eighty per cent or more of the laboratories do only soil analyses, but the remainder perform a wide variety of tests, with plant analyses being the most common. About 17 of the laboratories test only farmers' samples.

Direct appropriations are the principal support of most laboratories, including the majority of those which charge for their services. Eight charge for testing soil samples, ten do not, and information is lacking for the other laboratories.

Five laboratories claim to do more than 2,000 farmers' samples per year (Pelotas, Porto Alegre State Laboratory, Belo Horizonte, Edaphos, and Campinas, which does 6,000), while three claim over 2,000 research samples (Pelotas, Campinas and IPEANE-Recife). In total fertility samples, Pelotas and Campinas are very close, with Campinas probably ahead if its three laboratories are combined. In terms of total individual determinations, the IPEANE laboratory possibly ranks with the other two. Probably 80% of the laboratories average less than 1,000 samples per year.

Probably only one laboratory (Edaphos) gets its result out in less than ten days after receipt of the soil samples. A few others may do it in less than 20 days, but the average is usually well beyond 20.

The daily capacity of most of the laboratories, under pressure, is about 20 samples. With 250 working days per year, this means that Brazil, theoretically, has a current capacity of about 150,000 samples per year. Actually, the current production of all types of soil samples is probably about 30,000 to 35,000 of which about 20,000 are for farmers. Current modernization operations in Rio, Campinas, Rio Grande do Sul, and Recife will soon provide a combined capacity much greater than that of all of the other laboratories put together, and several other laboratories will probably also be modernized in 1965. Capacity and production are not the same, but capacity is essential for prompt service, which in turn, is needed to encourage farmers to send in samples. These figures are cited to give an idea of how the scale of operations is changing approximately by an order of magnitude--which means that soil analysis should soon no longer be a major bottleneck in the national soil fertility program.

Sampling: At least 15 laboratories have sheets available giving instructions on how to take farmers' samples. At the present time, no laboratory is known to provide sample containers for submitting soil samples. Practically all farmers' samples are taken by the farmer himself. Recommended sampling depth varies from 15 to 30 cm. with little agreement. Few laboratories suggest subsoil sampling. In general, composite samples are recommended, although several laboratories fail to do so. Some suggest maximum areas, but these vary widely. Most laboratories suggest the use of a spade or similar tool for sampling. Only one or two laboratories have held training meetings on taking soil samples. Frequency of sampling is very seldom specified, but a majority feel that sampling should be done annually. The time of the year to sample is likewise seldom specified.

The laboratories which provide sampling instructions also require information sheets. Usually these are not filled in at all well. Most farmers' samples are submitted to the laboratory by the farmer himself.

Laboratories: Probably all the laboratories give serial numbers to their samples. Most laboratories air-dry the samples. Only a few laboratories have storage racks and trays for samples. Sample retention time after testing varies greatly. Probably a majority hold samples for possible rechecks, but probably none consider using these as a research reserve. No laboratoires were observed to use a hood to reduce dust during sample preparation. Most laboratories use a wooden rolling pin to crush samples. Some use a mortar and pestle. No mechanical crushers have been seen. Most of the laboratories use 2 mm. as the maximum size limit, with most discarding that which is not readily crushed. Notes are not normally taken on the nature of the discarded portion.

Samples are probably never intentionally stored before analysis, even though this technique may be useful in standardizing certain determinations, e.g., NO_3. So far as is known, only the Pelotas and Rio laboratories use volume measurements. Equilibrium and leaching procedures are about equally used. Few laboratories use clarifying agents, such as activated charcoal. Control samples are not used, except casually. Very few laboratories determine texture on farmers' samples. Percentage base saturation is usually calculated on the basis of cation exchange capacity being the sum of basic cations plus the acidity extracted by 1 N calcium acetate. Salts and carbonates are determined on farmers' samples except occasionally in the Northeast. Analytical procedures used generally are those followed by the Rio, Campinas or Pelotas laboratories.

Analytical Techniques for Farmers' Samples

Nitrogen	Somewhat more than half of the laboratories determine nitrogen on farmers' samples. Most use a normal Kjeldahl procedure, with a few using semi-micro techniques and at lease two use diffusion to collect the ammonia.
Organic Matter	Most laboratories get a figure for organic matter on farmers' samples. Some use dry combustion, some use Walkley-Black methods, and some multiply N x 20.
Phosphorus	Probably most laboratories extract P with 0.05 N H_2SO_4 - 25:1. Ratios may vary, and at least two laboratories use Mehlich's extractant, with different ratios. Probably all of these give approximately the same results, since the low-medium split is at about the same point. A few laboratories use the modified Truog method. The Bray No. 1 method is used on survey samples in Rio, but it disperses many samples so, probably it will be abandoned. Most laboratories use a molybdenum blue method, with a great variety of colorimeters.
Potassium	The most common extractant for K is .05 N HNO_3, although a few laboratories use ammonium acetate and at least two use the Mehlich extract. Almost all measure with flame photometers, of a variety of makes.
Calcium and Magnesium	Are usually measured on the K extract, using EDTA.
pH	Is usually measured with a water-soil ratio of 1:1 or 2.5:1 using a wide variety of glass electrode potentiometers.
Lime Requirement	Is usually calculated on the basis of equivalence with the acidity extracted by 1 N calcium acetate. The Niterói laboratory has developed a kit, using 3 lime tablets and an indicator, which is distributed commercially.
Cation Exchange Capacity	Is usually determined by summation of bases plus calcium acetate acidity.
Aluminum	Several laboratories measure the acidity displaced by 1 N KCl and this extractant has wide theoretical acceptance in Brazil.

Physical Equipment: Essentially all of the laboratories are adequately supplied in terms of space, utilities, and electronic equipment, but most need mass production labor-saving devices of the following categories (among others):

Sample drying and storage cabinets with trays
Sample crushing machines
Solution dispensers, aliquoters, etc.
Multiple washers

Laboratory staff is usually adequate for the foreseeable future, but more agronomists and secretaries will be needed for an expanded program.

Interpretation: Probably all laboratories record their results in terms of milliequivalents per 100 grams or similar values. Usually the results are interpreted for the farmer in terms of low-medium-high or a similar breakdown, using a relatively arbitrary table. Possible crop differences are seldom taken into account in the use of these tables. In general, the low-medium split is at the point where responses drop off sharply, i.e., the "critical level", but fertilizer is still recommended for medium soil. For high, practices are highly individual, even within the same organization.

In theory, crop differences climate, soil types, topography, etc., are considered in making interpretations, but this is not done systematically.

Recommendations: With the exceptions of Campinas and Cotia, and possibly a few others, the fertilizer recommendations are made by laboratory personnel, usually agronomists. Usually only the farmer receives the report, occasionally the extension agent, and very seldom the fertilizer company. In practice, however, the farmer often goes to the fertilizer salesman for interpretation. Virtually all of the laboratories assume "ideal" management in making their recommendations, i.e., these are based on direct extrapolation from research field trials.

Fertilizers are usually recommended both as N-P_2O_5-K_2O and in terms of locally available materials. Fertilizer recommendations are usually designed to overcome a measured deficiency, or maintain an adequate level of the nutrient element. Most laboratories have been surprised at the suggestion that this is not necessarily the same as calculating a profitable annual response. In fact, although there is much talk about economics, there is very little direct linking of recommendations to responses to profits.

Lime recommendations are generally recognized as weak. Where a system exists, it is usually on the basis of partial or complete liming of the "H and Al" extracted with calcium acetate. Frequency and maximum rates are highly variable and subjective.

Fixation of P and K are probably never really taken into account.

Animal and green manure contributions of NPK are usually not formally considered, although they may be recommended as supplementary practices to raise organic matter. Topdressings of N are often recommended. Otherwise, specific suggestions regarding application methods are rare and variable.

Tissue tests and deficiency symptoms are only sporadically used in conjunction with fertilizer recommendations. Special tests, such as salinity for greenhouse soils, are seldom, if ever used.

A few laboratories recognize the desirability of having guide sheets for systematic interpretations and recommendations.

Follow-up: So far as is known, no visual aids are used in Brazil to promote the soil testing program, except the well-designed posters in the Ribeirão Preto Area. Several laboratories have produced literature encouraging soil testing, but much remains to be done. Educational material is virtually never included with soil test results that are sent to the farmer.

Only a few meetings have been held to explain the program and test results. Most laboratories try to keep informed as to the fertilizer materials locally available. Probably no formal surveys have been made as to the use and understanding of the soil test reports and recommendations.

Rio Grande do Sul, Minas Gerais, and the Estado do Rio have summarized some soil test data in the form of maps, but probably only São Paulo has sufficient data to warrant this type of activity. Dr. Gargantini is currently working on this matter, using data from about 100,000 samples.

Research: A little work has been done in São Paulo on the sampling problem, such as depth, number of samples, etc., but this remains a weakness. Probably no formal studies have been made on the effects of sample handling on test results.

Several inconclusive studies have been made on extractant comparisons, fixation, etc., but the field has only been scratched.

Some greenhouse studies have been run, but this aspect has been greatly neglected. Thousands of field trials have been run, but correlation with soil analyses has seldom been achieved. This situation is now changing, and much useful data is being obtained, particularly in São Paulo.

Reconnaisance-level soil survey maps (showing great soil group associations) are available for perhaps 50 per cent of the "intensely cultivated" lands of Brazil and exploratory-level maps are available for most of the rest of the cultivated land.

Several laboratories have attempted to calculate analysis costs, but these efforts have been vitiated by the extreme inefficiency of most of the laboratories.

Probably no formal studies have been made of the effectiveness at the various means of communication, e.g., forms, visual aids, etc.

So far as is known, no formal plans have been made for advanced training in the field of soil testing except by U. S. Universities having AID contracts in Brazil.

Foliar Analysis: Although considerable interest exists, very few foliar analyses are being done for farmers at the present time.

Fertilizer Use: The available information on this subject has been summarized in the report by Agr. Research, Inc., "Economic and Technical Feasibility of Increased Manufacture and Use of Fertilizers, Agricultural Limestone and Livestock Minerals in Brazil." A flaw in the economic side of this book is that fertilizer response data has been averaged.

Bolivia, Ecuador and Perú

D. L. Waugh - Regional Director

Soil testing has been done for several years in Bolivia, Ecuador, and Perú, with the forms of and purposes for soil analyses varying from laboratory to laboratory. Most of the laboratories, however, were established primarily to carry out analyses associated with soil characterization and research. In the process of operation, the laboratories eventually encountered requests from farmers to make some soil tests, and in this manner all of the laboratories have become involved in the testing of farmer samples as a service. In general, the laboratories have assumed the role of doing whatever kind of analyses seem to be in demand, perhaps even to the point of carrying out some analyses that have little significance in fertilizer recommendations or that cannot be effectively interpreted. A well developed soil testing program, based on adequate research information and designed especially for the purposes of encouraging widespread sampling, evaluating soil fertility, and making fertilizer recommendations, is yet to be realized.

Soil and Plant Analyses Laboratories visited:

BOLIVIA

In Bolivia soil testing is being done by two laboratories.

Laboratorio de Suelos, Ministerio de Agricultura, La Paz

Head of Soil Testing: Dr. Fernando López Gallardo

Estación Experimental Agrícola "La Tamborada", which is operated by La Universidad Mayor de San Simón on contract with the Ministerio de Agricultura, located at Cochabamba.

Head: Laboratorio de Suelos - Ing. José Amurrio R.

ECUADOR

Three laboratories test farmer samples in Ecuador:

Departamento de Química Agronomía y Suelos, Facultad de Agronomía Universidad Central, Quito

Head: Dr. Julio Peña Herrera

In charge of tissue testing: Ing. Víctor Hugo Alvarez

Departamento de Suelos, Ministerio de Agricultura, Quito

In charge of the Laboratorio de Edafología:

Ing. Beatriz Hidalgo de Mena and Dra. Laura M. Iza G.

Centro Reconversión Economía Azuay-Cañar y M. Santiago, Cuenca

Head: Laboratorio de Análisis de Suelos - Dr. Nelson Delgado Ochoa

(In addition, a laboratory at the Pichilinque Experimental Station has done some tissue testing in their work with coffee.)

PERU

There are almost a dozen laboratories in Peru which analyze soil samples, some for research and some for farmer samples. So many changes in operation, directorship and functions of some of the laboratories have taken place that a general summary can represent only the status at the time of the survey.

Laboratories operated by Servicio de Investigación y Promoción Agrícola (SIPA) Ministerios de Agricultura:

Estación Experimental Agrícola de la Molina, Lima

Head: Departamento de Suelos - Ing. Carlos Valverde S.

Estación Experimental Agrícola de Lambayeque, Lambayeque

Head: Laboratorio de Suelos - Ing. Miguel Carmen-Cuba

Laboratorio de Química y Suelos, División Fomento, Arequipa

Head: Ing. Gladys Soto de Velásquez

Laboratories operated by Agrarian Universities:

Departamento de Suelos, Universidad Agraria de La Molina, Lima

Head: Ing. José Estrada

Departamento de Suelos, Facultad de Agronomía, Universidad Agraria del Norte, Lambayeque

Head: Ing. Jorge A. Mercado L.

Departamento de Suelos y Química Agrícola, Universidad, ICA

Head: Ing. Marcelino Damian Suárez

Commercial Laboratory operated by "Abonos Completos", fertilizer company near Lima.

In charge of Soil Testing: Ing. Sven Villagarcia and
Ing. Ricardo Pineda

Three laboratories in the process of development or redevelopment at the Agrarian Universities in Tingo Maria, Puno, and Piura.

Several private or Agricultural Association Soil Laboratories.

General Observations

The number of technicians varies from 2 to 6, with most laboratories employing one or more helpers in addition. In some cases the laboratory director serves as a technician, especially where the supply of trained technicians is insufficient.

All of the laboratories surveyed operate as individual units, although the SIPA laboratories in Peru have some interchange of program.

With the exception of the Central University in Quito, which has a rather well developed program of tissue testing, most of the laboratories test only soils on a routine basis. All of the laboratories, however, do, on occasion or fairly regularly, test plant tissue, water, and various other agricultural products.

Direct appropriations support all of the laboratories. In some cases charges are made for the analysis but, if all costs are taken into account, the laboratories are not self-supporting. At the time of the survey, the charges for testing at most of the laboratories were high enough to be out of the range of a majority of the small farmers who might use the soil testing service.

The two laboratories in Bolivia have been testing about 2,000 samples a year, while the three laboratories in Ecuador test on the order of 3,000 samples a year. In both countries a part of these analyses are for research samples. All the laboratories in Peru together test between 2,000 and 3,000 samples per year for farmers and research projects. Not any of the laboratories surveyed are designed for high capacity in numbers of samples they can test per day.

All of the laboratories surveyed have difficulty in getting results back to farmers in less than two weeks, on a sustained schedule. Most of the time it takes considerably longer. The two reasons for this delay are: (1) the fact that many laboratories mix research work with testing farmer samples and cannot get at the samples immediately, and (2) the fact that all laboratories experience rush periods and do not have the facilities necessary to handle samples in large numbers.

The daily capcity of all laboratories is much too low for an effective soil testing program. A number of laboratories claim to be able to analyze 20 samples per day, but actual production is probably less. A satisfactory sustained rate of analysis is also difficult to achieve due to the number of non-working days and problems in getting repairs and materials when needed.

Sampling: All the laboratories have instruction sheets available describing how to take samples, but no real effort is made to distribute these sheets and promote soil testing. The limiting factor, again, is that the laboratories could not handle more samples with their present capacity.

Only one laboratory has sample containers which are available to farmers for sending in soil samples, although several other laboratories have models of a sampling container which they expect to develop for this use.

With regard to the actual taking of samples there is no set pattern except to say that anyone and everyone takes them. The SIPA laboratories in Peru try to encourage farmers to use the Extension Service in taking samples by offering a special analysis price for these samples. The Universities in Peru, Ecuador, and Bolivia often do the sampling themselves, as does the fertilizer company in Peru, "Abonos Completos:. The rest of the samples are taken by farmers, usually without instructions, and brought to the laboratory.

The instruction sheets of all the laboratories recommend that composite samples be taken, but all expressed doubt as to how well this recommendation is followed. Two of the laboratories in Ecuador recommend I hectare as the maximum area to include in one sample, while the laboratories in Peru and Bolivia recommend up to 5 hectares. Tools used to take samples vary widely but the spade is the most commonly used.

There have been no meetings held by any of the laboratories to explain and promote soil testing, although the Extension Service of the Ministry of Agriculture in Ecuador and of SIPA in Peru have made some mention of soil testing in their meetings. In most cases the laboratories depend on explaining and promoting soil testing through personal contacts with farmers who come to the laboratory.

About half the laboratories suggest soil testing on an annual basis, while the other half of the laboratories adopt the philosophy that when there are problems in production the soil should be tested. Time of sampling is left pretty much up to the farmer, which in most cases means the samples are taken just before planting. This time of sampling means the majority of the samples in the mountain areas are taken near the end of the dry season and are sent to the laboratory in a dry state.

The three laboratories in Ecuador and several in Peru have information sheets which are to be filled out when the sample is taken; only about half the time are the sheets properly used. Probably about half the samples are sent to the laboratory by extension agents or by laboratory representatives, while half are brought to the laboratory by the farmers themselves.

Laboratories: Most of the laboratories use some sort of serial numbers for the samples which are received for analysis. All the laboratories air-dry the samples. All the laboratories have storage racks for samples. None of the laboratories use trays and racks to analyze samples in groups by means of automatic pipettes, aliquoters and washers. Each of the laboratories holds the samples for a time following analysis, usually just long enough to be sure a recheck is not needed. Storage capacity for samples which have been tested in general is small. Not any of the laboratories have a sample preparation room equipped with hoods to remove dust. Most of the laboratories use a wooden rolling pin to crush the samples prior to sieving. One laboratory, Central University in Quito, has a mechanical crusher. All laboratories also use a mortar and pestle for some soils. After crushing, the soils are passed through a 2 mm. screen with the portion larger than this particle size being discarded. Notes on the discarded portion are not usually taken. Samples are not intentionally stored in any of the laboratories before analysis.

Most of the laboratories use weight measurements of samples for analysis rather than volume measurements. All of the laboratories use an equilibrium extraction procedure, and one laboratory reports that it uses leaching as well. All but two of the laboratories are using a charcoal clarifying agent, such as Darco 60. Control samples are not in use in any of the laboratories on a routine basis, that is, samples of soil which have been established as a standard against which the procedure is tested. All laboratories do use reagent blanks, but not with regularity.

Most of the laboratories determine texture by the Bouyoucos method, and often this is included as part of the routine analysis. Percentage base saturation is not determined on farmer samples. Soluble salts are determined on soil samples in all the laboratories on a routine basis, in many cases. Carbonates are sometimes determined on a special test basis.

Analytical Techniques for Farmers' Samples

Nitrogen	About half of the laboratories are making nitrogen determination on farmers' samples, using the Kjeldahl procedure.

Organic Matter	All but two of the laboratories make a determination for organic matter, usually with the Walkley-Black method.
Phosphorus	Two laboratories use soil testing kits, 7 use the Olsen extraction, and the other 3 use the Peech extraction for phosphorus. The soil-solution ratio used with the Olsen method is 1:20 in each case, and the ratio used with the Peech method is 1:5. All laboratories have colorimeters of various makes and models for the determination of P.
Potassium	The Ministry Laboratory in Bolivia, the laboratory in Cuenca, Ecuador, and about half of the laboratories in Peru extract with NaO Ac, pH 4.8 and determine the K turbidimetrically; the other laboratories in Peru and the two in Quito, Ecuador, extract with dilute acids or NH_4O Ac pH 7.0 and determine K with flame photometers.
Calcium and Magnesium -	are not included in the routine procedure of most of the laboratories, although all the laboratories make these analyses at times. The most common extractant is ammonium acetate with flame photometer determination. Two laboratories in Ecuador extract with weak acids and determine Ca and Mg with flame photometers
pH	All the laboratories determine pH with potentiometers, using soil solution ratio of 1:1, 1:2.5, and paste.
Lime Requirements -	are not determined by any of the laboratories.

Cation Exchange Capacity is determined only on research samples.

Aluminum is not determined by any of the laboratories.

Soluble Salts	All of the laboratories determine soluble salts with a salt bridge, using a saturation extract.

Physical Equipment: The greatest limiting factor in all of the laboratories attempting to handle farmer samples is a lack of mass-production techniques and apparatus. In addition, some laboratories are confined to space which is not suited to service analyses. Most of the smaller laboratories, although lacking physical facilities for service analyses, could devote their efforts to basic

research rather easily. The University laboratories, especially, are reasonably well equipped with sensitive instruments suitable for research work, but poorly equipped with rugged equipment needed for constant routine work. Each country needs to specialize some laboratories to handle samples for farmers and others to assume their responsibility of research and education.

Laboratory staffing: There is a shortage of technicians in all three countries. However, Peru and Ecuador have a sufficient number of scientists to operate a strong program of soil testing, including both the research and service analysis phases.

Interpretation: All of the laboratories making readings with instruments record the test results as milliequivalents per 100 g., lbs. per hectare, or similar readings. Laboratories reading from color charts usually read as low, medium or high.

A great variation of reporting systems are used in getting the results to farmers. The laboratories using standard forms usually list a laboratory reading and provide a scale to show how to interpret the value, then complete the form with a recommendation. At least half of the laboratories report to farmers orally, with the agronomists explaining the results.

The results are classified as low, medium, and high in most interpretations and as many as 5 divisions in others, especially for nitrogen. Generally, the laboratory employs the interpretation scale prepared by the person who developed the analytical procedure which they are following.

Recommendations: In all cases the recommendations are made by an agronomist or laboratory director. At least half the time in Peru, the recommendations are made orally when the farmer visits the laboratory. The reports, when written, are sent to the farmer and one copy kept in the laboratory.

The level of overall management is always considered to be better than average when the recommendations are made, since largely the more progressive farmers are having their soils analyzed.

Fertilizers are recommended as pounds of a certain fertilizer grade; most recommendations are for materials rather than mixed fertilizers, even though a great variety of complete fertilizers are available.

The rate of fertilizer generally recommended is aimed at developing and maintaining adequate levels of nutrients in the soil, rather than overcoming deficiencies. Furthermore, farmers using fertilizers are primarily concerned with maximum yields.

Lime recommendations are not made in Bolivia or Peru, and very seldom in Ecuador. Little, if anything, is known about the response in the soil being tested for lime requirements due to the lack of research. This is due primarily to the fact that most soils tested come from calcareous soils of the coast and mountains. Very few soils from the higher rainfall areas have been tested or studied.

Fixation of phosphorus and potassium generally are not taken into account in the recommendations, as little information is available on which to make adjustments.

Use of animal manures, green manures, and legumes in the rotation are encouraged and some allowances are made for the fertility contributed from these sources; fertilizer recommendations are adjusted accordingly.

None of the laboratories visited had formal guide sheets from which recommendations are made; usually the agronomist weighs the considerations mentally and makes a recommendation on the basis of the test results and the crop to be grown.

Instructions on time and placement of fertilizer are suggested by all of the laboratories, although much more explicit instructions are available for N than for P and K.

Probably the only laboratory that uses tissue tests effectively in conjunction with soil tests for fertilizer recommendations is the Central University in Quito. The other laboratories, of course, use deficiency symptom information if it is available. No doubt, the laboratory handling the most soil samples from garden or florist greenhouses is "Abonos Completos", a fertilizer company near Lima.

Follow-up: Most of the laboratories have a limited amount of educational material on hand which is available to farmers who come into the laboratory, but in most cases such materials are not mailed out with the soil test results. Visual aids to promote soil testing are limited to pictures accompanying information on crop production. No slide sets or films are in use by the laboratories themselves. A limited amount of literature is available to promote soil testing, but to date no program of mass distribution has been attempted because of limited facilities to handle samples.

The only educational meetings held on the subject of soil testing have been conducted by the Extension Service of the countries, and these were included with other programs rather than being developed separately.

Most laboratories keep informed of the fertilizer materials available.

The laboratories get some idea of the degree to which recommendations and reports are used and understood by the discussions with farmers who come in. Otherwise, no formal surveys have been made to compile such information.

To date maps showing trends of soil test data have not been prepared.

Research: None of the laboratories have carried out studies to determine how to take representative soil samples. All laboratories use a patterned or random sampling technique with a number of cores in a composite sample.

Handling of soil samples has not been studied to determine the effects on soil test results; for example, drying, sieving, mixing, etc.

Several studies on the extraction procedures best suited for the soils being tested have been initiated by the La Molina SIPA laboratory, the Agrarian University at La Molina, and the Cochabamba laboratory in Bolivia. Very little information is yet available from these projects, however,

No greenhouse studies have been done by any of the laboratories, simply because of a general lack of greenhouse space. However, several greenhouses are either now operating or being built at the Agrarian University in Lima and at the University of Puno in Peru, and at the two laboratories in Quito, Ecuador. Soil test correlation, fixation, release of nutrients, and other studies are being initiated.

Perhaps field studies are the strongest phase of the research program in these countries. Most of the laboratories have been conducting fertilizer experiments for several years. This data is now being pulled together for correlation with soil analysis, although in many cases no soil tests are available from the field plots.

Many years will be required to complete the detailed level desired for soil surveys of all land under cultivation. Bolivia, Ecuador, and Peru have a very limited amount of detailed mapping completed although such mapping is in progress. Most important agricultural areas have some reconnaissance-level surveys.

All of the laboratories have a general idea of the costs involved in soil analysis under their present system. Exact figures are difficult to obtain, largely because the laboratories are used for several purposes and the personnel are working at a number of things in addition to soil testing. The figures that are available indicate very high costs per sample, owing to the low productivity under the present system of analysis.

No formal studies have been carried out to determine the effectiveness of the various means of communication as regards soil testing, but the extension system of each country could readily develop programs of communication which would be adequate, based on experience in other areas of their work.

Advanced training in soil testing has been accomplished by sending students to the United States for advanced degrees. Since this system can be offered only to a limited number of the technicians, programs of training are needed. With the development of a number of new universities in these countries, educational programs for technicians should be available.

Countries Not Surveyed: Chile, Colombia, and Venezuela

Observations by J. W. Fitts and E. J. Kamprath

At the time the soil testing-plant analysis survey was made, no regional soil scientist was working in Chile, Colombia or Venezuela. However, E. J. Kamprath at the invitation of the Rockefeller Foundation and the Colombian Government, spent a month in that country reviewing soil testing. J. W. Fitts spent several days in each of the countries discussing soil testing programs and briefly reviewing what was being done. The following observations should not be considered a complete report on soil testing-plant analyses in these countries:

Soil Testing-Plant Analyses Laboratories

CHILE

Ministry of Agriculture (probably now in the Institute of Agricultural Development - INDAP) - Santiago

Ing. Russi - in charge of laboratory; much of their work is in analyzing samples from soil survey and from field fertility plots. They test about 2,000 samples for farmers annually.

The Catholic University - Santiago

Director: Boris Yopo; Ing. Aldo Norero, in charge of soils

Most of the soils analyses are in relation to student research but samples are tested also for farms on which soil management practices are outlined.

The University of Concepción - Chillan

Head of Soils Department: Ing. José Barrios

This laboratory was analyzing only soil samples for research. They hoped to start testing samples for farmers when sufficient data had been obtained for correlation purposes.

University of Chile - Santiago

Soils analyses made here are for teaching and research.

No samples are analyzed for farmers.

University of Austrol - Valdivia

The soils program is just beginning and is confined to teaching and research.

The Aero Service Corporation - Santiago

Director: Charles N. Hodell

This corporation was completing a survey of the Central Valley of Chile; an area extending from approximately 50 miles north to 600 miles south of Santiago. In making the survey about 4,000 soil samples were collected from about 750 soil profiles representing 200 soil series. Analyses made on the samples included pH, organic carbon, cation exchange capacity, exchangeable calcium, potassium, sodium, available phosphorus (Bray), mechanical analyses (hydrometer) and moisture equivalent. On selected samples mineralogical studies were made, C/N ratio determined, and an analysis made of the amount of iron and aluminum oxide present.

COLOMBIA

There are a number of laboratories making soil and plant analyses in Colombia, but the number of samples tested varies greatly.

Colombian Agricultural Institute (ICA): Much of the soil fertility research and soil testing for farmers is done by ICA. They operate laboratories at the National Research Stations at Tibaitata (near Bogotá), Palmira and Medellin. The laboratory at Palmira is under the direction of Ing. Marin and the most of the samples for farmers that are tested in Colombia are tested in this laboratory.

National University has faculties of Agronomy in Bogotá, Palmira and Medellin. Most of their soil and plant analyses is in relation to teaching and research. The Facultad at Palmira do soil testing for farmers on a contractual basis.

Agustin Codazzi - (Institute for Geography) on campus of National University, Bogotá. Ing. Victor Vega is in charge of soils work. Most of the work of this laboratory is with soil survey samples, but they also test samples for farmers.

The National Chemical Laboratory of the Ministry of Mines - on campus of National University - Bogotá. This laboratory tests samples for farmers.

Several Institutes and Federations also maintain laboratories for soil and plant analyses. Included in the group are the Coffee Federation, Colombian Cereals Institute, and the Tobacco Institute.

VENEZUELA

Ministry of Agriculture - Maracay

Head of Soils: Ing. Emilio Hidalgo - Test largely samples from soil survey but also test about 3,000 farmers' samples annually.

National University - Soils Department, Maracay

Largely research and teaching.

No concentrated effort was being made in any of the countries for testing soil samples for farmers. Less than 4,000 samples are tested for farmers in either Chile or Venezuela. In Colombia, few, if any, of the laboratories test over 2,000 or 3,000 samples annually, with the exception of the ICA laboratory at Palmira. This laboratory is equipped with multiple dispensers, trays, etc., for handling 100 samples a day. The apparatus, built locally, is much like that used in several laboratories in the United States.

Several different extractants are used, especially in the various laboratories in Colombia. The Bray No. 2 and North Carolina extractants are used most widely in Colombia but several use soil test kit extractants. In Chile, The Olsen sodium bicarbonate and Bray extractant are mostly used. In Venezuela, sodium acetate as an extractant is popular.

The Rockefeller Foundation has been conducting a study on procedures that are best adapted for use in Colombian soils. Nine extractants are employed in the study. Soil samples tested are from their field trials. In general, very few correlation studies have been made in any of the laboratories other than the Rockefeller ICA study. Interpretations used are those published in soil kit manuals or in books on tropical soils.

With the exception of those laboratories utilizing soil testing kits, most of the laboratories are well equipped with the basic apparatus such as pH meters, colorimeters, flame photometers, and conductivity bridges. This was especially true of the laboratories in Venezuela. However, only the ICA laboratory at Palmira had multiple extractant apparatus. Thus, the capacity of the laboratories generally was low.

No educational programs for taking soil samples or "follow-up" meetings

were apparent in any of the countries. However, the laboratory at Palmira has embarked on these important phases of soil testing. They have held some meetings with Extension personnel and commercial agronomists to explain the role of soil testing, taking soil samples, tests to be run, interpretation of the results, and recommendations.

FUTURE PROGRAMS

There is little doubt but what commercial fertilizers will play an important role in increasing the crop production in Latin America. Before fertilizers can be used efficiently, however, more information is needed on which soils are deficient in nutrient elements. Soil analysis is an excellent tool to obtain the necessary information for an effective soil fertility program.

The questionnaire outlined the six phases of soil testing for fertility purposes. It also served to show each laboratory where their program needs strengthening. The challenge generally has been met enthusiastically by Latin American Soil Scientists. Committees have been appointed in most countries to review their situation and to outline responsibilities that should be assumed by the various agencies and institutions. Universities generally undertake the responsibility of training scientists and technicians and for conducting basic research. Service laboratories for testing farmers' samples and field trials frequently fall under the Ministry of Agriculture or affiliated agencies. The Extension Services are responsible for soil sampling programs and for follow-up training meetings to educate farmers on the use of soil tests as a basis for liming and fertilizing their farms.

Under the cooperative attack of Dr. Leandro Vettori, Maestre Abreu, and Prof. Robert Cate, Jr., special equipment was designed and built to upgrade the capacity of the Brazilian Soil Testing laboratories. Currently their laboratories are operating with a capacity of several hundred samples a day. Similar changes are rapidly taking place in other countries too, and, by January 1, 1966, it is anticipated that all of the cooperating countries of Latin America will have laboratories with a capacity of several hundred samples per day.

The goal of a good soil analysis-soil fertility program, to increase crop yields through the effective use of fertilizers, will not be fully realized immediately, but an enthusiastic start has been made.