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AGRONOMIC-ECONOMIC RESEARCH ON SOILS OF THE TROPICS

1980-1981 Technical Report

Soil Science Department
North Carolina University
Raleigh, North Carolina 27650 USA

supported by
Contract AID/ta-C-1236
with the
U.S. Agency for International Department

AGRONOMIC-ECONOMIC RESEARCH

ON SOILS OF THE TROPICS

1980-1981 Technical Report

Edited by

J. J. Nicholaides, III
W. Couto
M. K. Wade

Soil Science Department
North Carolina State University
Raleigh, North Carolina 27650 USA

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A very special word of appreciation must go to Dr. Walter Couto (formerly of our staff and now with EMBRAPA at CPAC through IICA) who worked diligently with raw data supplied by many of those listed as authors to develop the text for much of this report. Thanks are due also to Dr. M. K. Wade who aided the editing of this report. Appreciation is due to Mrs. Linda Edwards for her fine word processing of the final text, to Mrs. Dawn Silsbee, Mrs. Jan Holman, Ms. Mariela Gonzalez for the typing of the drafts, and to Mrs. Ann Matrone for most of the excellent figures contained herein. Thanks are due to Mr. Julio Alegre, Mr. Miguel Ara, Mr. Dan Gill, Ms. Laurie Newman, and Ms. Cheryl Palm for the final proofing of these drafts.

A word of explanation and apology is due our readers for the lateness of this report. In 1980 and 1981, most of our staff were involved in planning the Title XII Soil Management Collaborative Research Support Program, now known as TROPSOILS. Our planning efforts resulted not only in TROPSOILS becoming reality, but also in this technical report taking the back burner. Then in August, 1982, Dr. P. A. Sanchez, who was to have handled this report was transferred to Lima, Peru, to lead NCSU's Research, Education and Extension Program in that country. Such delays should not again occur as our 1982-1983 Technical Report is being edited and will go to press immediately following this one.

J. J. Nicholaides, III, Coordinator
Tropical Soils Research Program
October 1983

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1. PROGRAM SCOPE

J. J. Nicholaides, III

This is the eighth formal report of North Carolina State University's Tropical Soils Research Program, supported by the U. S. Agency for International Development under Contract AID/ta-C-1236. The report covers the period from 1980 through 1981, when that contract terminated.

The information presented in this series of reports since 1972 has developed worldwide interest in the activities of the Program by the research, educational and extension divisions of national and international institutions and agencies involved in international agricultural development. The need for increasing the world's food production capability and improving small farmers' income in developing countries of the tropics encouraged financial support to the Program from USAID and other institutions. The highly promising results obtained in the research locations and the interest developed in this kind of activity in other tropical areas of the world encouraged USAID interest in planning and supporting the worldwide collaborative soil management research program (TROPSOILS).

This new program involves four American universities (Cornell, Hawaii, North Carolina State, and Texas A&M) working in cooperation with each other and with national and international institutions in the humid tropics of Peru and Indonesia, in the semi-arid tropics of Niger and in the acid savannas of Brazil. New and continuing research activities of NCSU's Tropical Soils Research Program in Peru, Brazil and Indonesia will be presented in forthcoming technical reports of TROPSOILS, the Soil Management Collaborative Research and Support Program, supported by USAID Grant DAN-1311-G-SS-1083-00.

1.1 Objectives

The overall objectives of the Tropical Soils Research Program are to: 1) develop economically sound soil-crop management systems for tropical rainforests and acid savannas, 2) validate these systems on small farms presently under shifting cultivation, and 3) refine means to extrapolate results to other areas of the world with similar agronomic and socioeconomic conditions. Presented herein is evidence of a program which is meeting these objectives.

1.2 Organization

The Tropical Soils Research Program is an integral component of the Soil Science Department of the School of Agriculture and Life Sciences of North Carolina State University. As such, the Soil Science Department Head is responsible for the Program. Planning, implementation, and evaluation of the research activities are coordinated by the two Program Coordinators. On-site Project Leaders, other senior and junior scientists and support personnel are based in Yurimaguas, Peru and Manaus, Brazil. Research implemented by these individuals and their

host country counterparts is supported by other senior and junior scientists and support staff located on-campus. Training of host country nationals, especially via degree programs, is a major factor contributing to the success of the Program and to the development of increased capability of host countries in addressing soil-crop management problems. It has also offered excellent training opportunities to U. S. and third world country students interested in tropical soils. The involvement of a large number of faculty members in the implementation of the Program represents also an improved teaching and research capability within the Soil Science Department and a better understanding of development opportunities and difficulties in the tropical regions.

1.3 Primary Research Components

The following primary research components are being addressed to meet the Program's three basic objectives:

Objective 1:

Continuously producing annual crops on jungle soils near Yurimaguas, Peru by

a) overcoming soil fertility constraints,
b) overcoming soil physical constraints,
c) developing low-input technologies,
d) developing legume-grass pastures,
e) developing efficient intercropping systems, and
f) producing flooded rice on fertile, alluvial soils.

Objective 2:

Agronomically and economically validating alternative technology with shifting cultivators in the Yurimaguas area.

Objective 3:

Extrapolation of results for refining technologies at other tropical locations.

Such research began in mid-1981 near Manaus, Brazil and in mid-1983 near Sitiung, Sumatra, Indonesia and will be presented in forthcoming technical reports.

1.4 Source of Funds

The primary core support for the Program's research activities was from the centrally funded USAID contract during the 1980-1981 period. Additional funding has come from INIPA's allocation of PL-480 funds to Yurimaguas, CORDELOR's provision of funds to support work on alluvial soils in Yurimaguas and Iquitos, funding of the work in Manaus by the

Rockefeller Foundation and EMBRAPA and support by the Potash/Phosphate Institute for soil fertility evaluation research.

The logistical support provided by the International Potato Center (CIP) in Peru and the Interamerican Institute for Cooperation in Agriculture (IICA) in Brazil has been as indispensable for the Program's operations as have been the funds detailed above.

Sincere appreciation is extended to all these groups.

2. PERSONNEL AND INSTITUTIONS

2.1 North Carolina State University Personnel

Administration

Charles B. McCants, Department Head[1]
Robert H. Miller, Department Head[2]
John J. Nicholaides, III, Program Coordinator
Pedro A. Sanchez, Program Coordinator
Bertha I. Monar, Administrative Secretary
Dawn M. Silsbee, Bilingual Secretary
Mariela Gonzalez, Bilingual Secretary
Janice M. Holman, Secretary
Jamie Powell, Research Technician
Paul Smithson, Research Technician

DEVELOPMENT OF SOIL-CROP MANAGEMENT SYSTEMS FOR TROPICAL RAINFORESTS ULTISOLS

Dale E. Bandy, Project Leader and Visiting Assistant Professor
Jose R. Benites, Visiting Assistant Professor
Julio Alegre, Research Assistant
Miguel Ara, Research Assistant
Melvyn Piha, Research Assistant
John Van Diepen, Research Assistant
Stanley W. Buol, Professor
D. Keith Cassel, Professor
Fred R. Cox, Professor
Charles B. Davey, Professor of Forestry
Robert E. McCollum, Associate Professor
John J. Nicholaides, III, Associate Professor
Pedro A. Sanchez, Professor

ECONOMIC EVALUATION

Arthur J. Chutu, Professor of Economics
Diane Hernandez, Research Economist

EXTRAPOLATION TO AMAZON BASIN OXISOLS

T. Jot Smyth, Brazil Project Leader and Visiting Assistant Professor*
Dale E. Bandy, Peru Project Leader and Visiting Assistant Professor
John J. Nicholaides, III, Associate Professor
Pedro A. Sanchez, Professor

SOIL CHARACTERIZATION

Stanley W. Buol
Tony C. Moniz
Alfredo Alvarado

---

[1] Through 1981
[2] 1982-present
*IICA Personal Asociado

2.2 Collaborating Institutions and Individuals

Without the excellent collaboration of the following key administrators and scientists in several national and international institutions, the research reported herein would not have been possible:

Peru

INIPA (Instituto Nacional de Investigación y Promoción Agropecuaria)

Dr. Alex Grobman (Head)
Dr. Carlos Valverde, Director of Planning and Budget**
Dr. Raul Figeroa, Director of Research
Dr. Manuel Guardia-Mayorga, Director of Extension

CORDELOR (Corporación Regional para el Desarrollo de Loreto)

Ing. Ramón Ruiz, Director of Agricultural Programs

Yurimaguas Agricultural Experiment Station

Ing. Ruben Mesía, Experiment Station Head

CIPA (Centro Regional de Investigación y Promoción Agropecuaria)

Ing. Roger Beuzeville, Director of Iquitos Center

IVITA (Instituto Veterinario de Investigación del Trópico y de Altura)

Dr. Jaime Moro, Director

UNA (Universidad Nacional Agraria)

Dr. Hugo Villachica, Professor of Soils

CIP (Centro Internacional de la Papa)

Dr. Richard Sawyer, Director General
Dr. Roger Rowe, Former Deputy Director General
Dr. Adrian Fajardo, Executive Director
Mr. William Hamann, Assistant Executive Director
Mr. Len Hussey, Controller
Mr. Oscar Gill, Deputy Controller

USAID/Lima

Mr. Len Yaeger, Director*
Mr. Malcolm Butler, Director
Mr. John O'Donnell, Multisector Loan Officer*
Dr. Loren Schulze, Agricultural Officer*

---

*Left during report period.
**Host institution designated liaison.

Brazil

EMBRAPA (Empresa Brasileira de Pesquisa Agropecuaria)

Dr. Eliseu Roberto de Andrade Alves, President
Dr. Raymundo Fonseca Souza, Director
Dr. José Prazeres Ramalho de Castro, Director
Dr. Ágide Gorgatti Netto, Director
Dr. Pompeu Memoria, Head, International Coordination
Dr. Elmar Wagner, Director, CPAC
Dr. Wenceslau Goedert, Technical Director,*,** CPAC
Dr. Edson Lobato, Technical Director,** CPAC

EMBRAPA-UEPAE/Manaus

Ing. Antelmo Silva Melo, Head**
Ing. Leopoldo Texeira Brito, Assoc. Head
Inga. María Pinehro Correa, Assoc. Head
Ing. Oscar Lamiera Noguiera
Ing. Expedito O. Galvao
Ing. Joaquim Braga Bastos, UEPAE Program Coordinator
Ing. José Carlos Correa

USAID/Brasilia

Mr. Samuel Taylor, In-Charge, AID Affairs Office

IICA (Interamerican Institute for Cooperation in Agriculture)

Dr. José Irineo Cabral, Director
Dr. Juan C. Scarsi, EMBRAPA-IICA Program's Coordinator

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*Left during report period.
**Host institution designated liaison.

Aerial view of the Yurimaguas Agricultural Experiment Station's physical plant and approximately one-fifth of area under experimentation. May, 1980.

3.1 Soil and Climatic Properties

Dale E. Bandy and J. J. Nicholaides, III

The research trials on the upland soils of the experiment station, as since 1972, were conducted on fine-loamy, siliceous, isohyperthermic Typic Paleudults (Yurimaguas series) which are representative of a large portion of the soils in the upper or western Amazon Basin of Peru and Brazil. In 1981, a major research effort was begun on the alluvial soils of the lowland areas of the experiment station. These fertile soils are tentatively classed as Typic Tropaqualfs and Aquic Dystropepts and are representative of about 8% of the soils of the Amazon Basin.

As in past years, rainfall played the dominant influential role in crop growth and production. Only in June and July of 1980 and in May of 1981 (Table 3.1:1) did evaporation exceed precipitation. Rainfall has increased in the Yurimaguas area during the last four years, going from 2,082 mm in 1978 to 2,214 mm in 1979 to 2,331 mm in 1980 to 2,520 mm in 1981.

Average maximum, minimum and mean monthly air temperatures were 31, 21 and 26°C during the 1980-1981 period. Average daily solar radiation was below 300 langleys/day in 1981 for the first time since 1978 (Table 3.1:1); low solar radiation during some months of 1981 may have had an adverse effect on crop yields. Mean minimum relative humidity averaged 51% for 1980-1981 (Table 3.1:1), lower than the 54% for the 1978-1979 period.

Table 3.1:1. Summary of climatic data for 1980 and 1981 at the Yurimaguas Agricultural Experiment Station.

Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.	Total
1980:														
Rainfall (total), mm	213	178	211	198	161	77	68	200	211	250	278	286	194	2,331
Evaporation (total), mm	65	78	73	78	83	85	90	96	111	81	88	88	85	1,016
Solar radiation (ave.), lang/day	335	337	279	333	309	273	315	384	363	335	309	329	325	
Relative Humidity (ave. min.), %	-	60	60	61	56	53	49	43	42	53	52	51	53	
Temperature (ave. max.), °C	31.0	32.3	30.5	31.2	31.3	31.3	30.9	32.1	32.0	31.0	31.3	31.3	31.4	
Temperature (ave. min.), °C	21.7	21.6	21.3	21.1	20.9	20.1	19.2	19.6	19.6	20.8	21.2	21.1	20.7	
Temperature (ave. mean), °C	26.4	27.0	25.9	26.2	26.1	25.7	25.1	25.9	25.8	25.9	26.3	26.2	26.0	
1981:														
Rainfall (total), mm	175	355	366	175	55	220	100	153	211	206	235	269	210	2,520
Evaporation (total), mm	101	56	76	78	94	64	88	77	94	91	89	82	83	990
Solar radiation (ave.), lang/day	354	281	279	304	280	237	270	300	334	327	324	280	298	
Relative Humidity (ave. Min.), %	47	55	55	53	51	53	42	44	40	45	47	54	49	
Temperature (ave. max.), °C	31.8	30.6	30.6	31.3	31.2	30.0	29.8	31.3	31.8	31.4	31.9	30.5	31.0	
Temperature (ave. min.), °C	20.9	20.8	20.8	21.3	20.8	19.7	17.4	18.9	19.3	19.8	20.6	20.5	20.1	
Temperature (ave. mean), °C	26.2	25.7	25.7	26.3	26.0	24.9	23.6	25.1	25.5	25.6	26.3	25.2	25.5	

Continuous Cultivation of Annual Crops

Corn as the 18th consecutive crop under the traditional system (left) and with the improved management system (right). Mid-1979. Yurimaguas, Peru.

3.2 Continuous Cultivation of Annual Crops

Since land first was cleared in August, 1972 in Yurimaguas for the joint NCSU/INIPA research, the overriding question has been "Is continuous cropping possible for soils normally subjected to shifting cultivation?" The answer, we have found, is unquestionably "yes" when proper management practices as dictated by a constant monitoring of soil dynamics are used. This section gives an updated summary of the continuous cultivation work, and consequent improvement of subsoil fertility, and overcoming potassium limitations.

3.21 Continuous cultivation and nutrient dynamics

P. A. Sanchez, D. E. Bandy, J. H. Villachica and
J. J. Nicholaides, III

The grain yields of 21 consecutive crops harvested from the same field since it was cleared by slash-and-burn and cultivated in October 1972 with the rice, corn, and soybean rotation are shown in Figure 3.21:1. Without fertilization, the long-term annual average of this rotation, replicated in three fields, was 7.4 tons of grain per hectare.

The upland rice, peanut, and soybean rotation was also successful and may be even more appropriate since peanuts have a higher yield than corn in this environment. Corn was affected by the low solar radiation and high night temperatures, and was subjected to more insect attacks than the other three crops. Figure 3.21:2 shows the long-term average yields of 88 harvests of these four crops with and without adequate fertilization through 1980. Upland rice, soybean, and peanut yields are excellent; corn yields moderate. Figure 3.21:2 also indicates that a reasonable yield stability was obtained for the four crops. These results attest to the fact that continuous production can be achieved in the Amazon with adequate fertilization.

Nutrient dynamics. The term "adequate fertilization" was not arrived at easily. It took about 4 years to gather conclusive data on the changes in soil properties that occurred after clearing and burning a 17-year old secondary forest and growing annual crops continuously. The nutrient dynamics were monitored by sampling soils after each harvest and analyzing for pH, organic C, total N, exchangeable Al, K, Ca, Mg, effective CEC, and available P, Zn, Cu, Fe and Mn. Levels of S, B, and Mo were determined periodically by plant analysis. Records were kept for three fields cleared in 1972, 1973 and 1974 which were given complete, intermediate, or no fertilization and replicated four times. Timing of appearance of soil fertility limitations and intensity of their expression varied among fields, even though they were near each other, were on the same soil mapping unit, and had the same vegetation before clearing. Intensity of the fire during clearing was considered a factor contributing to this variability.

Ash from the burning produced a temporary increase in pH, available N, P, K, Ca, Mg and some micronutrients and a decrease in exchangeable Al to below toxic levels. As a result, upland rice, the

first crop planted, did not suffer from soil fertility limitations. By about 8 months after clearing, however, the levels of available N and K were reduced such that crops were affected adversely; in addition, sporadic S, Cu, and B deficiencies appeared. Organic matter in the topsoil decreased sharply during the first year, with a decomposition rate of 25 percent per year. Organic matter reached a new equilibrium level starting with the second year. The rapid organic matter decomposition probably released many H^+ ions that acidified the soil and increased exchangeable Al to toxic levels, reversing the liming effect of the ash.

During the second year, P and Mg became deficient, Ca during the first 30 months, and Zn during the fourth year. Suspected after the eighth year was a Mn deficiency. Molybdenum deficiencies were sometimes detected in soybean.

Fertilizers and lime were added according to recommendations based on soils analysis for the complete treatments. During the second or third year, however, all yields began to decline rapidly. Soil analysis identified two responsible factors: a shorter than expected residual effect of the lime applied, and the triggering of a Mg deficiency induced by the K applications. After these problems were corrected, crop yields essentially stabilized (Fig. 3.21:2). Thus, a monitoring of the nutrient dynamics during the period when the soil was undergoing a transition from forest to cropland provided the key for establishing continuous cultivation.

Table 3.21:1 presents lime and fertilizer recommendations developed during 8 years of research at Yurimaguas. These fertilizer recommendations, as are all sound ones, are site-specific. Nevertheless, they are representative of the level of fertilizer and lime inputs required for continuous crop production in Ultisols. They do not differ substantially from those used to produce corn, soybeans, and peanuts in Ultisols of the southeastern United States. The total amounts of fertilizer required on an annual basis are higher in the Amazon Basin than in the Southeast U.S. because three crops are grown instead of one.

Table 3.21:1. Fertilizer requirements for continuous cropping of annual rotations of rice-corn-soybean or rice-peanut-soybean on an acid Ultisol in Yurimaguas, Peru.

Amendment*	Elemental rate/ha	Frequency
Lime	3 t $CaCO_3$ - equivalent	Per 3 years
N	80-100 kg	Only rice and corn
P	25 kg	Per crop
K	100 kg	Per crop, split application
Mg	25 kg	Per crop, unless dolomite is used
Cu	1 kg	Per year or two**
Zn	1 kg	Per year or two**
B	1 kg	Per year or two**
Mo	20 g	Only with legume seed

*Plant Ca and S needs are supplied by lime, simple superphosphate and Mg, Cu and Zn carriers.

**According to soil test recommendations.

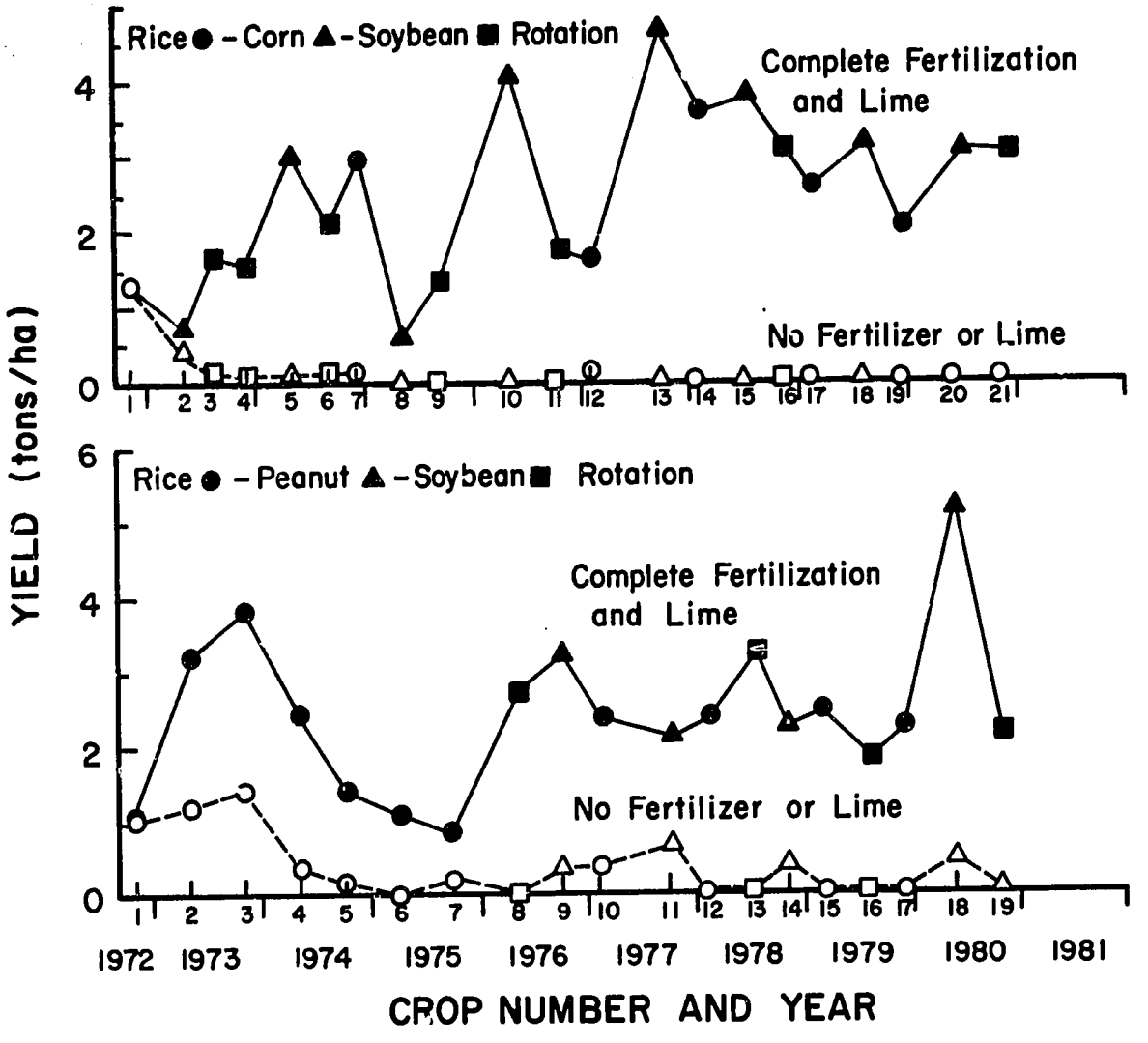


Figure 3.21:1. Yield record for two continuously cultivated plots at Yurimaguas, with and without fertilization and lime.

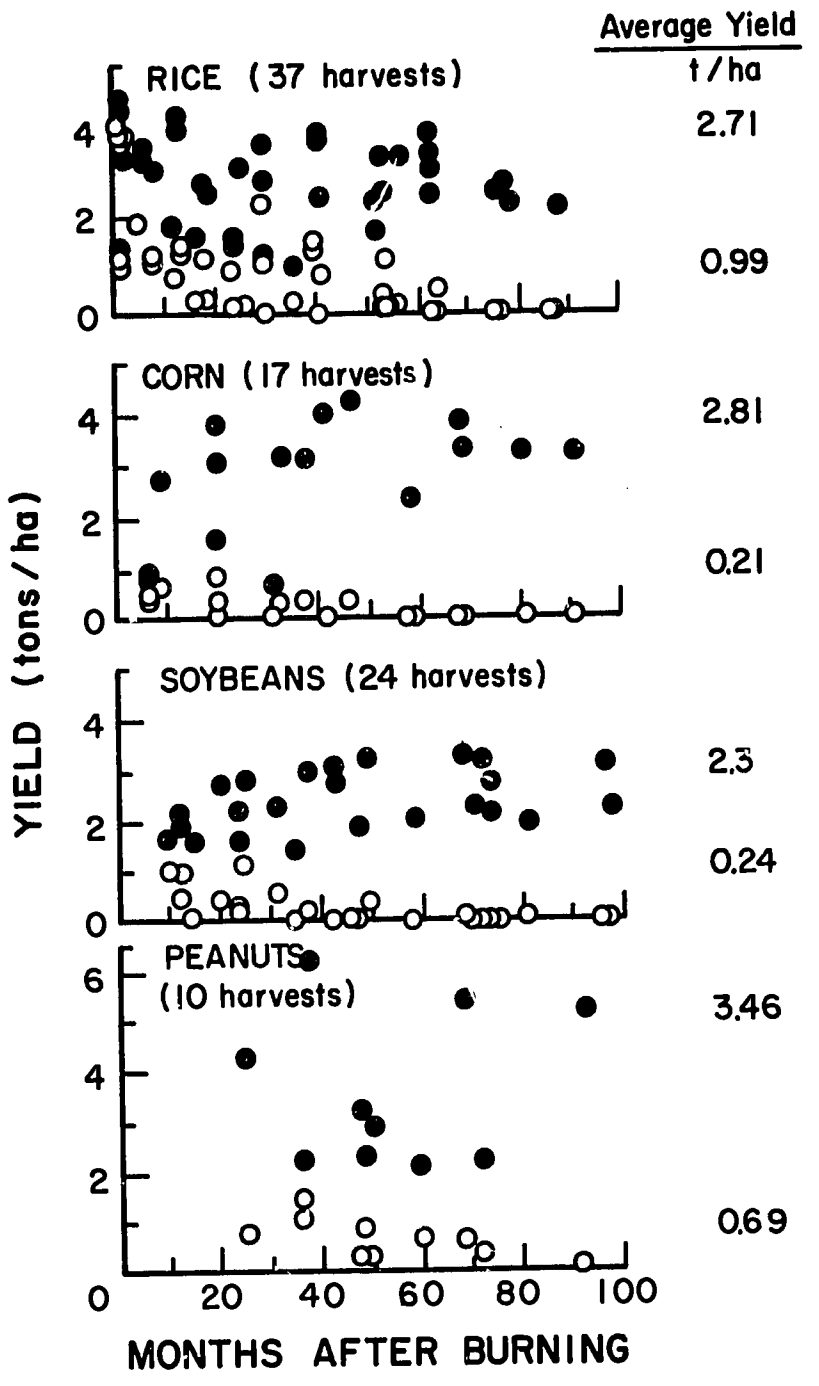


Figure 3.21:2. Crop yields at Yurimaguas (1972 to 1980) with complete fertilization (●) and with no fertilization (o).

The key to continuous crop production is continual soil testing. Here Sra. Luzmilla Ara and Sr. Juan Witman analyze soils in Yurimaguas Agricultural Experiment Station laboratory.

3.22 Improvement of subsoil fertility

D. E. Bandy

That deep incorporation of lime improved subsoil water use by crops was shown in the previous report for 1978-1979. This was the effect of better root development resulting from neutralization of subsoil acidity. Improved root growth in the subsoil is extremely important for those crops that can be adversely affected by short-term dry periods since water-holding capacity is limited in Ultisols with the physical characteristics of Yurimaguas soils.

A series of experiments was initiated to determine optimum lime levels required for corn, soybean, peanut and rice for better root development and increased yields. The effect of lime placement was also studied for these crops as well as the rate of downward movement of Ca and Mg and the residual effect of lime applications.

Since tolerance to aluminum varies with species and percent aluminum saturation is related to soil pH, it was of first interest to establish soil pH-percent aluminum saturation relationships for Yurimaguas soils. Previous studies conducted at Yurimaguas (1978-1979 Report) showed that essentially all exchangeable aluminum was precipitated as soil pH approaches 5.2.

Soil pH-relative grain yield relationships have been established for corn, peanuts and rice (1978-1979 Report). While maximum rice yields occurred at soil pH values of 5.5, maximum for corn and peanuts occurred at 6.2 and 5.8, respectively. If 90% of maximum yield is adopted as a more realistic target, soil pH does not need to be higher than 5.0 and 4.8 for corn and peanuts, respectively. Moreover, there was an overliming effect when pH was above 6.5 for corn and above 6.0 for peanuts. In terms of exchangeable aluminum, to obtain 90% of maximum yield exchangeable aluminum should not be greater than 0.40 and 0.60 meq/100 cc for corn and peanuts, respectively. As is well known, rice is less sensitive to aluminum and was able to produce maximum yields at pH values of 4.6 or 1.0 meq Al/100 cc.

Besides knowing the optimum soil pH and amount of lime required for optimum crop yields, it is interesting to know the potential of Ca and Mg leaching into the soil profile as a means for better root growth in the subsoil.

Experimental results from Yurimaguas showed that Ca and Mg move rather rapidly through the soil profile (Table 3.22:1). The highest lime levels promoted more Ca and Mg leaching into the soil profile. Downward movement of Ca and Mg is a function of not only lime levels, but also of time. Ca and Mg leaching increased with time and occurred well below the 30 cm depth. Figure 3.22:1 presents data from a previous experiment started in 1972, showing exchangeable Ca levels and percent Al saturations at varying depths on soil samples taken 102 months after the experiment was initiated.

The increase in exchangeable Ca levels at 45 cm depth was quite significant, especially when the very low values observed on unlimed plots were considered. As shown previously, increased exchangeable Ca levels and lower percent Al saturation in the subsoil improved root proliferation and exploitation of available water and nutrients. This means less water stress during short drought periods and improved nutrient recovery.

Deeper lime placement could help Ca and Mg to reach the subsoil faster and, therefore, promote better root development in the first crop. An experiment was initiated in 1974 to determine the depth at which lime must be incorporated to more rapidly neutralize subsoil acidity and to determine the consequent effect on plant yield and tolerance to drought stress. The experiment consisted of three lime placement treatments: 15 cm with rototiller incorporation, 15 cm by hoe incorporation, and 3 cm rake incorporation. Lime was applied at 1.8 ton/ha for all treatments. Corn was planted initially and for the second and third crops. A concurrent crop rotation of cowpea, peanut and rice was also subjected to these same treatments. Table 3.22:2 shows results of the six crops. Best placement treatment has been incorporation to 15 cm depth by rototiller and thus, all results are expressed as a percent of yield obtained with this treatment. It can be seen that for the other lime incorporation treatments, there was a lower yield initially, but later yields approached those corresponding to best treatment.

The excellent results obtained with deep incorporation of lime encouraged new experiments including deeper lime placement. A new experiment was initiated with the following treatments: incorporation to 15 cm with rototiller, band placement at 15 cm, and band placement at 30 cm. The amount of lime applied was 4 tons/ha for every 15 cm depth. Corn was planted as a test crop and soil sampled at varying depths after each crop. Results presented in the 1978-1979 report showed higher yields on those plots where more neutralization of subsoil acidity occurred; this corresponded to deeper lime placement. This was the result of better root distribution, increased nutrient uptake and better use of soil water.

Effects of lime and fertilizer application on subsoil chemical properties on continuous cropping systems is shown by Figure 3.22:2. Presented are selected soil chemical characteristics at varying depths up to 50 cm prior to clearing and after nearly eight years of continuous cropping. Results show that although no deep incorporation of lime was performed in that experiment, Ca and Mg leached into the subsoil over time, reducing Al saturation at a depth of 50 cm and increasing effective cation exchange capacity. Soil pH increased only slightly at 50 cm depth but significant increases were measured at 30 cm depth.

Table 3.22:1. Exchangeable Ca and Mg at two soil depths and six initial rates of application 39 months following application

Lime	Exch. Ca + Mg		Al Sat'n.	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
t/ha	----- meq/100 cc -----		-------- % ---------	
0	1.6	1.4	59	74
1	1.9	1.4	55	65
2	2.7	1.4	39	63
4	3.6	1.8	15	53
8	4.7	2.8	9	30
16	5.2	3.7	5	13

Table 3.22:2 Effect of methods of lime application on relative yield of corn, peanut, cowpea and rice.

Lime Incorporation Method	Depth	Continuous Corn			Rotation		
		1st	2nd	3rd	Cowpea	Peanut	Rice
	cm	---------- Relative Yield, % ----------					
Rototiller	15	100	100	100	100	100	100
Hoe	15	77	85	94	98	81	98
Rake	3	71	60	80	74	65	88
Control (no lime)	-	2	7	0	30	53	26

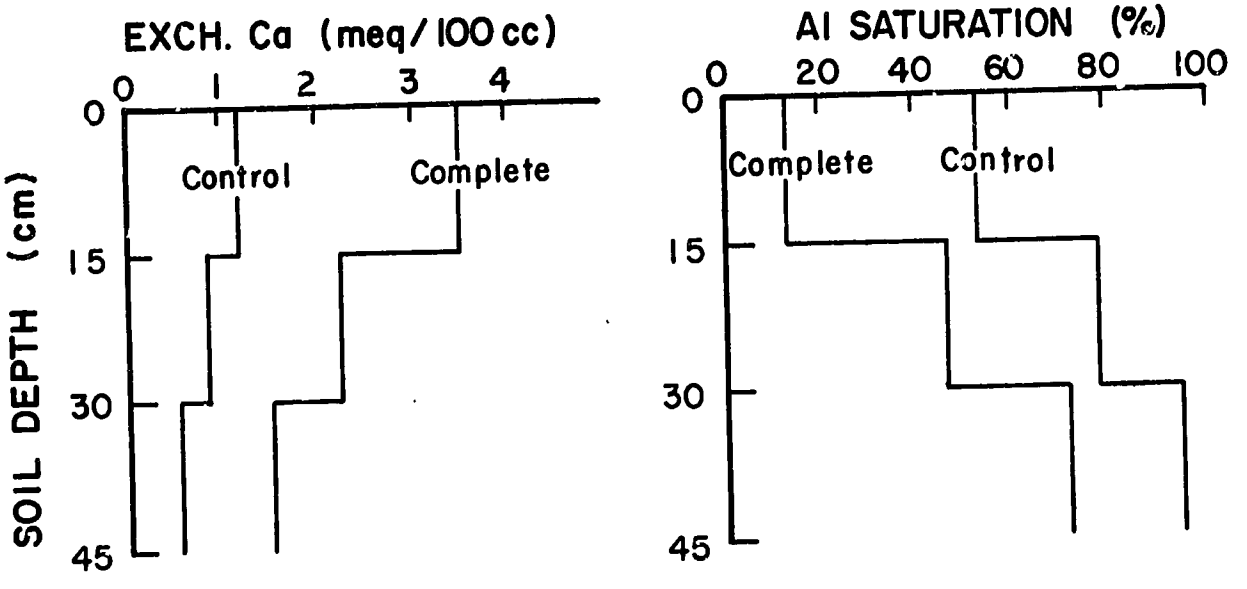


Figure 3.22:1. Effect of lime movement 102 months after first lime application (lime was applied 4 times at rates between 1.5 - 2.0 t/ha depending on soil analysis.) Yurimaguas, Peru.

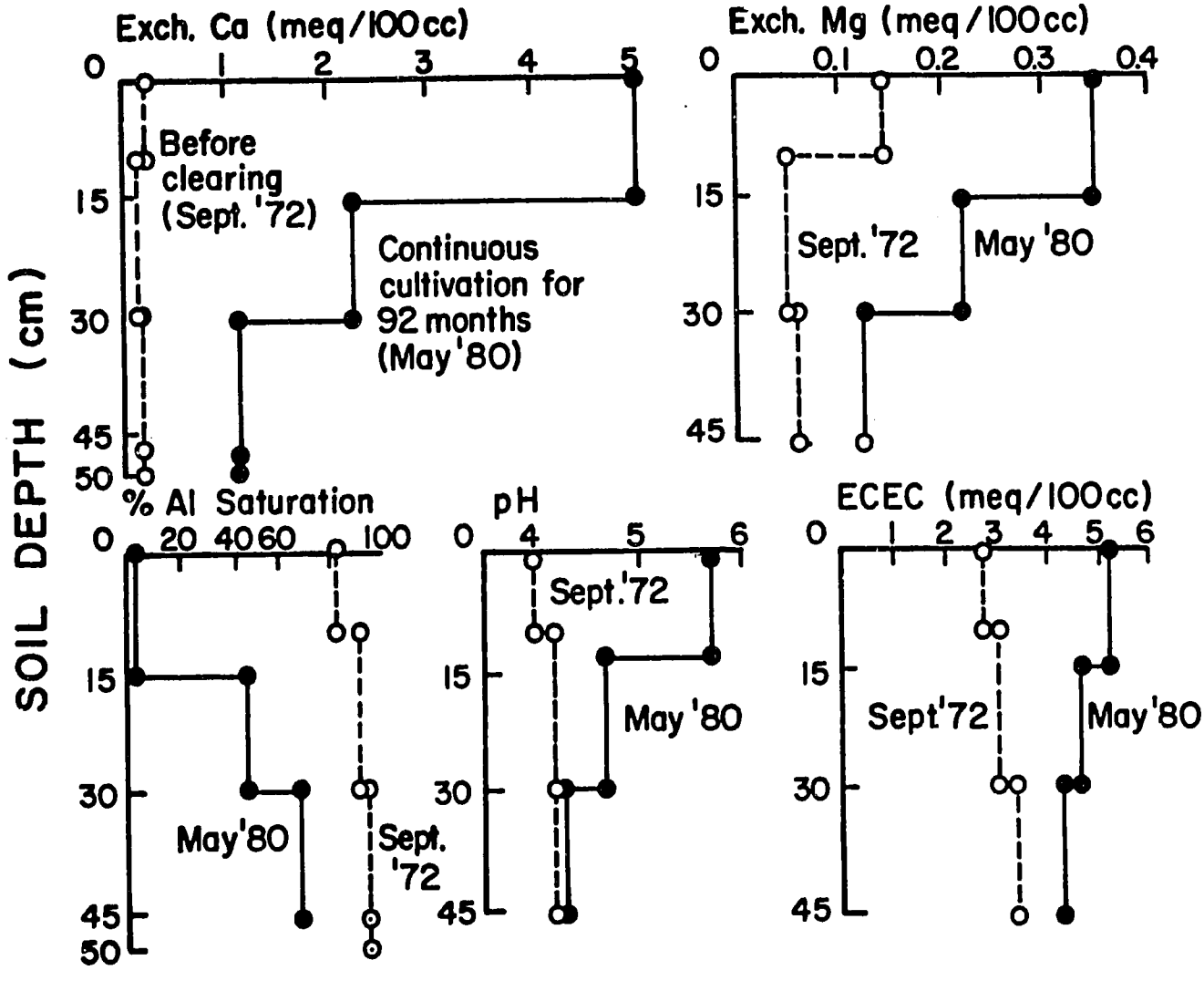


Figure 3.22:2. Effect of lime and fertilization on continuous cropping system on selected soil chemical characteristics at varying sampling depths. Chacra I, Yurimaguas, Peru.

3.23 Overcoming potassium limitations

J. J. Nicholaides, III, D. E. Bandy and M. I. Piha

Typic Paleudults such as those being cropped at the Yurimaguas Experiment Station are characterized by 1) their lack of weatherable minerals which could release K during the weathering process, 2) their lack of secondary minerals structurally able to fix and later release K for plant availability, and 3) consequent K mobility. This situation makes high yielding continuous cropping depend directly on a proper supply of K fertilization at the time the crops need it. Refinement in potassium rates and time of application, therefore, are critical for sustaining the high yields produced three times a year by continuous cropping at Yurimaguas. An enlarged program on K research was developed in 1981 in order to develop improved soil fertility management practices for continuous cropping on Yurimaguas Ultisols. This program was developed under a new agreement for K research with the Potash and Phosphate Institute which provides partial financial support for these studies.

Continuous cropping studies

The earlier NCSU research had resulted in the K rates for the long-term continuous cropping studies being increased from 77 to 107 kg/ha at year 5. From years 5 to 8 in the continuous cropping studies, however, exchangeable K levels in the topsoil sampled at crop harvest from plots receiving the increased K fertilization never were greater than 0.15 meq/100 cc and many times were one-half that amount. As the K level of 0.15 meq/100 cc is regarded as the critical level for most annual crops (rice, corn, peanuts, soybeans) grown on these sandy loam soils in Yurimaguas, there was concern that crop yields were being limited by either the rates themselves or time of application. Contributing to the lack of build-up of soil test K levels was the fact that crop uptake of K exceeded K fertilizer additions on both clearings of the continuous cropping study (Table 3:23:1).

Yields of annual crops on the complete fertilization plots have been declining slowly but steadily since 1978 (refer to Fig. 3.21:1). These factors again reinforced the hypothesis that either K rates or time of application were limiting soil test K levels and perhaps crop yields themselves.

Time of K application studies

A field trial was established in Yurimaguas, Peru on a Typic Paleudult in late April 1981 to determine the relation of timing of K applications to yields of rice and corn. Soil test K level was 0.12 meq/100 cc. Soil tests indicated that no other nutrients were limiting. Design was randomized complete block with four replications and a plot size of 21 m^2. Potassium rate of 100 kg/ha was that normally used for rice and corn at the Yurimaguas Experiment Station. Treatments were as detailed in Table 3.23:2.

Upland rice (cv. IR-4-2 from the International Rice Research Institute) was the first crop planted; harvest was August 21, 1981. Yields (Table 3.23:3) were abnormally low due to rainfall paucity during growth. It was extremely dry at grain filling stage.

Treatment 2, in which all K was applied at planting, gave the highest yields because 1) the low rainfall produced less leaching of K than would be expected during a higher rainfall period, and 2) the plants were not burned by the K salts as were those receiving partial K applications during growth. Results suggest that for a crop of rice grown during the drier time of year May-August it is best to apply all K at planting.

Corn (a Peruvian composite cultivar, Amarillo Planta Baja) was then planted on the plots; harvest was December 18, 1981. Yield results (Table 3.23:4) were more indicative of normal corn yields than were those of rice.

Corn grain yield results suggest that 1) K applications at planting (treatment 2) are better than split or late applications, and 2) an obvious K deficiency existed in zero K plots (treatment 1).

Upland rice (cv. IR-4-2) was then planted in early January 1982 on the plots. Harvest data are not available for the third crop at time of writing, but will be included in the next report.

K rate x time of application study

A field study was established in Yurimaguas, Peru on a Typic Paleudult in September 1981 to determine the effect of K rate and time of application on peanut yields. Soil test K level was 0.12 meq/100 cc. Soil tests indicated that no nutrients were limiting. Design was randomized complete block, thrice replicated, with treatments as detailed in Table 3.23:5. The local cultivar (Blanco Tarapoto, a Valencia-type peanut) was employed.

Results (Table 3.23:6 and Fig. 3.23:1) revealed that 1) the highest peanut yields were obtained when 180 kg K/ha were applied, and 2) that rate was only advantageous when split applied 1/3 preplant and 2/3 preflowering (probably related to the rainfall pattern during growth). The additional yield of 280 kg shelled peanuts/ha produced by the extra 60 kg K/ha, when the 180 kg K/ha was split applied, produced a rate of return to capital exceeding 300%. Such a rate of return would be attractive to farmers of the area.

Implication and continuing activities

Various K rate x time of application studies will continue in order to define the maximum yield response. The work reported herein indicates that the K rates currently used on peanuts at the Yurimaguas Experiment Station may be insufficient. Similar experimentation with

other important crops in the region must be conducted and is being initiated.

Movement of K into the subsoil of similar sandy loam soils in the Southeastern United States has been documented by Woodruff and co-workers. Whether such K movement occurs in these Amazon jungle soils and how much of that K is plant available must be determined in order to better facilitate fertilizer recommendations for the area. Work to that end was initiated in early 1982.

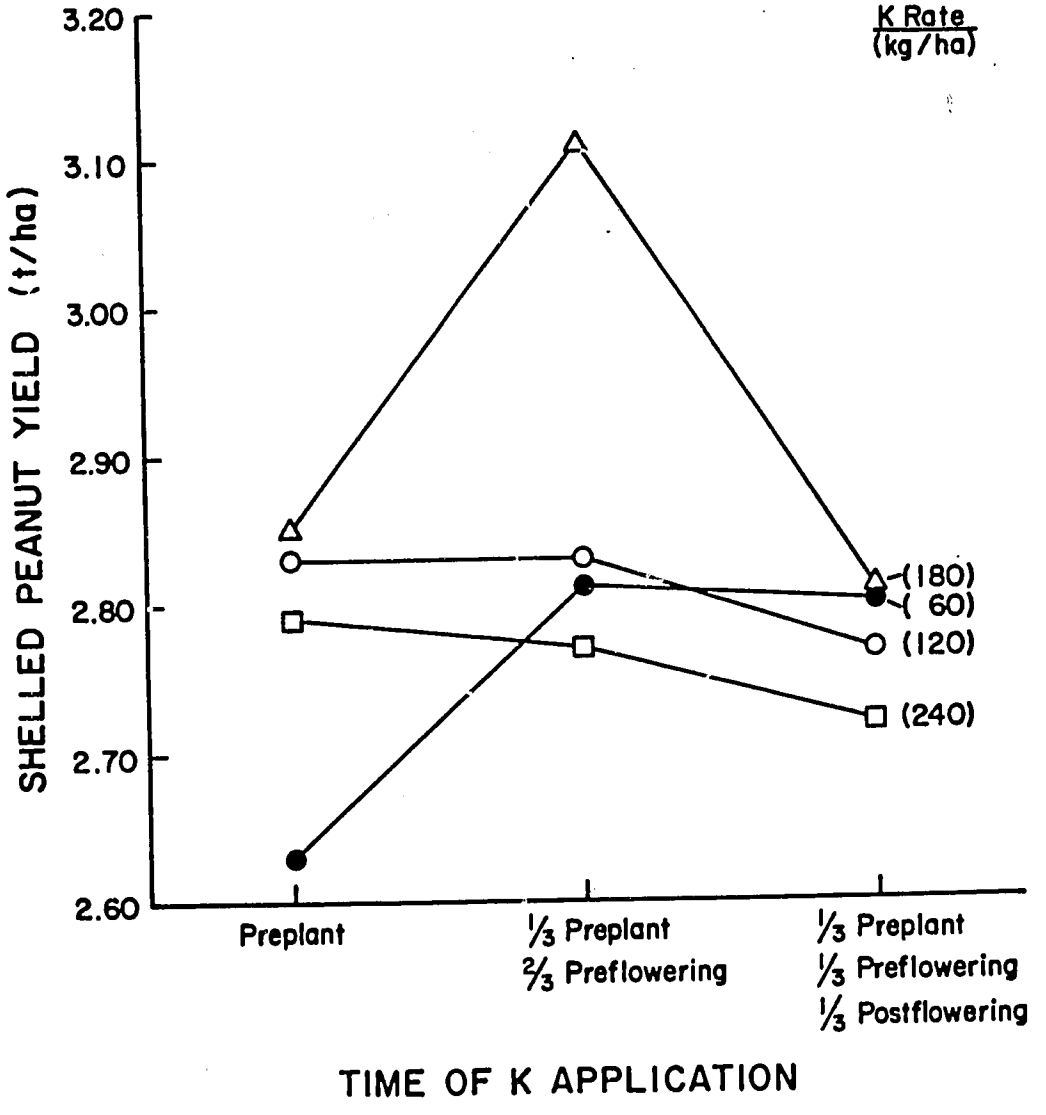


Fig. 3.23:1. Shelled peanut yield as influenced by K rate and time of application; Yurimaguas; Peru, 1981-1982.

Table 3.23:1. Potassium fertilizer additions, crop uptake, and soil test levels over time on two clearings on a fine-loamy, siliceous, isohyperthermic Typic Paleudult in Yurimaguas, Peru, 1972-1980.

Clearing, Crops, Years	Fertilizer Additions	Crop Uptake	Balance	Soil test exchangeable K levels at x months after slash and burn 1	69*	94**
	kg/ha			meq/100 cc		
Chacra I, 19 crops, 8 years	1740	1837	(97)	0.32	--	0.11
Chacra III, 13 crops, 5-1/2 years	1340	1504	(164)	0.57	0.12	--

*With K fertilization.

Table 3.23:2. Treatments of time of K application to rice and corn study. Yurimaguas, Peru, 1981.

Treatment	Portion of 100 kg K/ha applied at x days after planting 0 Days	15 Days	30-40 Days*	60-70 Days**
	%			
1	0	0	0	0
2	100	0	0	0
3	50	0	50	0
4	20	40	40	0
5	25	25	25	25
6	0	50	0	50

*Maximum tillering (rice).

**Panicle initiation (rice).

Table 3.23:3. Rice grain (at 14% moisture) and dry matter straw yield as influenced by time of K application. Yurimaguas, Peru, 1981.

Treatment	Rice Yield	
	Grain	Straw
	t/ha	
1	0.98	2.01
2	1.65	2.44
3	1.35	2.43
4	1.13	1.99
5	1.15	2.54
6	0.97	1.61

Table 3.23:4. Corn grain (at 15.5% moisture) and dry matter straw yield as influenced by time of K application. Yurimaguas, Peru, 1981.

Treatment	Corn Yield	
	Grain	Straw
	t/ha	
1	0.95	2.93
2	3.48	6.76
3	3.38	7.33
4	3.14	5.63
5	3.08	7.35
6	2.40	4.45

Table 3.23:5 Treatments of K rate x time of application to peanut study, Yurimaguas, Peru. 1981-1982.

Treatment	K Rate	Portion of K Applied at: Preplant	Preflowering	Postflowering
	kg/ha	%		
1	0	--	--	--
2	60	100	--	--
3	60	33	67	--
4	60	33	33	33
5	120	100	--	--
6	120	33	67	--
7	120	33	33	33
8	180	100	--	--
9	180	33	67	--
10	180	33	33	33
11	240	100	--	--
12	240	33	67	33
13	240	33	33	33

Table 3.23:6. Shelled peanut yield as influenced by K rate (average of three replications over three times of application).

K Rate	Shelled Peaunt Yield ($\bar{x}$ of all times of application)
kg/ha	t/ha
0	2.51
60	2.75
120	2.81
180	2.92
240	2.76

3.3 Overcoming Soil Physical Constraints

The early years of the Yurimaguas Project saw the research centering on the management of soil chemical properties. In 1978, the Project began looking at the effect of land clearing and continuous cultivation techniques on the rate of change of selected soil physical properties (1978-1979 Report). Conclusions from these studies were that 1) the greatest change in soil physical properties (bulk density, soil water characteristics and mechanical impedance) occurred within the first year after clearing, 2) the affected soil physical properties were not significantly changed by intensive continuous cropping, even after seven years, and 3) the affected soil physical properties, once changed, have not reverted back to their original states, even after 15 years of secondary forest.

Since soil compaction was a major detrimental effect of bulldozer clearing and adversely affected crop yields and since the compaction had not been alleviated by continuous crop production, two additional studies related to soil physical property management were initiated in 1980. The purpose of one was to determine the best method to reclaim soil compacted by bulldozer clearing. The purpose of the other was to determine whether some mechanized land clearing technique other than that originally used might have less detrimental effects on soil physical properties and crop yields.

3.31 Reclamation of compacted bulldozed areas

J. Alegre and D. K. Cassel

An area was cleared in 1972 with a D-6 bulldozer using a conventional blade. Half of the cleared area's plots were cropped with rice for two years, during which time soil aeration and infiltration decreased, bulk density increased, and rice yields declined.

The other half of the cleared area's plots were planted to guinea grass (*Panicum maximum*), which was abandoned after four months. Secondary regrowth of the forest was very poor and guinea grass consequently invaded the entire bulldozed area.

During 1979, selected soil physical properties were measured in these plots. A compacted zone between 15 to 45 cm depth, as evidenced by an increase in bulk density and penetrometer resistance and a reduction in the infiltration rate, was found (Annual Report 1978-1979).

Objectives

In February 1980, an experiment was initiated on this bulldozed area to determine the best technique for reclaiming these bulldozed plots. Rice, soybean and corn were test crops used.

Materials and Methods

Treatments were:

1. Control, no till, cut grass and burn, plant with stick.
2. Control, till, cut and burn, rototill (14HP) and plant with stick.
3. Cut and burn, rototill (14HP) and plant with Planet Jr.
4. Cut and burn, chisel plow (35 cm), rototill (65HP tractor), and plant with Planet Jr.
5. Controlled traffic, cut and burn, rototill (14HP) and plant with Planet Jr. Assignment of pathways for foot traffic inside the plot.
6. Bedding, cut and burn, rototill (14HP) and plant with stick.
7. Digging subsoil (by shovel), cut and burn, rototill (14HP) and plant with Planet Jr.
8. Mulching, cut and burn, rototill (14HP) and plant with Planet Jr. Mulch applied when seedlings 10-25 cm high.

A completely randomized block design with four replications was used. Rice (cv. IR 4-2), the first crop of the sequence was planted February 2 and harvested on June 6, 1980. A basal fertilizer rate, in kg/ha of 80 N, 44 P, 66 K and 12 Mg and 1 ton/ha of lime were applied. Plant spacing was 20 cm x 20 cm (with stick) and continuous row with 20 cm between rows (Planet Jr.). The crop was hand-weeded twice. Soybean (cv. Jupiter), the second crop of the sequence, was planted on June 3 and harvested on October 15, 1980. A basal rate (kg/ha) of 20 N, 44 P, 66 K and 24 Mg was applied. Seeds were inoculated with Rhizobium (Nitragin). Spacing was 40 cm x 5 cm (with stick) and continuous row with 40 cm between rows (Planet Jr.). The crop was hand-weeded once.

Results and Discussion

Rice. Rice straw and grain yields are shown in Table 3.31:1. Grain yield differences existed at the 5% level. Lowest yields occurred on the bedding and mulching treatments. No differences among other treatments were found. Significant differences at the 1% level were found for straw. Lowest straw yield was from the no-till control. No differences among the other treatments were realized.

Monthly rainfall distribution during the growing season looked very regular (Fig. 3:31:1), but the daily distribution was irregular (Fig. 3:31:2). For example, drought periods occurred 15, 23, and 44 days after rice planting. It is assumed that the droughts extended the rice vegetative period and thereby reduced yields. The small amount of rain was not enough to maintain proper soil moisture because the potential evapotranspiration was high during these hot (33°C) cloudless days.

For all treatments, bulk density changed (Table 3.31:2), being lower than the initial state. The bedding and mulching treatments had the lowest bulk densities, but also gave the lowest yields. The bedding

treatment had less plants because it had been planted with a stick and the pathways reduced the area. Since the only grass available for mulch at that time was flowering, many grass seed germinated and competed with the rice for water and nutrients. This plus insufficient amounts of mulch applied are the probable reasons for the negative response of rice grain yields to these treatments. For the chisel and digging treatments, no differences in yields (Table 3.31:1) nor bulk density were found.

The mechanical impedance results (Table 3.31:3) correlated well with bulk densities at 0-15 cm. The magnitude of both physical properties were higher in the non-tilled control and lower in the bedding and chisel treatments.

Since the controlled traffic treatment compared to the tilled treatment showed no differences in yields (Table 3.31:1), it can be assumed that surficial compaction was not a problem for rice.

Soybean. Stover and grain yields for soybeans are shown in Table 3.31:1. The effects of plowing and subsoiling are clear. Significant differences at 5% level were found for both stover and grain yields, the lowest yields occurring for the control no-tilled treatments. The chisel and digging treatments produced the best yields.

The rainfall distribution during the growing season (Fig. 3:31:3) was not uniform. For this reason, the crop had severe water stress problems and yields for all the treatments were low. Several drought periods occurred.

The mulching treatment did not show any advantage over the unmulched treatment. This may be due to the small amount of mulch applied and associated weed problems; moreover, no hilling-up was done when the second and third applications of nitrogen and potassium were applied.

The soil physical properties did change a little, but are not shown by bulk densities (Table 3.31:2). Penetrometer resistance was highest in the control-no tilled treatment. The mulching and bedding treatments showed lower penetrometer resistance than the tilled treatments. Surficial compaction in the tilled treatments was not a problem for soybeans.

Conclusions

1. The different land preparations improved soil physical conditions.
2. Water stress is a critical factor in determining rice and soybean grain yields, with rainfall distribution and soil waterholding capacity being the most important factors.
3. Since Guinea grass was grown in the plots for seven years with no cattle grazing, the topsoil (0-15 cm) had good structure and surficial compaction consequently did not limit rice yields.
4. Significant soybean response to subsoiling was due to breakup of hardpan.
5. Mulching did not show any advantage over the unmulched treatment.

Table 3.31:1. Rice and soybean grain and straw yields (for first and second crops in reclamation study). Yurimaguas, Peru. 1980.

Treatment	Rice		Soybean	
	Grain	Straw	Grain	Stover
	t/ha			
1 Control, no-tilled	2.09	3.78	0.32	0.22
2 Control, tilled	2.24	5.13	1.17	0.56
3 Tilled	2.15	5.52	0.98	0.57
4 Chisel	1.99	5.14	1.40	0.61
5 Controlled traffic	2.19	5.62	0.78	0.56
6 Bedding	1.56	4.57	1.01	0.53
7 Digging	2.15	5.19	1.28	0.72
8 Mulching	1.63	4.90	1.16	0.63
Means	2.00	4.98	1.01	0.55
$LSD_{0.01}$	--	1.28	--	--
$LSD_{0.05}$	0.44	0.97	0.31	0.23

Table 3.31:2. Bulk densities at 0-15 cm depth, initially and prior to rice and soybean harvests (average of 12 replications). Yurimaguas, Peru. 1980.

Treatment	Initial State	Before Rice Harvest	Before Soybean Harvest
	g/cc		
1 Control, no-tilled	1.55	1.42	1.39
2 Control, tilled	1.55	1.33	1.38
3 Tilled	1.55	1.37	1.41
4 Chisel	1.55	1.35	1.31
5 Controlled traffic	1.55	1.33	1.36
6 Bedding	1.55	1.23	1.32
7 Digging	1.55	1.34	1.42
8 Mulching	1.55	1.30	1.33

Table 3.31:3. Mechanical impedance and soil moisture at two depths prior to rice and soybean harvests (average of 20 replications). Yurimaguas, Peru. 1980.

Treatment	Depth	Rice Penetrometer Resistance	Rice Moisture	Soybeans Penetrometer Resistance	Soybeans Moisture
	- cm -	kg/cm^2	% by wt.	kg/cm^2	% by wt.
1 Control, no-tilled	0-15	1.54	18.0	1.37	15.53
	15-25	0.97	18.7	0.95	17.48
2 Control, tilled	0-15	1.21	17.4	0.83	17.80
	15-25	1.03	18.0	0.81	17.81
3 Tilled	0-15	1.11	16.7	0.76	17.38
	15-25	0.96	17.8	0.87	18.14
4 Chisel	0-15	0.55	16.2	0.81	16.68
	15-25	0.89	17.4	0.98	17.12
5 Controlled traffic	0-15	0.78	17.1	0.78	16.48
	15-25	1.03	18.2	0.99	17.32
6 Bedding	0-15	0.47	16.5	0.67	17.18
	15-25	1.00	17.3	1.05	16.94
7 Digging	0-15	0.69	16.5	0.62	15.96
	15-25	0.91	16.9	0.71	17.17
8 Mulching	0-15	0.72	17.8	0.58	18.17
	15-25	0.64	19.5	0.63	17.11

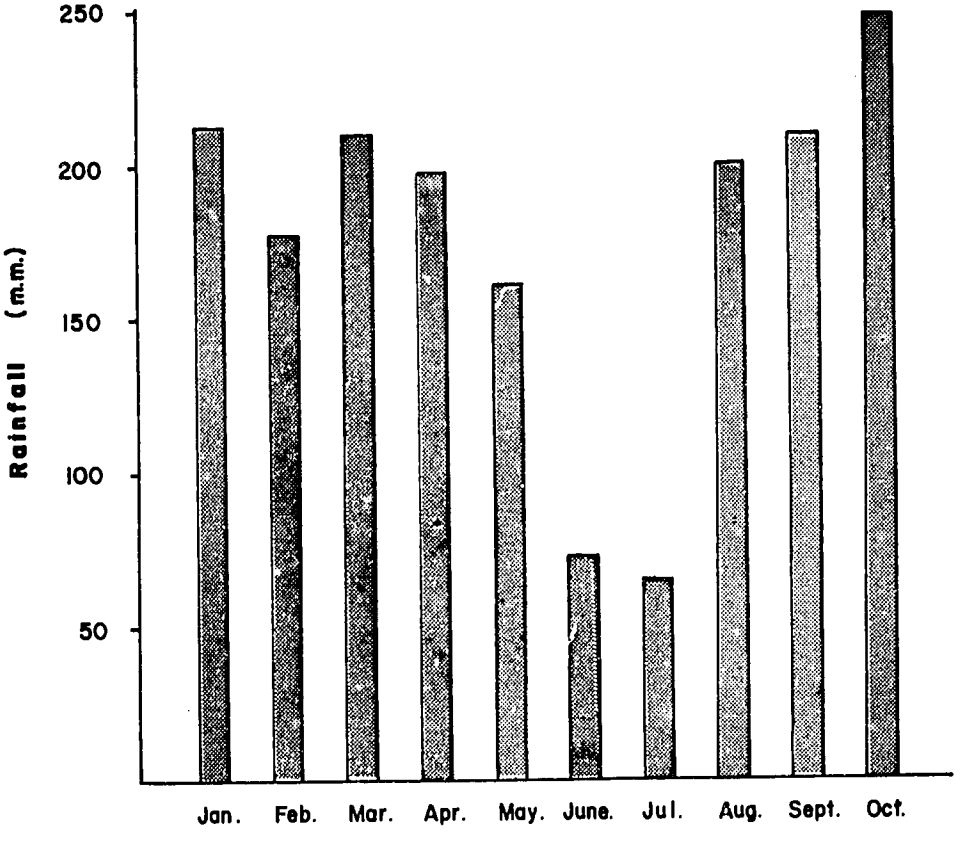


Figure 3.31:1. Monthly rainfall at Yurimaguas Station during the growing season 1980 with rice and soybean.

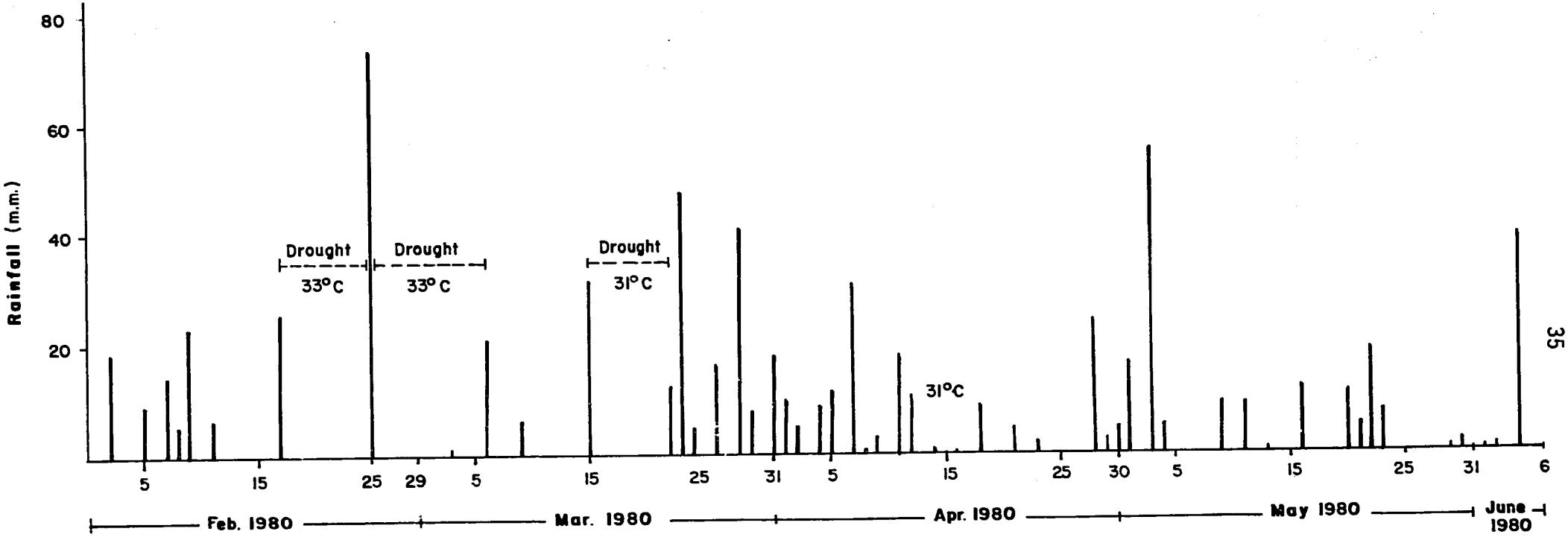


Figure 3.31:2. Daily rainfall at Yurimaguas Station during the 1980 rice growing season.

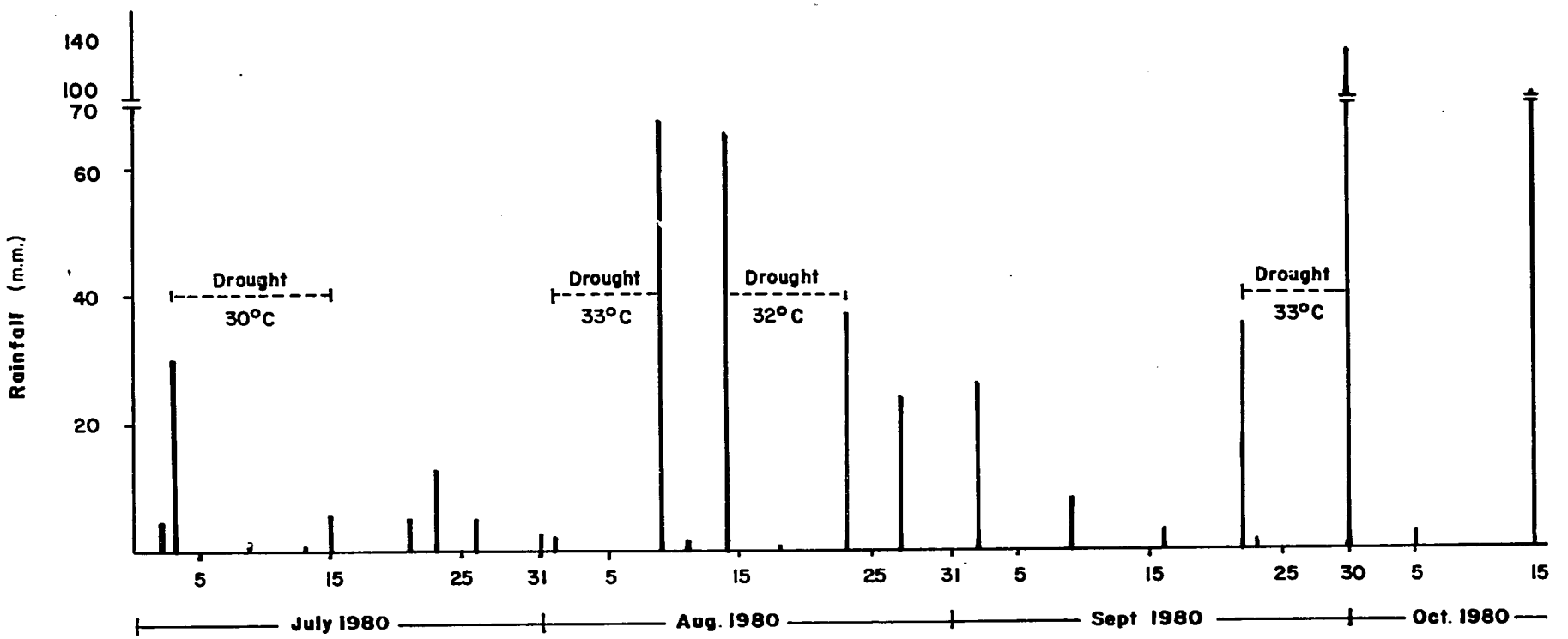


Figure 3.31:3. Daily rainfall at Yurimaguas Station during the 1980 soybean growing season.

3.32 Effect of land clearing methods on soil properties and crop performances

J. Alegre, D. K. Cassel, and D. E. Bandy

Land clearing research conducted in Yurimaguas in 1972 (see 1972 and 1973 annual reports) revealed that severe soil compaction decreased crop yields and led to abandonment of the land two years later. Because the 1972 study was not as comprehensive as it might have been, a decision was made to evaluate several alternative and clearing soil management systems for mechanical land clearing of Ultisols. Specific objectives of the study are 1) to determine the rate of change of selected soil physical properties resulting from alternative land clearing-soil management practices and 2) to evaluate crop performance as affected by the land clearing-soil management practices.

The study was conducted on a 2.5 ha site on the Yurimaguas Experiment Station. The Yurimaguas series soil was covered with a 20-year old secondary evergreen forest which had 232 m^2 wood per ha. Soil chemical properties of the soil prior to clearing are shown in Table 3.32:1.

The experimental design was that of a split plot replicated three times. The intent to replicate treatments four times was negated by limited availability of continguous land having the same age of secondary forest. The six main plot treatments were land clearing--soil tillage combinations and are defined in Table 3.32:2. The slash and burn treatment was located near the center of a block in order to prevent soil compaction during the process of mechanically clearing the other five treatments. The two plots cleared by "bulldozer with straight blade" were located side by side as were the three plots cleared by "bulldozer with KG blade." The main treatments minimized the use of large tractors for land preparation following clearing because no large tractors are available in the area.

The disking operation that followed clearing in treatments 4 and 6 was imposed by the same bulldozer used for the clearing operation. The disking operation cut up the larger tree roots that remained in the soil and incorporated trash left on the soil surface. One potential disadvantage of imposing this disking operation was further compaction of the soil. Moreover, disking too deeply mixes finer textured, B horizon material with the surface soil which may lead to soil crusting problems. Subplot treatments were various combinations of fertility and soil management practices as indicated in Table 3.32:3. Subplot size was 26 m x 6.5 m. Each crop and its date of planting and harvest are shown in Table 3.32:4.

Table 3.32:5 indicates the soil physical and chemical properties that were and continue to be intensively monitored with time. Changes in two of the soil physical properties listed above as influenced by clearing method are shown in Table 3.32:6. Bulk density in the 0 to 15 cm depth increased for all treatments including slash and burn;

increases in bulk density induced by clearing method were greatest in the following order: straight blade > KG blade > slash and burn. Bulk density increased by only 0.1 g/cm^3 in the 15-25 cm depth for both types of bulldozer clearing. The before-clearing infiltration rate of 64 cm/hr was reduced to values equal to only 8 and 14% of this initial rate for the straight blade and KG blade, respectively. Infiltration rate for soil cleared by slash and burn maintained a high infiltration rate of 51 cm/hr.

Grain yields for rice, the first crop planted on the cleared land, are given in Table 3.32:7. Rice yields for the non-fertilized plots were greater for treatments 1 and 4 because these treatments benefited from nutrients released by burning the vegetation. No ash was present in the other four treatments because the vegetation was physically removed from the plot area during the clearing operations. Fertilizer and lime applied to both the flat planted and bedded subplots increased grain yield for all treatments. Without the addition of fertilizer or lime, all mechanized clearing treatments decreased rice yields compared with the slash and burn treatment.

Table 3.32:1. Selected soil chemical properties on August 22, 1980, prior to land cleared. Yurimaguas, Peru.

Depth	pH	Acidity	Ca++ plus Mg++	Avail P	Al saturation
--cm--		-----meq/100cc-----		ppm	%
0-15	4.29	3.76	0.57	5.9	85
15-30	4.24	4.52	0.91	3.6	82
30-45	4.30	4.41	0.88	2.2	83

Table 3.32:2. Land clearing - soil tillage treatments. Yurimaguas, Peru.

Treatment No.	Description
1	Slash and burn with tree trunk removal by hand; plant with stick.
2	D-6 bulldozer with straight blade; trees immediately windrowed; plant with Planet, Jr.
3	D-6 bulldozer with straight blade; trees immediately windrowed; land chisel plowed, plant with Planet, Jr.
4	D-6 bulldozer with KG blade; vegetation dried on land, burned, then logs removed by bulldozer; disk with bulldozer; plant with Planet, Jr.
5	D-6 bulldozer clearing with KG blade; rotovate land with 65 h.p. tractor; plant with Planet, Jr.
6	D-6 bulldozer with KG blade; disk with bulldozer; 14 h.p. rotovator; plant with Planet, Jr.

Table 3.32:3. Subplot treatments for land clearing study. Yurimaguas, Peru.

Treatment No.	Description
1	Flat planted; no fertilizer or lime.
2	Flat planted; fertilizer and lime added based on soil test.[+]
3	Bedded at 1.1 m spacing; fertilizer and lime added based on soil test.

[+]Treatment 1 was rotovated with 14 h.p. rotovator when fertilizer applied.

Table 3.32:4. Chronological cropping history of land clearing study. Yurimaguas, Peru.

Crop	Date Planted	Date Harvested
Rice	November 28, 1980	March 30, 1981
Soybean	May 27, 1981	September 17, 1981
Corn+	September 30, 1981	November 18, 1981

+A severe windstorm lodged this crop; no grain was produced.

Table 3.32:5 Soil physical and chemical properties monitored during the land clearing study. Yurimaguas, Peru.

	Before Clearing	Immediately after Clearing	Later
Physical			
Bulk density	X	X	X
Particle size analysis	X	X	X
Soil water characteristic	X	X	X
Mechanical impedance	X	X	X
Infiltration rate	X	X	X
Aggregate stability	X	X	X
1500-KPa percentage	X	X	X
Chemical			
Organic matter content	X		X
Effective C.E.C.	X		X
Exchangeable cations	X	X	X
pH	X	X	X
Available P	X	X	X
Inorganic N	X	X	X

Table 3.32:6 Bulk density and infiltration rate before and immediately after clearing.

	Clearing Method	Bulk Density 0-15 cm	Bulk Density 15-25 cm	Infiltration Rate
		------- g/cc ------		cm/hr
Before Clearing		1.16	1.39	64
After Clearing	Straight blade	1.42	1.49	5.1
	KG blade	1.31	1.50	10
	Slash and burn	1.27	1.37	51

Table 3.32:7. Rice grain yield for the first crop harvested in the land clearing study. Yurimaguas, Peru.

Treatment	No Fertilizer	With Fertilizer	Bedded With Fertilizer	$\bar{X}$
	---------- Yield, t/ha ----------			
1	3.10	3.56	3.98	3.55
2	0.91	2.75	3.38	2.35
3	1.14	2.84	2.85	2.28
4	2.39	3.06	3.68	3.04
5	1.27	3.02	3.20	2.49
6	0.91	2.58	2.74	2.07
$\bar{x}$	1.62	2.98	3.30	

LSD = 0.43 Treatment
0.26 Subplots
0.65 Treatment x Subplots

This study will continue indefinitely until it appears that the rapid changes in soil physical properties have ceased. Based upon data collected to the present, the first two crops benefited from the nutrients released by the ash. Other than the nutrient effect, no clear recommendation about land clearing techniques can be made at the present time.

Development of technologies appropriate for and acceptable to the small farmers of the humid tropics is important.

3.4 Low Input Technologies

The major new research thrusts in Yurimaguas during the 1980-1981 period have centered on low input technologies. The continuous cropping work has shown that with adequate fertilizer and lime inputs relatively high yields of annual crops in rotation can be sustained over time. The potential with high inputs is there; what yet remain to be done is maintaining similar or even better yields by reducing or modifying the various inputs. Examples would include using crop varieties better adapted to the acid soil conditions, using the acidity of the soil to dissolve rock phosphate rather than having this done in a fertililzer factory and using organic amendments (with increased labor) to provide some crop nutrients normally obtained from inorganic lime and fertilizers. These and other low input approaches are discussed.

3.41 Selection of acid-tolerant cultivars

This activity focuses on the selection of species and cultivars best adapted to the soil and environmental conditions represented at the Yurimaguas Agricultural Experiment Station. The program is conducted in cooperation with national and international organizations which provide lines or cultivars which have been identified as most promising for the acid soils of the humid tropics. Starting with corn varieties supplied by the National Corn Program of Peru and CIMMYT in 1975, it expanded during the 1980-1981 period to soybean, cowpea, rice, various beans, sweet potato, and sugarcane from the Peruvian National Programs and IITA, ICRISAT, AVRDC, CIP and INTSOY. We extend our appreciation to these organizations for their excellent cooperation, as well as our thanks to NIFTAL who supplied *Rhizobium* strains for the soybean trials.

3.41A Cowpea (*Vigna unguiculta*)

M. I. Piha and J. J. Nicholaides, III

Preliminary 1980 experiment. Twenty-seven cowpea varieties were evaluated for their acid tolerance on an Ultisol in adjacent unlimed and limed trials, both arranged in completely randomized designs with four replications. Individual plots were 2 m x 2.5 m, each with four rows at 50 cm spacing.

Initial soil pH was 4.3-4.5, with Al saturation being 60-70% of the effective CEC of 1.4-1.9 meq/100 cc. Both trials received per hectare 40 kg P, 2 kg B, 2 kg Zn, 400 g Cu, 1 g Mo and sufficient K and Mg, as per soil test analysis, to give 0.3 and 0.4 meq/100 cc soil, respectively. All fertilizers were applied at planting, except for K which was thrice split at planting, two and five weeks. All seed were inoculated with the proper *Rhizobium* and 20 kg N/ha was applied as starter. Hydrated lime was applied to the limed trial at 1.65 times the exchangeable acidity.

Indices of varietal performance were plant height, grain yield, seed size and number, and harvest date and duration. Due to the indeterminance of most of the varieties, four harvest were taken from 65-85 days after planting.

Table 3.41A:1 shows the 27 varieties ranked according to their yield under acid (unlimed) conditions. Also shown is each variety's respective yield when grown on limed soil. With only four exceptions, all varieties yielded less under limed conditions than under native acid soil conditions. In some cases, yields were drastically reduced (more than 50%). Vegetative growth of the unlimed plots on the other hand, as measured by plant height at 50 days, was between 86 and 103% of the limed treatments for all varieties, except Tvx 2394-01F which was 79% (Table 3.41A:1). This verified field observations that in both soils plants were generally of good color and vigor, showing little vegetative effect by soil acidity. Also shown in Table 3.41A:1 is the seed set (seed/m^2) of the acid-grown cowpeas relative to the limed plots. These data reflect the relative yield data. It is apparent, therefore, that although liming had little effect on vegetative growth, it had a marked detrimental effect on reproductive growth. Reduced flowering and pod set (i.e., seed set) resulted in reduced yields.

Several agronomic characteristics of the 27 cowpea varieties are given in Table 3.41A:2. The days to final harvest of several varieties were increased by liming, although days to initial harvest were generally unaffected by lime. The other factors showed little or no effect due to liming and thus the values are the means of both acid and limed plots.

Dry season 1981 experiment. Ten cowpea varieties selected on the basis of their performance the previous season were further tested under both acid and limed soil conditions. The experiment consisted of a split-plot design with one half of each plot being acid and the other half limed (Table 3.41A:3).

Fertilization prior to planting consisted of 35 kg P, 50 kg K, 30 kg Mg, 3 kg Zn, 2 kg B, 400 g Cu and 200 g Mo on a per hectare basis, with a follow-up application of 50 kg K three weeks after crop emergence. During the growing season plant height at 30 and 35 days was recorded in order to evaluate the effect of soil acidity on vegetative growth. Harvesting commenced 62 days after planting and three harvests, at weekly intervals, were made for each variety.

Table 3.41A:4 summarizes the data for yield, relative yield, relative height, and relative pod number. Relative yield was defined as the ratio between the yield on acid soil over yield on lime soil. The same criteria was following for other variables.

The data indicate good performance of most cowpea varieties under these strongly acid soil conditions, with Vita 5 being the only variety significantly more sensitive to acid soil conditions. Vita 5 was more sensitive than the other varieties, both in terms of vegetative growth (relative height) and in grain yield (relative yield). This variety was included as a sensitive control on the basis of its performance the previous year, whereas all the other varieties were included as a result of their acid tolerance.

The average relative grain yield for the tolerant varieties was 90% (at 71% Al saturation), whereas the average relative height was 78% indicating a greater sensitivity of vegetative growth to acid soil conditions. This agrees with results of the previous season, i.e., where it was observed that the sink and not the source limited the yields of most cowpea varieties. Unlike the previous year, however, the liming did not decrease flower production, and hence, did not decrease yields.

In fact, as can be seen from Table 3.41A:4 the yield reductions on acid soils were due to a slight reduction in pod number, with no significant reduction in pod or seed size.

It should be pointed out that drought stress was experienced from 40 to 70 days after planting with only 51 mm of rain falling in this 30 day period. There is no doubt that the effect of this stress on yield was significant and may have affected the response to soil acidity.

The varieties Vita 4, Vita 6, Vita 7 and Vita 8 appear well adapted to the acid soils and climate during the dry season. Cowpea appears to be the ideal crop for low input production during the dry season and fits in very well with upland rice as part of a rotation for an acid soil. Nearly 20 t/ha can be produced in only 80 days with very little weed control due to the rapid vegetative growth of this species. However, good insect control is required due to severe attack by leaf chewing beetles, and more recently by flower thrips. Also signs of Mosaic virus were observed in all varieties toward the end of the season and should viral problems increase this could seriously jeopardize the future of this crop.

Table 3.41A:1. Yield of 27 varieties of cowpeas on acid and limed soil, and the relative yield, plant height at 50 days and seed set ratios of the acid plots compared to their respective limed plots, Yurimaguas, Peru, 1980.

Variety	Yield Acid	Yield Limed	Relative Yield	Relative Height	Relative Seed Set
	---- t/ha ---		------ acid/limed x 100, % ------		
Tvx 66-2H (Vita 8)	2.47	1.09	226	101	261
Tvx 1999-01F	2.38	1.43	166	99	162
Tvx 1999-02E	2.20	1.66	133	97	133
Vita 4	2.20	1.59	138	97	141
Tvx 289-4G (Vita 7)	2.13	1.56	137	87	134
Tvx 2949-01D	2.06	1.63	126	87	120
Tvx 1836-015J	2.04	1.64	124	89	131
Tvx 2394-02F	2.01	0.80	251	88	274
Vita 3	1.99	1.26	158	93	161
Tvx 3218-02D	1.95	1.20	163	103	207
Tvx 1948-01E	1.94	1.62	120	95	120
Tvx 1952-01E	1.89	1.97	96	--	94
Tvx 2949-03D	1.88	1.75	107	88	121
Tvx 3048-02D	1.87	1.56	120	93	120
Tvx 2907-02D	1.85	1.58	117	93	117
Tvx 2912-011D	1.81	1.41	128	86	135
Tvx 2939-09D	1.81	1.11	163	97	158
4R-0267-1F	1.79	1.40	128	93	132
Local	1.79	0.72	250	95	250
California BE 5	1.75	1.90	92	97	88
Tvx 33-1J	1.74	1.57	111	94	121
Vita 5	1.72	2.04	84	91	91
Tvx 1576-01E	1.71	1.30	132	93	131
Tvx 1850-01E	1.69	1.88	90	94	88
Tvx 2394-01F	1.68	0.58	290	79	318
Ife Brown	1.57	1.47	107	100	124
Tvx 7-4K	1.30	1.21	107	86	119

Table 3.41A:2. Agronomic characteristics for acid-limed cowpea trial, Yurimaguas, Peru, 1980.

Variety	Plant Height @ 50 days	Seed Weight per 100	Days to First Harvest 1/	Days to Final Harvest 1/	Lodging 2/	Seed Quality 3/	Growth Habit 4/
	- cm -	--g--	A - L	A - L	(0-4)	(0-4)	(0-3)
Tvx 66-2H	76	10.3	67-68	77-76	2.0	2.0	1
Tvx 1999-01F	62	10.7	65-66	76-78	1.4	1.0	1
Tvx 1999-02E	64	11.7	70-69	81-84	0.0	1.5	3
Vita 4	63	9.1	68-67	79-84	0.8	0.0	1
Tvx 289-4G	66	14.0	65-65	74-78	1.6	2.0	1
Tvx 2949-01D	70	13.9	66-65	74-77	3.0	2.5	3
Tvx 1836-015J	58	10.2	65-65	74-74	2.3	2.0	1
Tvx 2394-02F	70	11.0	68-69	74-79	2.5	1.5	3
Vita 3	70	17.1	65-66	74-77	1.5	3.5	3
Tvx 3218-02D	69	7.2	66-68	74-80	2.3	1.0	2
Tvx 1948-01E	68	10.6	66-66	74-77	1.4	2.0	3
Tvx 1952-01E	--	11.9	65-65	74-74	2.5	1.0	0
Tvx 2949-03D	72	10.0	65-65	74-79	2.9	0.0	3
Tvx 3048-02D	64	10.0	68-66	77-80	0.8	0.5	3
Tvx 2907-02D	68	10.4	65-66	74-76	3.0	0.5	3
Tvx 2912-011D	60	15.6	67-65	74-77	3.0	1.0	3
Tvx 2939-09D	71	11.6	66-67	80-85	1.5	2.0	3
4R-0267-1F	66	8.0	65-65	77-77	2.9	2.5	1
Local	72	13.6	67-69	85-85	1.1	1.5	3
California BE 5	77	17.3	65-65	76-76	3.0	2.5	1
Tvx 33-1J	72	10.6	65-66	74-80	2.5	3.0	3
Vita 5	54	10.6	65-66	74-79	1.1	1.0	1
Tvx 1576-01E	74	11.4	66-66	76-77	3.0	2.0	1
Tvx 1850-01E	66	11.6	65-66	74-79	1.9	2.0	1
Tvx 2394-01F	70	12.2	68-71	80-81	1.5	1.0	3
Ife Brown	68	14.2	67-68	79-83	0.3	4.0	3
Tvx 7-4K	60	6.6	65-66	74-76	2.6	0.0	0

1/ A = Acid; L = Limed

2/ Lodging data averaged for all eight replicates; 0.0 = no lodging increasing to 4.0 = all plants lodged.

3/ Seed quality data averaged for all eight replicates; 0 = perfect quality, 1 = good quality, 2 = acceptable quality, 3 = poor quality, 4 = exceptionally poor quality.

4/ Growth habit varies from 0, i.e., completely upright with no rambling or climbing nature, to 3, i.e., rambling and climbing nature is very marked and these varieties should preferably be grown using stakes.

Table 3.41A:3. Selected chemical analysis of soil samples from 1981 acid-lime cowpea experiment prior to planting. Yurimaguas, Peru.

Soil	pH	Exchangeable Al	Exchangeable Ca+Mg	Al Saturation	Modified Olsen P
		--meq/100 cc--		%	ppm
Acid	4.2	3.6	1.5	71	12
Limed	5.0	1.2	3.7	24	11

Table 3.41A:4. Grain yield and relative grain yield, height and number of pods of ten cowpea varieties growing in acid and limed soils, Yurimaguas, Peru, 1981.

Variety	Yield on Acid Soil*	Yield on Limed Soil*	Relative Grain Yield	Relative Height	Relative Pod Number
	---------- t/ha --------		---------- % ----------		
Vita 4	2.05 a	2.12 a	96 a	79 a	93 a
Vita 6	1.91 ab	2.01 a	95 a	75 a	86 a
Vita 8	1.80 abc	2.03 ab	89 a	81 a	88 a
Vita 7	1.74 abc	2.05 a	85 a	80 a	83 a
1999-01F	1.70 bcd	1.83 ab	94 a	75 a	94 a
2-Mesino (Local)	1.68 bcd	1.88 ab	89 a	79 a	90 a
1952-01E	1.57 cde	2.02 ab	79 ab	80 a	84 a
1836-015J	1.40 def	1.74 b	80 ab	82 a	85 a
1836-013J	1.30 ef	1.32 c	99 a	74 a	99 a
Vita 5	1.16 f	1.95 ab	59 b	56 b	59 b

*Data follwed by the same letter are not statistically different from each other at the 5% level by the Waller-Duncan test.

3.41B Peanut (Arachis hypogea)

M. I. Piha and J. J. Nicholaides, III

Preliminary 1980 observation. In a planting for observation to climatic adaptation, eight introduced varieties were compared with three local varieties on acid and limed soil (Table 3.41B:1). The introduced varieties were UF 78307, UF 78305, VA 78-336, Delhi, NC 3033, NC 2, NC 6, NC 7, Trifrun and Florigiant, all of which yielded less than 300 kg/ha due to a very severe attack of Cercospora (Table 3.41B:2). The three local varieties showed good resistance to Cercospora and gave yields of approximately 2 t/ha. Apart from the testa color, the three local varieties (Yungas, Tingo Maria, Blanco Tarapoto) were indistinguishable from one another.

Since susceptibility to Cercospora did not allow for studying the adaptability of these varieties to acid soil conditions, a new experiment was planned.

Acid-lime 1981 experiment. Nine introduced varieties were compared with the local variety, Blanco Tarapoto, under both acid and limed soil conditions. All varieties received a biweekly application of "benomyl" to control Cercospora.

Each variety was planted in a single line 3.5 m long with 50 cm between plants. Four replicates were planted on both the acid and on the limed soils. Both treatments received an application of 35 kg P, 37 kg Mg, 140 kg K, 3 kg B, 3 kg Zn, 1 kg Cu and 300 g Mo/ha. All fertilizers were applied and incorporated before planting, except for K which was split between pre-planting and at flowering. The chemical analyses of soil samples taken midway through the growing season are presented in Table 3.41B:3.

The seed was not inoculated nor was N applied, but fortunately it was apparent that the native rhizobium were adequate. In addition to the above fertilizers, 200 kg/ha of gypsum (46 kg Ca/ha) was broadcast at time of pegging. At maturity (110 days for Blanco Tarapoto, 120 days for all other varieties) the plants were harvested and data for top weights, yield, shelling percentage were recorded.

The biweekly applications of benomyl gave excellent control of Cercospora, thus allowing yield potential and acid tolerance to be evaluated. Data for yields and yield components under acid and limed conditions are summarized in Table 3.41B:4.

Under limed soil conditions, only one variety (UF 78307) significantly outyielded the local check (Blanco Tarapoto). Under acid soil conditions, however, Blanco Tarapoto proved to be one of the most sensitive varieties whereas UF 78307 was once again the top yielder. Relative yields of peanuts (yield on acid soil/yield on limed soil) ranged from 13% to 71% indicating a large variation in tolerance to soil acidity. The yield of UF 78307 at 82% Al saturation was 2.08 t/ha of shelled nuts or 2.82 t/ha of unshelled nuts. Such yield level suggests

that production of this variety under very acid soil conditions may be feasible, but unfortunately the need for frequent applications of fungicide limits its potential as a low input crop.

There appears to be strong varietal differences for peanuts with regard to the effect of soil acidity on vegetative growth and source: sink relationships. For instance, the harvest indices and shelling percentages of the varieties UF 78305 and UF 78307 were maintained under acid conditions, and the reduction of these varieties' yields as brought about by the soil acidity was essentially equivalent to the corresponding reduction in vegetative growth. For other varieties, such as Blanco Tarapoto, NC 6 and NC 7, acid conditions apparently interfered with the partitioning of photosynthate. These varieties showed no reduction in top weights at harvest due to soil acidity, but there was a strong effect on the harvest index and on the shelling percentage.

It is known that the seed formation process of peanuts has a very high requirement for elemental Ca and it is probable that the low levels of soil Ca in the acid soil treatment had a strong influence on the results. Calcium deficiency in peanuts is usually manifested by the presence of empty pods, and thus the reduction in shelling percentage observed in most varieties on the acid soil could be due to an insufficient supply of Ca rather than to high levels of soil Al.

Considering the yield performance of UF 78307 under both acid and limed conditions, this variety must be compared further with Blanco Tarapoto to ascertain where it should be introduced into the area. The sensitivity of UF 78307 to *Cercospora* is a serious drawback and the economics and the continued effectiveness of fungicidal applications need to be carefully evaluated. At present, however, the cost of the fungicide is equivalent to about 100 kg of peanuts, thus making chemical control of *Cercospora* economically worthwhile.

The local variety, Blanco Tarapoto, showed good resistance to *Cercospora*. As good yields of Blanco Tarapoto are possible without the use of fungicides, it becomes the obvious variety for low input conditions. As far as production under acid soil conditions is concerned, further research is clearly warranted. Considering the facts that the top growth of this variety has indicated high tolerance to soil acidity, and that good yields have been obtained in the liming experiment at Yurimaguas at levels of 55% Al saturation, it may be that the reason for the low yields in this experiment on the acid soil was due to Ca deficiency.

Table 3.41B:1. Selected chemical analysis of soil samples from preliminary acid-lime peanut observations. Yurimaguas, Peru.

Soil	pH	Exchangeable Al	Exchangeable Ca+Mg	Al Saturation	Modified Olsen P
		--meq/100 cc--		%	ppm
Acid	4.5	5.6	2.0	75	5
Limed	5.1	1.7	6.6	20	9

Table 3.41B:2. Yield data and Cercospora sensitivity of introduced and local peanut varieties in acid-limed treatment observation. Yurimaguas, Peru, 1980.

Variety	Seed Yield A*	Seed Yield L*	Seed Yield Relative	Stubble Weight A*	Stubble Weight L*	Stubble Weight Relative	Cercospora Sensitivity**
	--g/m--		%	--g/m--		%	
UF 78307	33	47	70	230	380	61	61
UF 78305	24	52	46	240	320	75	49
UF 75102	19	31	61	180	240	75	57
UA 7833-6	23	42	55	250	320	78	53
NC 3033	15	40	38	680	960	71	44
Florigiant	29	57	51	800	980	82	46
NC 7	41	47	87	720	510	141	51
Tifrun	26	26	100	190	280	68	52
Yungas	16	43	37	640	580	110	33
NC 2	18	28	64	1080	1140	95	33
NC 6	33	65	51	1040	980	106	44
Tingo Maria	17	45	38	670	650	103	8
B. Tarapoto	14	46	30	650	780	83	14
B. Tarapoto	18	48	38	770	740	92	16
B. Tarapoto	15	40	38	700	710	98	11

*A = Acid; L = Limed

**Percentage of the ten uppermost leaves that were lost, based on data taken at 70 and 100 days.

Table 3.41B:3. Selected chemical analysis of soil samples from acid-lime peanut experiment. Yurimaguas, Peru, 1981.

Soil	pH	Exchangeable Al	Exchangeable Ca+Mg	Al Saturation	Modified Olsen P
		--meq/100 cc--		%	ppm
Acid	4.2	4.7	5.7	82	10
Limed	4.9	1.9	5.4	35	10

Table 3.41B:4. Yield and selected yield components of peanut varieties under acid and limed conditions. Yurimaguas, Peru, 1981.

Variety	Acid Soil A*	Limed Soil L*	Relative Yield	Shelling Percentage A*	Shelling Percentage L*	Relative Shelling Percentage	Fresh Wt. of Tops A*	Fresh Wt. of Tops L*	Relative Top Weight	Harvest Index A*	Harvest Index L*	Relative Harvest Index
	------- t/ha -------		---------- % ----------				----- t/ha ------		%	(nut yield/fresh)		%
UF 78305	1.75	2.48	71	72	76	95	10.0	16.1	62	1.75	1.54	114
UF 78307	2.08	3.34	62	74	76	97	14.0	22.3	63	1.49	1.50	99
Florigiant	1.27	2.34	54	68	74	92	17.1	27.1	63	0.74	0.56	86
NC 2	1.22	2.24	54	67	71	94	23.7	30.6	77	0.51	0.73	70
Trifrun	1.02	2.38	43	66	76	59	11.5	20.9	55	0.89	1.14	75
NC 3033	0.84	2.08	40	61	75	81	24.1	30.7	79	0.35	0.68	81
NC 7	0.98	2.55	38	63	75	84	19.9	20.2	99	0.49	1.26	39
UA 7833-6	0.94	2.57	37	62	74	84	19.6	22.3	88	0.48	1.15	42
Blanco Tarapoto	0.55	2.69	20	40	74	54	28.3	22.4	126	0.20	1.20	17
NC 6	0.31	2.30	13	42	73	58	25.9	24.0	108	0.12	0.96	13

* A = Acid; L = Limed

3.41C Soybean (Glycine max L. Merr.)

M. I. Piha and J. J. Nicholaides, III

Twenty-two varieties of soybean were grown on an acid and limed soil in a completely randomized block with three replications. Each variety occupied a 2.5 m x 1.6 m plot (i.e., 4 rows at 40 cm apart, and 20 cm within row spacing). The chemical properties of the acid and limed soils taken before application of fertilizers are given in Table 3.41C:1.

Phosphorus was applied to both soils at a rate of 40 kg P/ha before planting. Although the acid soil had a lower soil P value before application, previous experience suggested that 40 kg P/ha was sufficient to eliminate P deficiency on such sandy soils. Molybdenum was mixed with the seed at the rate of 1 g Mo/kg seed. The remaining fertilizers were applied in three equal quantities at 0, 3 and 6 weeks after planting. Rates per hectare used were 63 kg Mg, 102 kg K, 2 kg B, 2 kg Zn, and 400 g Cu. The use of simple superphosphate and potassium-magnesium sulfate fertilizers supplied 85 kg Ca/ha and 170 kg S/ha. All seed were heavily inoculated with a mixture of rhizobium strains supplied by NiFTAL and "Nitragin". Both the inoculants contained bacterial strains considered well adapted to acid soils.

Initially crop growth and development was similar on both soils. However, as time progressed, soybeans growing on the acid soil showed obvious reduction in vegetatiave growth as compared with those on the limed soil. Height data was collected at 54 days as a means of comparing the relative vegetative growth of each variety on the two soils (Table 3.41C:2).

As each variety matured, grain yield data were collected from the two center rows. The varieties were ranked according to their acid tolerance, i.e., the most tolerant varieties are those with the highest yields relative to their respective limed soil yields (Table 3.41C:2).

Data were also collected for number of pods per plant, seed size and seeds per pod for both the acid and the limed treatments. The reduction in yield brought about by soil acidity was due to a combination of those three yield components. Table 3.41C:3 shows the relative component values of each of the above three factors under acid compared with limed conditions. Table 3.41C:4 gives a summary of other important agronomic data collected, including days to maturity, lodging, susceptibility to leaf chewing insects and weight per 100 seeds.

Soil acidity led to reduced yields of soybeans from 34 to 58% and in plant height from 68 to 92% of their respective limed plot values (Table 3.41C:2). However, reduction in yield was not correlated with reduction in height. The top three varieties with least yield reduction (Hardee, SJ 2 and Tunia ICA) were ranked 12, 18 and 21 in least height reduction. Although there was significant variability among the varieties, even these three tolerant varieties must be considered sensitive to soil acidity. They had yield reductions of 42% (58% of their

limed yields) due to soil acidity, while in an adjacent experiment of cowpea varieties, the most acid sensitive cowpea variety only showed a 16% yield decline, as brought about by similar levels of soil acidity.

It is interesting to note, that for 20 out of the 22 varieties, a reduction in pod number per plant was the single most important reason for yield reduction, as brought about by the soil acidity. Varieties L-109-ICA and Jupiter are two notable exceptions, in that on the acid soil they had a relatively high number of pods (Table 3.41C:3). Yield reduction of L-109-ICA and Jupiter was due mainly to the much smaller seed size produced by the plants on the acid soil. Jupiter is the current variety in the Yurimaguas area, and the data suggest that its continually reliable performance is probably related to the fact that the environment does not have too adverse an effect on the number of pods produced.

On the limed soil, Tunia was the highest yielding variety (2.50 t/ha), but these yields were not significantly higher than those of Jupiter (2.23 t/ha). Apart from soil acidity, another major limiting factor to soybean production in the area is leaf chewing insects. Most farmers do not have access to insecticides and sprayers, and if pesticides are not applied, these insects would probably totally eliminate the effective leaf area. As is shown in Table 3.41C:4, there is a range in susceptibility to attack by beetles, but no truly resistant variety was observed. Hardee showed considerably more resistance to insect attack than did Jupiter, and also outyielded Jupiter on the acid soil (1.23 t/ha vs. 0.93 t/ha). Yields on the limed soil were similar (Jupiter 2.23 t/ha, Hardee 2.13 t/ha), but one should take into account that Hardee had a much shorter growing season (87 days for Hardee vs. 100 days for Jupiter). Hardee should probably be recommended, therefore, as a variety for the area, especially for use in lower input systems.

Further work with soybeans in Yurimaguas should have three main objectives: (1) screening of a large amount of germplasm in order to determine if there are acid-tolerant lines; (2) selection for varieties which can outyield Jupiter under conditions of high input; (3) observation of germplasm for possible resistance to leaf chewing beetles. Interest in soybeans among the local farmers is exceptionally high, both as a source of income and for use as human food, thereby justifying further research.

Table 3.41C:1. Selected properties of soil samples from acid-limed soybean experiment, prior to fertilization. Yurimaguas, Peru, 1981.

Soil	pH	Exchangeable Al	Exchangeable Ca	Exchangeable Mg	Exchangeable K	Effective CEC	Al Saturation	Modified Olsen
		---------- meq/100 cc				----------	- % -	- ppm -
Acid	4.3-4.5	1.15-1.95	0.2	0.05	0.05	1.7-2.4	68-81	1-3
Limed	5.2-5.5	0.0-0.3	2.6	0.05	0.05	2.6-2.8	0-11	8-16

Table 3.41C:2. Grain yield and height of 22 soybean cultivars grown on acid and limed soils and their respective relative values (acid as a percentage of the limed). Yurimaguas, Peru, 1981.

Variety	Yield		Relative Yield (acid/limed)	Height		Relative Height (acid/limed)
	Acid Soil	Limed Soil		Acid Soil	Limed Soil	
	--- t/ha ----		%	---- cm -----		%
Hardee	1.23	2.13	58	17	23	74
SJ-2	1.20	2.07	58	46	64	72
Tunia ICA	1.13	1.97	58	39	50	78
Orba	1.20	2.17	55	46	56	82
Caribe ICA	1.17	2.13	55	49	55	89
L-109-ICA	1.17	2.13	55	32	44	73
Mineira	0.93	1.70	55	21	23	91
UFV-1	1.07	1.97	54	22	24	92
Davis	0.90	1.70	53	20	22	91
IAC-2	1.10	2.13	52	51	66	77
Lili-ICA	1.00	1.97	51	50	62	81
Mandarin-S_4-ICA	1.10	2.23	51	51	71	72
L 658-8	0.93	2.00	47	25	28	89
Pelicano	1.00	2.20	45	50	69	72
AC 2120	0.70	1.63	43	55	71	77
Jupiter	0.93	2.23	42	41	57	72
Caribe	0.87	2.10	41	43	55	78
Tunia	0.97	2.50	39	44	55	80
Tarua ICA	0.85	2.27	37	32	36	89
Pelican-SM-ICA	0.80	2.20	36	53	70	76
Improved Pelican	0.76	2.20	35	49	60	82
L-110-ICA	0.70	2.03	34	43	63	68

Table 3.41C:3. Yield components of 22 soybean varieties grown on acid soils, expressed as a percentage of their respective limed soil values. Yurimaguas, Peru, 1981.

Variety	Relative Pods/Plant	Relative Seeds/Pod	Relative Seed Weight
	--- acid soil plants/limed soil plants x 100, % ---		
Hardee	75	84	95
SJ-2	70	91	99
Tunia ICA	73	84	97
Orba	76	88	95
Caribe ICA	76	82	93
L-109-ICA	93	71	89
Mineira	70	90	92
UFV-1	79	78	97
Davis	68	85	96
IAC-2	74	81	92
Lili-ICA	65	97	91
Mandarin-S_4-ICA	67	88	90
L 658-8	62	88	92
Pelicano	55	89	96
AC 2120	56	94	89
Jupiter	90	64	88
Caribe	59	86	93
Tunia	66	85	91
Taroa ICA	51	95	94
Pelican-SM-ICA	58	95	88
Improved Pelican	52	82	96
L-110-ICA	55	88	93

Table 3.41C:4. Complementary agronomic data on soybean acid-limed experiment. All data are from the limed soil, unless otherwise stated. Yurimaguas, Peru, 1981.

Variety	Days to Maturity		Lodging[1]	Insect susceptibility[2]	100 Seed weight
	Acid soil	Limed soil			
					-- g --
Hardee	83	87	0	1.8	18.4
SJ-2	84	87	1.4	3.6	14.3
Tunia ICA	85	95	0	2.6	17.3
Orba	83	87	2.2	3.0	13.8
Caribe ICA	95	100	1.0	2.4	15.2
L-109-ICA	90	98	0.4	2.8	13.7
Mineira	83	84	0	2.0	17.0
UFV-1	85	96	0	1.8	19.0
Davis	84	88	0	1.8	18.0
IAC-2	83	89	2.2	3.0	17.5
Lili-ICA	90	94	2.6	3.2	15.6
Mandarin-S_4-ICA	87	95	1.8	3.4	16.4
L 658-8	83	95	0	2.0	18.8
Pelicano	84	90	1.6	3.2	15.0
AC 2120	92	94	2.2	2.8	6.9
Jupiter	91	100	1.0	2.8	22.3
Caribe	93	101	1.2	2.2	14.9
Tunia	87	97	0	3.6	17.7
Taroa ICA	83	87	0.4	3.0	17.2
Pelican-SM-ICA	84	87	2.8	3.8	14.3
Improved Pelican	83	88	1.0	3.0	16.3
L-110-ICA	84	92	1.2	2.8	15.3

[1]Lodging scale is: 0 = no lodging; 1 = few plants lodged; 2 = 50% lodged; 3 = all plants are lodged.

[2]Insect susceptibility scale is from 0 to 4: 0 indicates no holes in leaves due to leaf chewing insects; 1 indicates a low incidence; 1.5 is the threshold level, at about which the application of insecticides is needed; 4 indicates extremely severe insect attack.

3.41D Rice (Oryza sativa)

M. I. Piha and J. J. Nicholaides, III

Previous rice varietal selection at Yurimaguas has been concerned with blast tolerance and short plant stature to replace the tall traditional variety. The problem of blast is extremely severe with the majority of introduced varieties offering little resistance. Considering the seriousness of this disease, it was decided that the evaluation of acid tolerance would be carried out only on varieties which had been shown to have a fair degree of blast tolerance. Germplasm was supplied by Ing. Javier Alva of INIPA, on the basis of selection from various international nursery trials carried out the previous year at Yurimaguas. Fifty-two varieties were selected, all of which had produced an estimated yield of over 3 t/ha.

The experiment consisted of a split plot design with three replications. One half of each plot was limed at a rate of 4.2 t/ha, while the other half was left unlimed. Preplant soil analysis showed the soil to have a pH of 4.2, 4.5 meq Al/100 cc of soil, and 83% Al saturation. Soil analysis performed 50 days after planting showed a pH of 4.2 and 4.9, exchangeable Al 3.9 and 1.7 meq/100 cc, Ca + Mg 1.6 and 3.9 meq/100 cc, and 71% and 30% Al saturation for unlimed and limed plots, respectively. Available P was 15 ppm by modified Olsen method in both unlimed and limed plots. Each variety was planted in a single row, with 25 cm between rows, and the varieties being arranged approximately according to height to minimize differences due to shading. Seeds were planted 3 cm apart within the row. The overall plot length was 5 m, 2.5 m limed and 2.5 m acid.

Fertilization consisted of a preplant application per hectare of: 50 kg P, 60 kg K, 37 kg Mg, 3 kg B, 3 kg Zn, 2 kg Cu, and 1 kg Mo. Nitrogen and potassium were further added in three split applications at 25, 40 and 65 days, resulting in a final total of 90 kg N and 140 kg K per hectare.

The incidence of leaf blast was recorded at 27 and 48 days using the International Blast Tolerance Scale (0 = no attack to 9 = death). The results showed that plants growing under conditions of soil acidity were more seriously affected by blast than those on the limed soil. The mean blast score for all 52 varieties combined was 2.2 for the limed soil and 3.0 for the acid soil. The variation among varieties was, however, much greater, ranging from 0 to 7. By about 60 days, all varieties had recovered and there was very little evidence of leaf lesions.

Starting at about 50 days and continuing until 65 days the rice plants underwent a period of water stress, as could easily be seen by the rolling of the leaves. At the peak of this period the varieties were assessed for drought tolerance based on the extent of leaf rolling and root length in the 30-45 cm soil zone was measured using Newman's method (Table 3.41D:1).

The data reflect a tendency for drought tolerant varieties to have deep roots. Then again, the situation was more complicated, as the drought sensitive variety IR 10781-175-1 apparently had the same root length between 30-45 cm as did the very drought tolerant Moroberekan. In order to understand the apparent lack of stress visible in Colombia 1, a soil pit was dug to investigate its root system. It was observed that this variety had considerable rooting up to a depth of 75 cm, well into the nutrient poor and strongly acid subsoil.

The grain yields on both limed and acid soil are given in Table 3:41D:2, with the varieties ranked according to yield on acid soil. Several of the varieties yielded very well and/or showed little or no sensitivity to the acid conditions. This was even under a situation of high disease pressure.

The period between panicle emergence and grain fill for most varieties was one of cool, wet and cloudy conditions which consequently led to a very serious attack of neck blast. As a result of this blast, 20 out of the 52 varieties produced no grain at all and a further 17 varieties suffered from 50% or more empty panicles. This emphasizes the fact that blast tolerance is a critical selection criteria for introduced varieties to this area, especially considering that last year all 52 varieties produced over 3 t/ha. Table 3.41D:2 rates neck blast symptoms among the varieties. The scale used varies from 0 (no empty panicles) through 10 (100% empty panicles). Only the traditional African variety Moroberekan showed no signs of attack and only four other varieties showed 10% or less empty panicles (CICA 8, Suakoko 8, Carolino (local variety), TOX 494). Susceptibility to neck blast was probably the most important factor affecting grain yields in this trial; but, unlike leaf blast, there were no obvious differences between the acid and limed treatments.

The four highest yielders under conditions of soil acidity or limed soil were Colombia 1, CICA 8, IR 9671-01141-5, Suakoko 8. At present these four varieties would best be recommended for the region, but it must be noted that these results were obtained from single row plantings and that the actual yields obtained were probably strongly influenced by the competitive ability of the adjacent varieties. The selected lines will have to be further tested in individual blocks for several seasons to establish whether their blast tolerance is long lasting.

IR 4-2 is the currently recommended short stature variety for the area, based on continual blast tolerance and high yields over several years experience. The present data show IR 4-2 to be moderately acid tolerant and to have produced a yield of over 3 t/ha on the limed soil. However, the leaf blast rating of 4 and a loss of about 40% of the panicles at maturity due to neck blast is worrisome. In separate, but adjacent, experiments leaf blast reached a score of 6 on the international scale. Fortunately, however, other large plots at the experiment station but situated further away from the above experiment were totally free of blast.

Further work is being continued in the following directions: 1) Seven varieties have been selected from the above data to compare performance under drought conditions. These varieties were planted about two months before the end of the wet season. 2) About 15 selections from the above will be planted in a similar acid tolerance experiment next wet season, but blocks will be used instead of single lines. 3) Varieties Colombia 1 (acid tolerant, blast resistant, deep rooted, intermediate stature, low tillering) and IR 4-2 (short stature, high tillering, moderate acid and blast resistance) have been crossed and future selection will take place under acid soil conditions with the aim of producing a high yielding, acid tolerant, semi-dwarf and disease resistant variety. 4) The above 52 varieties are presently being evaluated for their potential as a ratoon crop.

For the moment, considering the yield of 3.57 t/ha by Colombia 1 under conditions of acid soil and drought stress, the potential for improved upland rice production under conditions of low input seems very promising.

Table 3.41D:1. Drought tolerance by leaf rolling and root length in the 30-45 cm soil depth for eight selected rice varieties. Yurimaguas, Peru, 1980.

Variety	Drought Tolerance	Relative Root Length @ 30-45 cm depth
		cm
Colombia 1	High	23
Moroberekan	High	14
Carolino	Moderate	26
IAC 47	Moderate	16
IR 4-2	Slight	18
Mahsuri	Sensitive	9
CICA 8	Sensitive	8
IR 10781-175-1	Sensitive	15

Table 3.41D:2. Upland grain yield, plant height and blast (*Pyricularia oryzae*) ratings for 32 rice varieties. Yurimaguas, Peru. 1980.

Variety	Grain yield on soils: acid	Grain yield on soils: limed	Relative Yield (acid/lime)	Height	Blast score: leaf	Blast score: neck
	--- t/ha ---		%	cm	0-9	0-10
Colombia 1	3.57	3.48	104	118	1	2
CICA 8	3.25	4.19	77	93	1	1
IR 9671-01141-5	3.16	3.51	88	106	2	3
Suakoko 8	3.14	3.21	97	123	1	1
IR 3262-3-9-4-5	2.46	2.55	95	84	2	4
IR-4-2	2.42	3.14	77	95	4	4
IAC 47	2.22	2.49	90	136	1	2
Moroberekan	2.09	2.48	84	144	0	0
Tox 494	2.03	3.04	70	128	3	1
IR-4422-6-2	2.03	1.81	113	112	2	4
IR-10781-75-3-2	1.96	2.32	88	102	3	4
IR 5853-198-1-2	1.78	2.34	75	95	3	5
IR 4505-4-1-2	1.50	2.14	70	95	4	4
CR 1113	1.48	2.66	57	94	1	5
Carolino (local)	1.48	2.43	62	150	1	1
IR 9849-72-3	1.45	1.47	96	104	2	5
MRC 172-9	1.40	1.84	81	108	3	4
IR 4288-78-2-1-3	1.18	1.46	81	130	1	5
Mahsuri	1.12	1.74	65	118	4	3
IR 10781-175-1	1.11	1.38	83	86	3	6
IR 3483-180-2	1.04	1.28	82	95	1	6
GAMA 318	1.02	1.45	69	97	4	6
IR-4744-257-1-3	0.86	1.50	56	109	3	7
C 186	0.71	0.98	77	103	5	6
BR 51-46-1-CI	0.68	0.94	72	111	3	5
IR 8073-231-3-3	0.66	1.18	55	93	4	4
IR 4722-167-1-1-3	0.52	0.78	71	91	1	5
C 22	0.50	1.06	49	120	3	5
IR 3880-13	0.50	0.75	71	96	5	6
IR 4215-27-3-2-2	0.47	0.86	54	124	4	5
IR 2061-522-6-9	0.44	0.74	61	82	4	8
INTI	0.34	1.97	18	82	5	6
$\bar{X}$ of 20 other lines	0	0	0	n.a.	2-7	10

3.41E Sweet Potatoes (Ipomea batatas)

M. I. Piha and J. J. Nicholaides, III

Performance in acid and limed conditions

A total of 20 varieties were selected from previous experiments and planted the following rainy season. Five commercial varieties from the coastal area of Peru were included in the experiment. The experiment consisted of a split plot design with three replications. One-half of each plot was limed at a rate of 2.2 t/ha, while the other half was left unlimed. Soil analysis taken midway through the growing season is shown in Table 3.41E:1.

The entire field was manually tilled up before planting, leaving one meter between ridges. Due to lack of sufficient planting material, four cuttings only were planted per ridge over a length of 2 meters. Throughout the experiment the trailing vines of the Me sweet potatoes were controlled so as to contain their vegetative growth within the 2 m x 1 m plots.

Preplant fertilization consisted of 25 kg P (as SSP), 30 kg N (as urea), 36 kg K and 22 kg Mg (as K $MgSO_4$)), 2 kg Zn, 2 kg B and 1 kg Cu on a per hectare basis. Further applications of potassium and nitrogen were made at 40 and at 55 days (i.e., 30 kg N, 72 kg K applied each time). After four months the plants were harvested and the weights of the fresh roots and tops recorded. Samples of the roots were dried in order to determine the percentage dry matter per each variety.

Yields were in general very good with the lines from IITA outyielding the Peruvian varieties, and with the yields on the limed soil being higher than on the acid soil. Relative root yields (acid soil/limed soil) ranged from 7% to 97% with dry matter content of the roots ranking from 21% to 40%. The overall results are summarized in Table 3.41E:2.

Table 3.41E:1. Soil analysis of limed and unlimed plots on sweet potatoes experiment.

Soil	pH	Exch. Al	Effective CEC	Al Saturation	Modified Olsen P
		------ meq/100 cc ------		- % -	- ppm -
Acid	4.3	2.0	3.0	67	12
Limed	4.9	1.1	3.2	34	13

Table 3.41E:2. Performance of several newly introduced and commercial varieties of sweet potatoes under acid and limed soil conditions.

Entry Number	Origin	Fresh Root Yield		Dry Matter Content	Relative Yield	Harvest Ratio*		Relative Harvest Index
		Acid Soil	Limed Soil			Acid	Limed	
		--------- % ---------		- % -	- % -			- % -
Y-2	IITA	10.8	20.0	37	54	.15	.19	79
Y-3	IITA	13.1	23.9	36	57	.14	.23	61
Y-4	Peru	6.5	13.3	31	48	.11	.18	61
Y-5	IITA	3.9	15.0	28	26	.04	.10	40
Y-6	IITA	13.9	24.6	29	57	.15	.31	48
Y-7	Peru	8.5	12.8	36	67	.19	.16	119
Y-8	IITA	15.2	28.1	36	54	.22	.33	67
Y-9	IITA	13.5	23.0	36	59	.46	.52	88
Y-10	IITA	21.1	29.7	26	71	.17	.18	94
Y-11	Peru	2.9	7.1	38	42	.05	.10	50
Y-12	IITA	--	--	--	--	--	--	--
Y-13	IITA	12.9	21.4	35	62	.16	.23	70
Y-14	IITA	10.2	16.7	31	62	.10	.16	63
Y-15	IITA	17.3	24.3	35	72	.35	.45	78
Y-16	IITA	20.1	25.5	29	79	.33	.41	80
Y-17	Peru	5.1	11.3	29	46	.10	.14	71
Y-18	IITA	19.4	25.6	31	76	.31	.53	58
Y-19	IITA	31.4	32.1	21	97	.43	.47	91
Y-20	IITA	18.0	38.1	33	47	.21	.36	58
Y-21	IITA	19.6	21.9	36	90	.39	.43	91
Y-22	IITA	20.3	32.6	32	62	.30	.34	88
Y-23	Peru	0.4	7.0	32	7	.005	.06	8
Y-24	IITA	16.5	24.8	35	67	.32	.45	71
Y-25	IITA	18.3	32.5	29	56	.21	.37	57
Y-26	IITA	21.1	27.5	40	77	.54	.56	96
Y-27	IITA	12.4	25.1	34	50	.16	.33	48

*Harvest ratio = Dry weight of root/fresh weight of top.

The table also indicates the harvest ratios observed (i.e., dry weight of root/fresh weight of top). There was a very large range in this harvest ratio (i.e., 0.005 to 0.40 on the acid soil, 0.06 to 0.56 on limed soil) indicating a conversion of leaf photosynthate into a harvestable root. For some varieties (i.e., Y-17, Y-10, Y-26) the soil acidity had no apparent affect on the harvest ratio (i.e., for these cases acidity did not affect source-sink relationships and the reduction in yield as brought about by soil acidity was essentially proportional to the reduction in vegetative growth). For other varieties (i.e., Y-27, Y-25, Y-24, Y-16, Y-14) there was no significant reduction in vegetative growth of the tops as recorded at harvest but yields were reduced on the acid soil due to a reduction in harvest ratio i.e., per these varieties soil acidity reduced yield only because of its effect on the source-sink relationship. For most varieties, however, reduction in yield on the acid soil was due to both a reduction in vegetative growth and a reduction of the harvest ratio.

Fresh root yields of 31 t/ha on an acid soil and 38 t/ha on limed soil are very high, and if such yields can be maintained on a larger scale the potential for sweet potatoes in the Amazon area will be excellent. Variety Y-20 produced 12.6 tons of dry matter in only four months which indicates good possibilities for the use of sweet potatoes as "energy crop." Considering the importance of pigs in the area there may also be a potential use for sweet potatoes as a source of pig feed (i.e., both tops and roots).

From one point of view sweet potato production on acid seems promising (i.e., the best varieties gave 8.4 t/ha dry matter or 3 t/ha fresh root in only four months). On the other hand, if one were to use lime, the best variety could produce 12 tons/ha dry matter i.e., an increase of 50% compared with the best acid variety. No doubt it would be economically advantageous to invest in 2 tons of lime if one were to obtain an extra 4 tons of dry matter. Further work is continuing under acid and limed conditions using 10 lines selected from the above trial.

3.41F Winged beans (Psophocarpus tetraglobonus)

M. I. Piha and J. J. Nicholaides, III

Forty-one varieties of winged beans were tested to obtain preliminary data on the potential of this high protein legume in the humid tropics. The experiment consisted of an unreplicated trial, using three stakes at a 50 cm by 50 cm spacing per variety, with three plants per stake. Adjacent to this experiment the same varieties were planted without staking, using a 50 cm row spacing between varieties. According to the literature, staking should promote the formation of pods, while unstaked plants should form fewer pods, and have tendency to produce high protein tuberous roots.

All seeds were planted at the beginning of the rainy season on a well fertilized limed soil. Fertilizer rates used per hectare were: 40 kg P, 100 kg K, 35 kg Mg, 3 kg Zn, 2 kg B, 600 g Cu, and lime at 1.65 times the exchangeable acidity, for the staked plants. The unstaked experiment was fertilized at the same rates, except that a higher amount of K was applied (180 kg/ha), owing to the generally beneficial effect of high levels of K on the yields of tuberous crops.

Although growth of winged beans was slow, after about three weeks growth rate compared well with that of other grain legumes. The uninoculated plants nodulated abundantly, with exceptionally large nodules being observed. During the vegetative stage the plants showed strong climbing characteristics, with all varieties exceeding over 2 m in height by eight weeks after planting.

No fungal or insect problems were observed until the flowering stage. The lack of insect problems was particularly interesting as adjacent fields of cowpeas and soybeans required biweekly applications of insecticide to control heavy infestations of leaf chewing insects. The earliest varieties commenced flowering 50 days after planting (Table 3.41F:1). Once flowering commenced, two problems were noted, both of which led to a lowering of yields. First, despite the very high number of flowers produced, the great majority of these failed to produce pods. This problem appeared to be physiological, as is the case with the common bean. Secondly, to add to this problem, the flowers were frequently visited by a species of small bees which would feed on the reproductive parts of the flower before pollination took place. These insects were impractical to control chemically due to the short lifespan of an individual flower. It was noted that the number of flowers initiated by the staked plants was very much greater than that of the unstaked plants.

Pod formation did however take place, despite the fact that this was at a level much lower than the theoretical potential. A large variation in pod size was noted among the varieties (Table 3:41F:1). It was noted that the mature pods had a remarkable resistance of fungal attack, despite the exceptionally wet and humid conditions. Cowpeas and soybeans maturing at the same period produced completely rotted seeds. Thus it was not necessary to make frequent harvests as the pods could be left on the plant for up to about one month after maturity. The bean

yields were generally low (Table 3.41F:1) especially considering the long growing season. The variety UCD12-11, however, may well be a notable exception, producing over 3 t/ha of high quality seed in a little under 6 months. The unstaked wing beans produced very few pods and, after five months of growth, no evidence of tuberous roots was observed in any of the varieties.

In summary, despite the long growing season and the need for staking, winged beans may definitely have a place in the farming systems of the area. The main advantage, apart from the exceptionally high protein content of the seed, appears to be that they are the only legumes, so far tested, that can produce an acceptable quality grain during the wet part of the year. Also, the fact that they are not attacked by leaf chewing insects offers an advantage to the farmers of the area, who do not have access to insecticides.

Table 3.41F:1. Summary of agronomic characteristics of winged bean varieties. Yurimaguas, 1981.

Variety	Days to full flowering	Day to final harvest	Vegetative vigor*	Pods per stake	Weight of seeds/ pod	Estimated yield (2 harvests)
					g	kg/ha
MITA940	51	168	3	9	2.8	1000
MITA942	105	180	3	0	N/A	0
MITA943	57	160	5	5	6.7	1330
MITA944	57	173	5	6	7.6	1835
MITA946	50	142	3	13	3.0	1516
MITA947	49	141	3	11	2.4	1104
MITA948	48	141	3	11	3.0	1330
MITA949	78	175	5	5	7.9	1686
MITA950	90	160	3	2	1.6	106
MITA951	73	160	3	2	5.4	505
MITA952	94	180	1	0	N/A	0
MITA953	69	160	4	11	3.1	1317
MITA954	95	180	3	0	N/A	0
MITA955	55	160	2	12	2.3	1078
MITA956	95	160	3	1	3.0	80
MITA957	130	180	3	0	N/A	0
MITA958	73	180	3	0	N/A	0
MITA959	57	[illegible]	3	6	3.0	758
MITA962	105	180	3	0	N/A	0
MITA963	53	173	3	4	4.5	718
MITA964	57	160	3	10	3.3	1290
MITA965	108	180	3	0	N/A	0
MITA966	N/A	180	3	0	N/A	0
MITA967	95	173	4	4	4.1	598
MITA968	N/A	180	2	0	N/A	0
MITA969	59	160	4	5	5.4	1157
MITA970	N/A	180	4	0	N/A	0
MITA989	55	108	2	13	2.5	1317
MITA1018	90	180	3	5	3.5	625
MITA1019	53	141	3	13	2.9	1463
UPS14	57	143	3	8	2.9	984
UPS31	48	141	3	12	2.8	1383
UPS47	48	141	3	12	3.2	1556
UPS49	48	160	3	7	3.5	971
UPS68	58	152	2	6	3.5	785
UPS103	58	160	1	4	2.5	439
UPS112	66	106	2	22	1.8	1529
UPS122	58	160	5	7	5.6	1649
UCD12-1	75	180	3	0	N/A	0
UCD12-11	73	173	4	17	4.5	3099
UCD19-7E	56	141	3	4	2.7	426

*Scale of 1 to 5; 5 = major vigor.

3.42 Composting and mulching

D. E. Bandy and J. J. Nicholaides, III

Experimental results presented in previous reports herein, show that continuous cropping is possible on the acid soils of the humid tropics if the correct amounts of the necessary nutrients are supplied by inorganic fertilizers. It was also shown that at the present fertilizer prices and product values this is an economically viable approach that can substitute for the traditional migratory agriculture. However, given the limited resources and limited access to credit that small farmers usually have in most developing countries, the Program has had an interest in minimizing the amount of external resources necessary for continuous cropping. A number of experiments have been conducted to determine the most feasible nutrient recycling systems for continuous cropping to replace migratory agriculture with minimum fertilizer use. Use of crop residues can return substantial amounts of nutrients to the soil. Composting with previous crop residues could be, at first glance, an inexpensive way to return nutrients to the soil and perhaps improve other soil properties. Mulching could provide nutrients to the soil and at the same time protect the soil surface from erosion and improve physical soil conditions.

Composting. Within these lines of thought, a field experiment was conducted to investigate alternative methods of providing the necessary nutrients to crops with less inorganic fertilizer inputs and improve soil physical conditions. Six composting materials were used: 1) corn stover, 2) peanut stover, 3) *Panicum maximum* hay, 4) kudzu vines, 5) fresh rice hulls, and 6) burned rice hulls. All materials were decomposed in pits under natural conditions for four months, then removed and incorporated into soil prior to planting. Ten crops were grown on the compost incorporated plots during four years from 1977-1981.

The amounts of nutrients supplied by each compost material was quite variable, especially for N and Ca. Table 3.42:1 shows the nutrients added to the soil when 10 t/ha of each compost was added to the soil. Total nutrient uptake for given yields of several crops are presented in Table 3.42:2. By comparing these two tables it becomes clear that the compost alone at 10 t/ha could provide a high proportion of the required P, Ca and Mg, but insufficient K and N. The deficiency is particularly important in the case of K since there is no other potential source as there is for N via rhizobial N-fixation in legumes.

Kudzu compost gave the best results both in terms of crop yields and improving soil nutrient status. Although the K content of kudzu compost was not better than the corn compost, higher K levels in the topsoil were found in the experimental plots where kudzu rather than corn compost had been applied (Fig. 3.42:1).

Crop yields as a percent of yield obtained with complete fertilization are presented in Table 3.42:3 for two compost treatments. Yields obtained with corn stover and kudzu composts were nearly as high as those obtained with complete fertilization for the first and second

crops. Thereafter, a decline in relative yields was observed until the seventh crop in which K fertilizer started being applied, due to an extreme K deficiency resulting from crop K requirements being unmatched by K supplied by compost materials.

The effect of two composts on selected soil physical characteristics are shown in Table 3.42:4. Both kudzu vine and corn stover composts decreased soil bulk density and increased infiltration rates, kudzu compost especially so. Such improvement would be expected to be reflected by crop performance due to better soil aeration, increased tolerance to drought stress and less risk of erosion.

The results show that composting is a feasible alternative to high input strategy, reducing the amount of fertilizers required for continuous cropping and improving soil physical properties. A simplified economic analysis considering the extra labor required for collecting compost materials and applying compost to soil and the additional land used, revealed an advantage in favor of composting, especially the kudzu compost (Table 3.42:5). However, this analysis was for the first six crops only, thus not considering the need for additional K amendments.

Mulching. After several years of experiments with mulching the results are still variable. The main controlling factor is a definite interaction between mulching and rainfall. When there is a shortage of available soil water to plants in the grain filling stage, as usually occurs from June through September, there is a favorable effect of mulching on yields. On the other hand, when there is excess water in the soil, such as usually occurs in October through May, mulch effect is negative, especially in corn. This mulching x rainfall interaction is clearly evident in the grain yield data presented in Table 3.42:6.

Some soil physical properties are improved by mulching (Table 3.42:7). Mechanical impedance is reduced by mulching. The reduction of soil temperature by mulching is considered helpful in the Yurimaguas environment.

There also is a favorable effect of mulching on supplying nutrients to plants. For example, using 4 t/ha of dry rice straw mulch added about 60 kg K/ha to the soil. After three continuous corn crops, each receiving 4 t/ha rice straw mulch and 101, 41 and 124 kg K/ha, respectively, as inorganic fertilizer, the exchangeable soil test K levels increased from 0.15 to 0.33 me/100 cc by the third harvest. This is one of the few instances in Yurimaguas where soil test K levels have been increased to greater than the critical level of 0.20 me/100 cc. However, as both the corn K uptake and yields were low, it is suspected that the increase in soil test K levels was due to the mulch reducing leaching of the K not utilized by the crop. This remaining K would be available for subsequent crops.

Table 3.42:1. Nutrients supplied by each compost material at 10 t dry matter/ha. Yurimaguas, Peru, 1978-1982.

Compost	N	P	K	Ca	Mg
	----------	----------	kg/ha	----------	----------
Corn stover	147	16	40	95	20
Peanut stover	133	12	13	98	12
P. maximum hay	157	13	32	66	15
Kudzu vines	202	15	34	87	18
Rice hulls (burned)	25	17	25	33	13
Rice hulls	23	21	53	36	16

Table 3.42:2. Total nutrient uptake for given yields of rice, soybean, peanut, and corn, Yurimaguas, Peru.

Crop	Yield	N	P	K	Ca	Mg	Cu	Zn
	-t/ha-	----------	----------	kg/ha	----------	----------	-- g/ha	--
Rice	3.5	100	13	100	27	10	40	350
Soybean	3.0	260	26	139	20	18	30	180
Peanut	4.3	340	35	243	92	17	220	360
Corn	4.0	110	26	183	28	23	40	150

Table 3.42:3. Crop yields from corn stover and kudzu vine compost relative to yields of complete fertilization treatment. Yurimaguas, Peru, 1977-1981.

Crop number	Corn stover	Kudzu vine
	%	
1	99	90
2	90	108
3	68	70
4	94	84
5	35	52
6	46	20
7*	65	93
8	46	82
9	72	79
10	59	74

*100 kg K/ha applied to this and subsequent crops.

Table 3.42:4. Effect of compost on selected soil physical properties and organic carbon.

Compost	Bulk density	Percent water by volume	Infiltration	Organic carbon
	g/cc	at .03 atm.	cm/hr.	%
None	1.55	29.3	10.0	0.92
Corn stover	1.45	26.4	13.7	0.95
Kudzu vines	1.36	26.9	25.1	1.21

Table 3.42:5. Simplified economic analysis comparing for the first six crops the net profits produced by supplying nutrients by inorganic vs. organic with some inorganic fertilizer.

Fertilizer	Man days	Area ratio	Rice production	Lime and fertilizer cost*	Net profit at farm gate
			t/ha	---------- $/ha	----------
Complete: Inorganic	--	--	3.1	208	257
Corn stover compost	20	7:1	2.7	129	276
Kudzu vine compost	55	4:1	3.9	164	421

*All treatments received lime at same rate; no K was added.

Table 3.42:6. Effects of mulching on yields of several crops. Yurimaguas, Peru. 1974-1979.

Crop	Yield		
	With mulching	Without mulching	Harvest date
	kg/ha		
Soybean	2450	1840	Jul. 1979
Maize	3950	2710	Jul. 1979
Rice	1870	2800	Feb. 1979
Rice	1850	2800	Feb. 1979
Soybean	2800	3110	Oct. 1978
Peanut	2350	2320	Oct. 1978
Maize	4530	4040	Jun. 1978
Soybean	3120	2920	Jun. 1978
Rice	2640	3000	Jan. 1978
Rice	2650	2630	Jan. 1978
Peanut	2800	2200	Sep. 1977
Maize	4300	3900	Sep. 1977
Rice	2063	2589	Feb. 1977
Rice	1298	2445	Feb. 1977
Maize	2965	3610	Apr. 1976
Soybean	2213	2546	Apr. 1976
Soybean	1933	2300	Sep. 1976
Peanut	4167	4133	Sep. 1976
Cowpea	640	740	1975
Peanut	2530	2880	1975
Rice	2310	2740	1975
Soybean	1000	1040	1974
Average	2565	2695	

Table 3.42:7. Soil physical properties as affected by mulching. Yurimaguas, Peru.

Treatment	Bulk density	Mechanical impedance	Field capacity	Soil temp at 2 PM
	g/cc	kg/cm^2	%	°C
Mulch	1.31	0.70	18.3	32
No Mulch	1.39	0.85	17.6	36

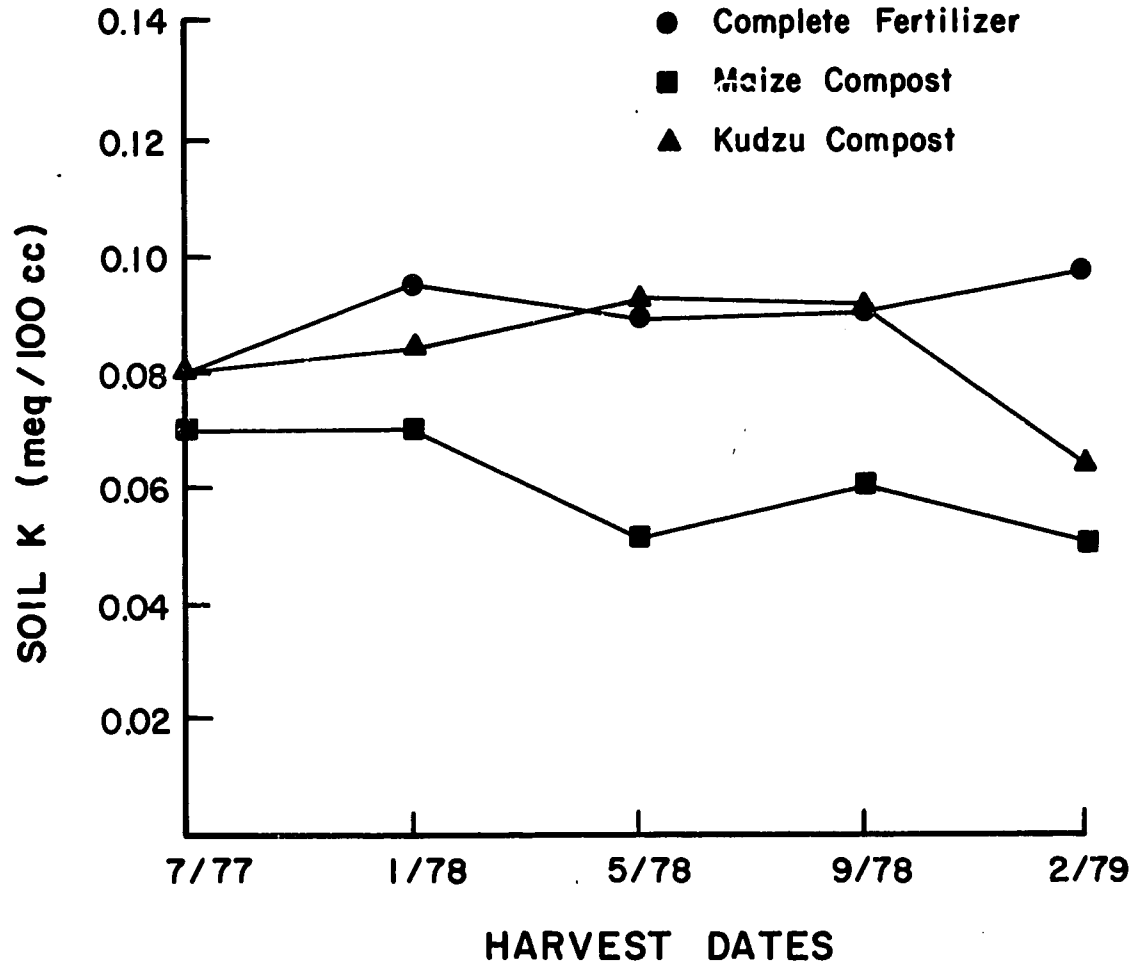


Figure 3.42:1. Available soil K in relation to compost type over time.

3.43 Rock phosphate utilization

D. E. Bandy and L. A. Leon

The need for P fertilizer for continued high yields in the acid soils of the humid tropics is well recognized. Ordinary superphosphate (OSP) and triple superphosphate (TSP) are the sources of P most commonly available in the market. As they are water soluble, their P is readily available to plants. However, they are comparatively expensive for unit of total phosphorus due to the industrial process required to transform phosphate rock into OSP or TSP. There are numerous phosphate rock deposits throughout Latin America some of which yield phosphate rock that can be used directly after grinding to a desirable particle size, with or without partial acidulation. The original soil acidity contributes to P solubilization from chemically untreated phosphate rock. Partial acidulation by simplified industrial procedures can also increase P availability from phosphate rock. A cooperative project between INIA-NCSU and the phosphorus program of International Fertilizer Development Center (IFDC) at CIAT was developed to (1) determine the agronomic efficiency of different phosphate rock and other P carriers in the acid soils of Yurimaguas, (2) study the effect of partial acidulation of phosphate rock on P availability to crops, (3) determine the rates of P carriers necessary for maximum or optimum economic yields, and (4) study the residual effect of different P carriers.

A field experiment was established in 1980, including three P carriers, three application rates and three acidulation treatments. Phosphorus carriers were Sechura phosphate rock (SPR), a moderately reactive phosphate rock, Florida phosphate rock (FPR) and ordinary superphosphate (OSP). Partial acidulation consisted in treatment of both Sechura and Florida phosphate rocks with 20% of the amount of acid required for complete treatment of phosphate rocks. Phosphoric acid (H_3PO_4) and sulfuric acid (H_2SO_4) were used as two partial acidulation treatments. A third acid treatment to 20% of acid requirements with H_3PO_4 made to a cogranulation of Sechura and Florida phosphate rocks with ordinary superphosphate was also included. All P carriers and partially acidulated products were applied at rates equivalent to 44, 88 and 176 kg P/ha at the time the first crop was planted, with no new applications thereafter. Two additional treatments consisting of 22 kg P/ha at the time each crop was planted, as OSP and SRP, were also included.

The relative agronomic efficiency for each level of applied P was computed as a ratio between the yield obtained with each P carrier at a given application rate and the yield obtained with the same level of applied P as OSP, expressed on a percentage basis.

Results obtained with three consecutive crops are presented in Table 3.43:1. As measured by the relative agronomic efficiency, both Sechura and Florida phosphate rocks reacted very fast in the soil, providing high P availability to the first crop. The partial acidulation process did not represent significant advantage over natural phosphate

for these two phosphate rocks, as measured by relative agronomic effectiveness. This was probably due to the relatively high reactivity of these two phosphate rocks in the unlimed soil.

This is confirmed by results from soil analysis performed after each crop, presented on Table 3.43:2. Available phosphorus in plots receiving SPR was similar to those receiving OSP at all levels except 176 kg P/ha. At this level, available P from OSP was higher, probably due to the reduced solubility of the rock at higher P concentrations in the soil solution.

The residual effect of both Sechura and Florida phosphate rocks was quite good. This is shown by Table 3.43:3 in which yield data for the third crop (rice) are presented. The mean yields of the rock phosphate sources (regardless of rate) were considerably higher than the check. However, these yields were lower than that for 22 kg P/ha per crop as OSP, which is the standard recommendation for upland rice at Yurimaguas. The untreated SPR rate of 176 kg P/ha did yield the same as this 22 kg P/crop, but such yields were not duplicated by the other treatments. The Florida phosphate rock tended to produce somewhat higher yields than the Sechura.

The residual effect of the Sechura phosphate rock as measured by available P (Table 3.43:2) also appears to be good. The available P is steady across successive crops, and the highest rate even showed substantial increase between the 2nd and 3rd crop. This same treatment also showed a considerable drop in Al saturation (Table 3.43:4) by that third crop. The preliminary indication is that with enough time this high rate of phosphate rock is dissolving to release more P as well as decreasing Al. Only time will tell if this dual benefit is consistent. The other treatments, including the OSP source, indicate no such effect on Al saturation.

Table 3:43:1. Relative agronomic effectiveness of phosphate rocks to OSP for three crops.

Source	Rate P	Relative agronomic effectiveness (% yield of respective OSP rates) Corn	Soybeans	Rice
	kg/ha	%		
Sechura (SPR)	44	117	108	100
	88	121	112	87
	176	108	84	109
	22/crop	103	76	89
Florida (FPR)	44	106	83	18
	88	110	73	90
	176	136	86	97
SPR + H_3PO_4	44	115	105	111
	88	124	68	97
	176	120	108	88
FPR + H_3PO_4	44	103	81	104
	88	110	125	103
	176	95	94	100
SPR + H_2SO_4	44	90	84	107
	88	124	83	107
	176	98	92	69
FPR + H_2SO_4	44	101	156	100
	88	78	112	100
	176	96	87	97
SPR + H_3PO_4 + OSP	44	116	75	100
	88	138	86	93
	176	122	127	82
FPR + H_3PO_4 + OSP	44	99	93	114
	88	111	66	90
	176	112	75	91
			Grain yield (t/ha)	
OSP	44	2.8	0.85	2.8
	88	2.6	0.95	3.2
	176	2.6	1.18	3.2
	22/crop	2.9	0.72	3.4
Check	0	2.0	0.35	2.5

Table 3.43:2. Available P* soil levels for 4 rates of OSP and SPR for three crops.

Source	Kg P/Ha	Crop No. 1	2	3
		---------- P (ppm) ----------		
	Check	7	4	4
OSP	22/crop	11	8	11
	44	13	6	7
	88	19	18	18
	176	54	40	49
SPR	22/crop	11	9	13
	44	11	9	9
	88	16	18	16
	176	22	19	36

*Modified Olsen: 0.5 N $NaHCO_3$ + 0.01 M EDTA (pH 8.5)

Table 3.43:3. Rice grain yields (3rd crop after P applications) as affected by rates of various sources of P.

P rates (kg/ha)	P source and treatment									$\bar{X}$ of all rock phosphate treatments
	OSP	SPR	SPR/ H_3PO_4	SPR/ H_2SO_4	SPR Cogran H_3PO_4	FPR	FPR/ H_3PO_4	FPR/ H_2SO_4	FPR Cogran H_3PO_4	
	t/ha									
0						2.47				
44	2.82	2.84	3.06	3.03	2.78	3.25	2.90	2.76	3.22	2.98
88	3.01	2.62	2.94	3.17	2.75	2.66	3.10	2.99	2.71	2.87
176	3.17	3.52	2.82	2.16	2.55	3.08	3.22	3.08	2.91	2.92
22/crop	3.45	3.09	-	-	-	-	-	-	-	-
$\bar{X}$ of 3 rates	3.00	2.99	2.94	2.79	2.69	3.00	3.07	2.94	2.95	2.92

$\bar{X}$ of Phospate Rocks SPR = 2.85 FPR = 2.99

Table 3.43:4. % Al-saturation in soil as related to residual effect of SPR and OSP at various P levels, 0-15 cm (depth).

Source	P	Al Saturation Crop No. 1	2	3
	kg/ha	---------- %	----------	
	Check	45	67	42
OSP	22/crop	31	52	42
	44	39	47	65
	176	22	44	45
SPR	22/crop	41	51	52
	44	31	45	51
	88	28	47	45
	176	25	47	32

3.44 Legume inoculation trials

3.44A Soybean

D. E. Bandy and M. I. Piha

A soybean inoculation trial was performed in 1980 in conjunction with INTSOY to determine the benefit of inoculating soybeans with the appropriate *Rhizobium*. Four treatments were included. They were: 1) uninoculated control, 2) inoculation, 3) inoculation plus 25 kg N/ha, 4) 25 kg N/ha only.

The results (Table 3.44A:1) a 40% yield increase over the control upon inoculation. The 25 kg N application was clearly too small a quantity to affect the grain yield, although it did lead to an increase in vegetative growth. Although inoculation did not lead to an increase in nodule number, it did lead to a higher percentage of active nodules over the control. Further experiments using much higher quantities of nitrogen would be useful to determine the true value of inoculation.

Table 3.44A:1. Effect of inoculation and N treatment on nodulation, active nodules, plant height, and soybean grain yield. Yurimaguas, Peru, 1980.

Treatment	Nodulation	Active nodules	Plant height	Grain yield
		%	cm	t/ha
1 Control	4.9	2.5	53	0.75
2 Inoculated	3.8	32.5	58	1.05
3 N + Inoculated	3.7	7.5	62	1.03
4 N only	4.7	3.8	64	0.83

3.44B Peanut

M. I. Piha

A peanut inculation trial was planted in May, 1980 on a soil that had no previous legume crop under two different fertility levels: low soil fertility (LSF) with only 7 kg P and 1.1 kg Mo per hectare added, and high soil fertility (HSF) with 40 kg P, 90 kg K, 40 kg Mg, 600 kg Ca $(OH)_2$, 1 kg B, 2 kg Zn, 0.25 kg Cu and 1.1 kg Mo per hectare added as fertilizer. This was on a soil prior to fertilization with a soil analysis, in meq/100 cc, as follows: 2.1 Ca, 0.2 Mg, 0.1 K and 0.6 Al soil for an Al saturation of 20%; pH was 5.2; modified Olsen extractable P was 15 ppm.

Each fertility level was combined with three additional treatments: (1) uninoculated control, (2) inoculated with Niftal strains, and (3) N fertilizer at 100 kg N/ha.

Nodulation data was collected at 50 days after planting, and harvest was at 110 days. The data are presented in Table 3.44B:1.

Yields were very good for all treatments. Neither fertilizer nor inoculant gave a significant yield increase over the control, although there was a tendency for inoculant under low soil fertility to increase yields. Nodule data was very erratic and neither number nor weight per plant was signficantly influenced by the inoculant. It would appear that native soil Rhizobia is sufficient to produce adequate nodulation on peanuts.

Table 3.44B.1. Yield (shelled) and nodule production of peanut as affected by soil fertility and inoculation. Yurimaguas, Peru, 1980.

Fertility treatment	Inoculation treatment	Yield	Nodules	
			No./plant	Wt./plant
		kg/ha		g
LSF	None	2000	143	0.45
	Niftal	2350	150	0.35
	N fertilizer	2009	-	-
HSF	None	2150	165	0.45
	Niftal	2238	217	0.62
	N fertilizer	2150	-	-

3.44C Cowpea

M. I. Piha

A cowpea inoculation trial was planted in May, 1980 on a field with no history of legumes (only corn had been grown since clearing). Soil analysis, in meq/100 cc, prior to the experiment was as follows: 2.3 Ca, 0.2 Mg, 0.1 K, and 0.8 Al meq/100 cc soil, with an Al saturation of 25% and a pH of 4.8; modified Olsen extractable P was 14 ppm.

Two soil fertility levels were used; (1) low (LSF) with 7 kg P and 1.1 kg Mo/ha, and (2) high (HSF) with 40 kg P, 90 kg K, 40 kg Mg, 1000 kg $Ca(OH)_2$, 1 kg B, 2 kg Zn, 0.25 kg Ca and 1.1 kg Mo/ha. Inoculant treatments were (1) no inoculant, (2) mixture of strains of TAL 209, TAL 193 and TAL 658 peat inoculant (Niftal) applied at the rate of 8 g peat/100 g seed, and (3) N fertilizer at the rate of 100 kg N/ha.

Nodule and plant dry weight data were taken at 45 days after planting. Cowpeas were harvested between 78 and 99 days after planting. The results are shown in Table 3.44C:1.

The inoculated treatments indicate the added Rhizobia definitely increased the infectiveness and effectiveness of the soil bacteria. This resulted in a somewhat greater vegetative growth; however, grain yield decreased under the better nodulated conditions. The high soil fertility (HSF) treatment had little effect on plant dry weight but, like the nodulation, tended to decrease grain yield.

Improved nutrient status, either by nodulation or applied fertilizers, appears to have a negative effect on yield. This is most likely due to a reduction in either flowering rate or pod set, although neither of these parameters were measured. It is not uncommon for certain legumes (e.g., cowpeas and mung beans), especially local varieties as in this experiment, to have a negative reproductive growth response to increased soil fertility.

Table 3.44C:1. Effect of soil fertility and inoculation on cowpea yield, plant height and nodule parameters. Yurimaguas, Peru, 1980.

Fertility level	Inoculant treatment	Grain yield	Plant dry weight @ 45 days	Nodules Wt./plant	Nodules No./plant	Nodules % Effective
		kg/ha	g/plant	g	no.	% red
LSF	none	1367	36	0.2	9	40
	inoculated	904	41	0.6	20	85
	N fertilizer	1479	37	-	-	-
HSF	none	1213	34	0.6	12	72
	inoculated	963	41	0.9	20	80
	N fertilizer	1054	37	-	-	-

3.45 Cooperative soybean variety trials

3.45A INIPA

D. E. Bandy and M. I. Piha

Eighteen soybean varieties supplied by the INIPA national Soybean Program were evaluated during the 1980 rainy season, as part of a nationwide variety trial. The experiment was carried out under conditions of high soil fertility, using "Nitragin" inoculant and controlling insect pests. Overall yields were moderately low probably due to the 13-day rainless period which occurred during the early pod filling stage. All varieties nodulated well and consequentially nodulation differences among varieties were not significant. In accordance with previous experiences, soybeans perform very well in the rainy season up until the late pod filling stage, when wet weather can seriously reduce seed quality due to fungal proliferation on seed and pod.

Table 3.45A:1 shows yield data together with other agronomic information. Five varieties (Improved Pelican, Lili-Ica, Pelicano, Jupiter and L658-8) appear most promising. The varieties Improved Pelican and Jupiter have consistently been shown to be high yielding and reliable, although not necessarily the highest yielders in any individual trial. Various trials, locally by the National Soybean Program and worldwide by INTSOY, have concluded that "Davis" and Jupiter are the highest yielding varieties for the tropics. Performance of the variety "Davis" in field trials at Yurimaguas has been extremely variable, ranging from best to worst, thus, on the basis of this unreliability, it cannot be recommended for the region.

Table 3.45A:1. Results of cooperative soybean variety trial with INIPA. Yurimaguas, Peru, 1980.

Variety	Grain yield	100 Seed wt	Seed Quality 1/	Lodging 2/	Shattering 3/	Plant height	No. of pods/plant	Nodulation 4/ Abundance		Nodulation 4/ Activity	Days to flowering	Dry matter
	kg/ha	g	1-5 Scale			cm		4 wts	Pod fill	Pod fill %		
Improved Pelican	1665	13.3	1.0	1.0	1.0	77	44	2.8	2.7	40	41	87
Lili-ICA	1642	17.5	2.0	1.0	1.8	74	38	2.9	2.5	43	40	85
Pelicano	1485	14.8	2.5	1.0	1.3	83	40	3.1	2.6	51	42	88
Jupiter	1437	16.2	2.3	1.0	1.3	73	36	3.5	2.7	55	45	90
L-658-8	1436	17.5	2.0	1.0	1.3	64	28	2.5	2.4	41	40	85
Nacional	1302	22.2	2.8	1.0	1.8	106	26	2.9	2.5	51	47	94
L 109-ICA	1256	9.9	2.3	1.0	1.0	74	49	2.9	3.0	73	46	96
Hardee	1187	14.6	2.5	1.0	1.5	54	34	2.5	2.5	25	38	88
Taroa-ICA	1174	16.7	2.3	1.0	1.5	62	26	3.3	3.1	29	41	84
Mineira	1119	14.8	2.0	1.5	2.0	58	38	3.0	2.6	51	40	88
L 110-ICA	1066	16.0	2.8	1.3	2.3	69	33	2.7	2.4	44	39	86
Lincoln	1035	16.4	3.0	1.0	2.5	76	26	3.4	3.1	25	34	84
Mandarin S_4-ICA	971	16.8	2.5	1.3	4.3	75	38	3.2	3.4	43	41	87
Tunia-ICA	946	16.5	3.0	1.0	2.5	58	23	3.0	2.4	43	40	88
Pelican-SM-ICA	945	16.3	3.5	1.0	2.0	73	37	3.8	2.8	46	41	89
Davis	890	15.9	2.5	1.3	1.8	43	24	3.2	3.3	25	32	82
Caribe-ICA	792	11.9	2.6	1.8	2.3	86	43	3.1	2.4	34	44	100
Hill	675	14.4	2.3	1.0	1.0	43	19	3.0	3.8	25	35	81

1/ Seed quality scale: (1) very good (2) good (3) fair (4) poor (5) very poor

2/ Lodging scale: (1) plants erect (2) 75-95% erect (3) 50-75% erect (4) 25-50% erect (5) 25% erect

3/ Shattering scale: (1) No shattering (2) 10% shattered (3) 10-25% shattered (4) 25-50% shattered (5) 50% shattered

4/ Nodule scale:
(1) 6 on main root, 15 on laterals
(2) 6 on main root, 2-15 on laterals
(3) 2-6 on main root, 15 on laterals
(4) 2-6 on main root, 2-15 on laterals
(5) No nodules

3.45B INTSOY

M. I. Piha and D. E. Bandy

Nineteen varieties of soybeans supplied as part of the 1980 INTSOY "spot" trials were planted together with the variety "Tunia" which had performed well in previous trials at Yurimaguas. The primary aim of soybean variety trials at Yurimaguas is currently focused on obtaining a variety that can consistently outyield the present variety "Jupiter."

The experiment was planted on a well limed and fertilized soil at the tail end of the dry season. As can be seen from Table 3.45B:1, all varieties performed well. This was probably due to the good rainfall distribution pattern, and the fact that all varieties, except four very late maturing ones, reached maturity before the onset of the heavy rains. Two varieties, "71-38" from Zambia and "IARA 44-A-73" from Senegal significantly outyielded "Jupiter." The top yielder "71-38" produced a mean yield of 3340 kg/ha, which can be considered high by any standards. Despite the high yield of "IARA 44-A-73", its susceptibility to lodging probably makes it unacceptable. The low yields of the four late maturing varieties once again brings out the point that for soybeans to perform well in the area they must reach maturity during a period of relatively low rainfall. Three other high yielding varieties are worth note i.e., "PK 7386", "ICA L-124", and "CEP 7717" as although their total yield was lower than that of "Jupiter," they did in fact outperform "Jupiter" on a yield/day basis.

No significant differences were observed among the varieties with regard to seed quality and shattering as these were largely dependent on the weather conditions at the time of harvest. The above six mentioned varieties will be further evaluated for yield and other characteristics.

Table 3.45B:1. Results of cooperative soybean variety trial with INTSOY. Yurimaguas, Peru, 1980.

Variety	Days to harvest	Height	Lodging Score* (1-5)	Pods per plant	Grain yield Rep 1	Grain yield Rep 2	Grain yield Rep 3	Mean	Grain yield per day
		cm			--------- kg/ha --------				kg/ha/day
UPL-SY-2	24	55	1.3	33	1940	2000	2320	2090	25
Amber 84	99	35	1.0	37	2110	2360	2460	2310	23
IARA 44-A-73	116	67	3.0	53	3110	3160	3360	3210	28
Tulumayo	155	126	4.0	42	2310	2340	2400	2350	15
71-38	115	39	1.0	82	3170	3460	3400	3340	29
CEP 7717	92	44	1.0	40	2760	2840	2460	2850	31
AGS 9	93	58	2.0	32	2110	2360	2360	2290	25
N78-8106	92	28	1.0	31	1820	1940	2040	1940	21
ICA L-125	152	133	3.3	41	2100	2210	2240	2180	14
Ecuador 1	108	50	1.0	38	2610	2940	2960	2840	26
Celeste	90	32	1.0	19	1940	2160	2480	2190	24
PK 7386	97	32	1.0	47	2480	3000	2920	2800	29
Siatsa 194	116	80	2.7	39	2270	2680	2640	2530	22
ICA L-124	101	43	1.0	39	2650	2720	2980	2780	28
IAC-73-2736	157	100	2.3	40	2210	2430	2510	2380	15
Santa Maria	107	75	3.0	40	2200	2580	2260	2350	22
SJ-4	102	66	2.0	35	2340	2640	2520	2500	25
GH-19-3-2 (1)-3-2	155	150	4.0	34	2100	2240	2230	2190	14
Jupiter	116	54	1.0	35	2630	3200	3240	3020	26
Tunia	110	48	1.0	31	2660	2800	3180	2890	26

*1 = no lodging; 5 = all plants lodged.

3.5 Legume-Based Pastures

W. Couto

In most common conditions a spontaneous secondary forest regrowth follows annual crops in a shifting cultivation operation. However, pastures are sometimes planted after the last crop to obtain additional benefits from previous clearing. Most commonly, Guinea grass (Panicum maximum) is sown after the last crop, utilizing the residual effect of previous burning and some N availability from the mineralization of any remaining soil organic matter. After a few years, with no fertilizer applications, the initial Guinea grass population is reduced and productivity declines sharply.

Results presented in previous Annual Reports showed that rather high amounts of N, P and lime are required to maintain a highly productive Guinea grass pasture in the conditions of Yurimaguas. Some of the requirements could be supplied by a companion legume and other nutrient requirements can be reduced by using a grass adapted to the acid soils of the humid tropics. With the purpose of studying the adaptation of several pasture species to the conditions of Yurimaguas, an experiment was initiated in 1978. New experiments followed the initial introduction experiment in order to test adaptability of newly available material, to study the compatability between most promising grasses and legume species, and finally, to assess their productivity and persistence under grazing. This part of the program has been developed as a joint effort between INIA/NCSU and the Tropical Pastures Program of CIAT.

3.51 Germplasm evaluation

M. Ara, P. A. Sanchez, D. E. Bandy and J. M. Toledo

The species adaptation is evaluated by means of a qualitative rating system and dry matter production. Qualitative characteristics were: vigor, seed and leaf production potential, and pest and disease tolerance.

A new species adaptation experiment was initiated in 1980 and evaluated through 1981, including 6 new legume accessions and 4 new grasses. Fertilization was 22 kg P/ha and 41 kg K/ha per year. Grasses received also 100 kg N/ha per year.

The establishment characteristics of legumes and grasses were studied by estimating cover rate at 4, 8, 12 and 16 weeks after sowing. Figures 3.51:1 and 3.51:2 show results for 14 legumes and 6 grasses respectively. Fastest cover rates were estimated for Calapagonium mucunoides common and Pueraria phaseoloides 9900. Axonopus compressus (a native grass) was faster than other grasses in cover rate.

Growth rate was estimated on the basis of plant height at the same number of weeks after planting (4, 8, 12, 16 and 20 weeks). Results are presented in Figures 3.51:3 and 3.51:4. Only Desmodium gyroides 3001 at 16 weeks showed a significant height increase over many of the other entries. Within grasses, Andropogon gayanus 621, Paspalum plicatulum and Panicum maximum 604 were best in growth rate as measured by height.

From these results and complementary information from previous experiments it was concluded that the legumes P. phaseoloides 9900, D. ovalifolium 350, S. guianensis 136 and the grasses A. gayanus 621, B. decumbens 606 and P. maximum 604 should be tested for establishment compatibility in association. Promising accessions that were found are Z. latifolia 728, D. gyroides 3001 and B. humidicola.

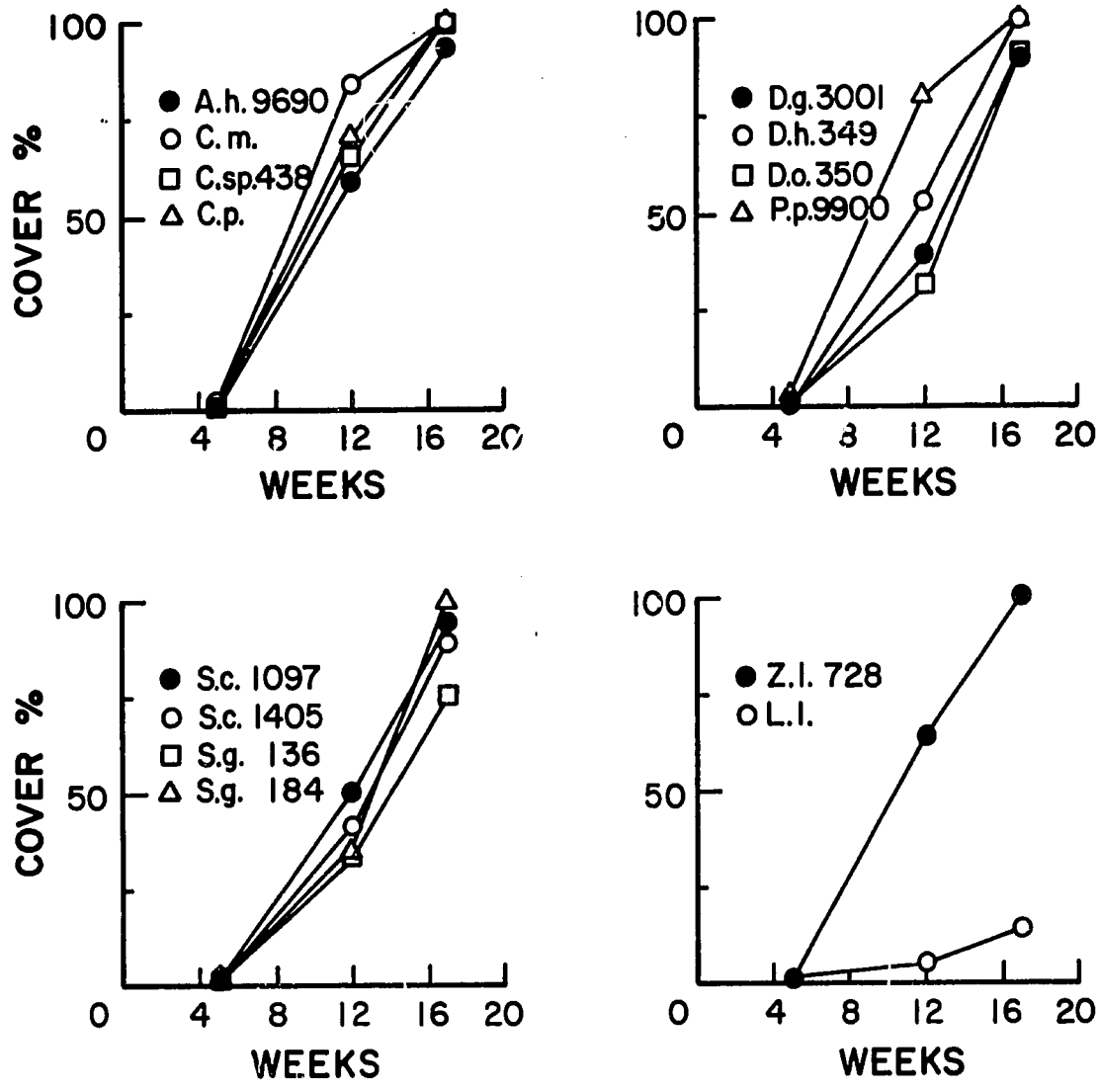


Figure 3.51:1. Cover rate for legumes in forage adaptation trial at Yurimaguas.

A.h. Aeschynomene histrix 9690
C.m. Calopogoniom mucunoides common
C.sp. Centrosema sp 438
C.p. Centrosema pubescens common
D.g. Desmodium gyroides 3001
D.h. Desmodium heterophilum 349
D.o. Desmodium ovalifolium 350
P.p. Pueraria phaseoloides 9900
S.c. Stylosanthes capitata 1097, 1405
S.g. Stylosanthes guianensis 136, 184
Z.l. Zornia latifolia 728
L.l. Leucaena leucocephala common

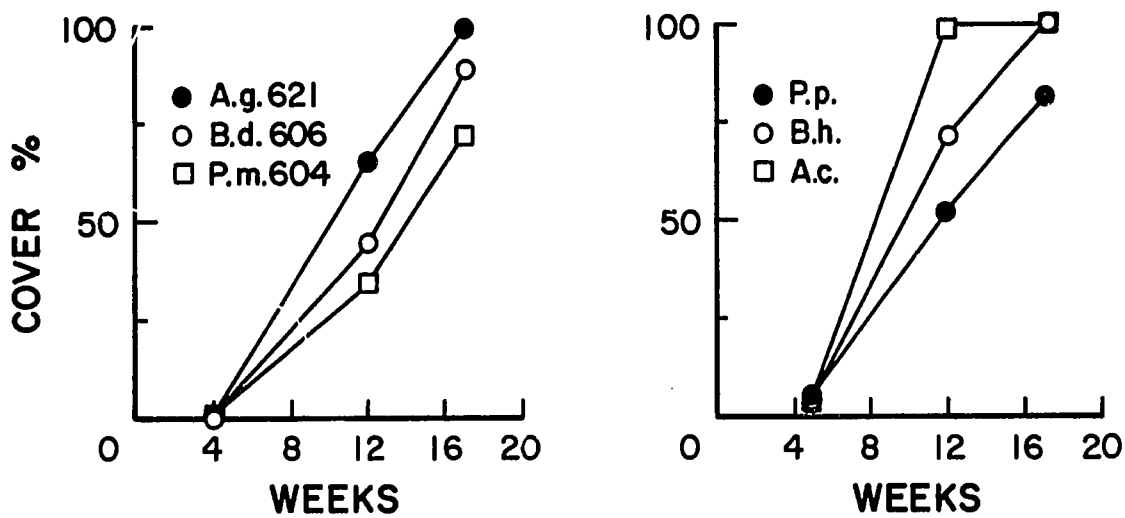


Figure 3.51:2. Cover rate for grasses in forage adaptation trial.
A.g. Andropogon gayanus 621
B.d. Brachiaria decumbens 606
P.m. Panicum maximum 604
P.p. Paspalum plicatulum common
B.h. Brachiaria humidicola common
A.c. Axonopus compressus common

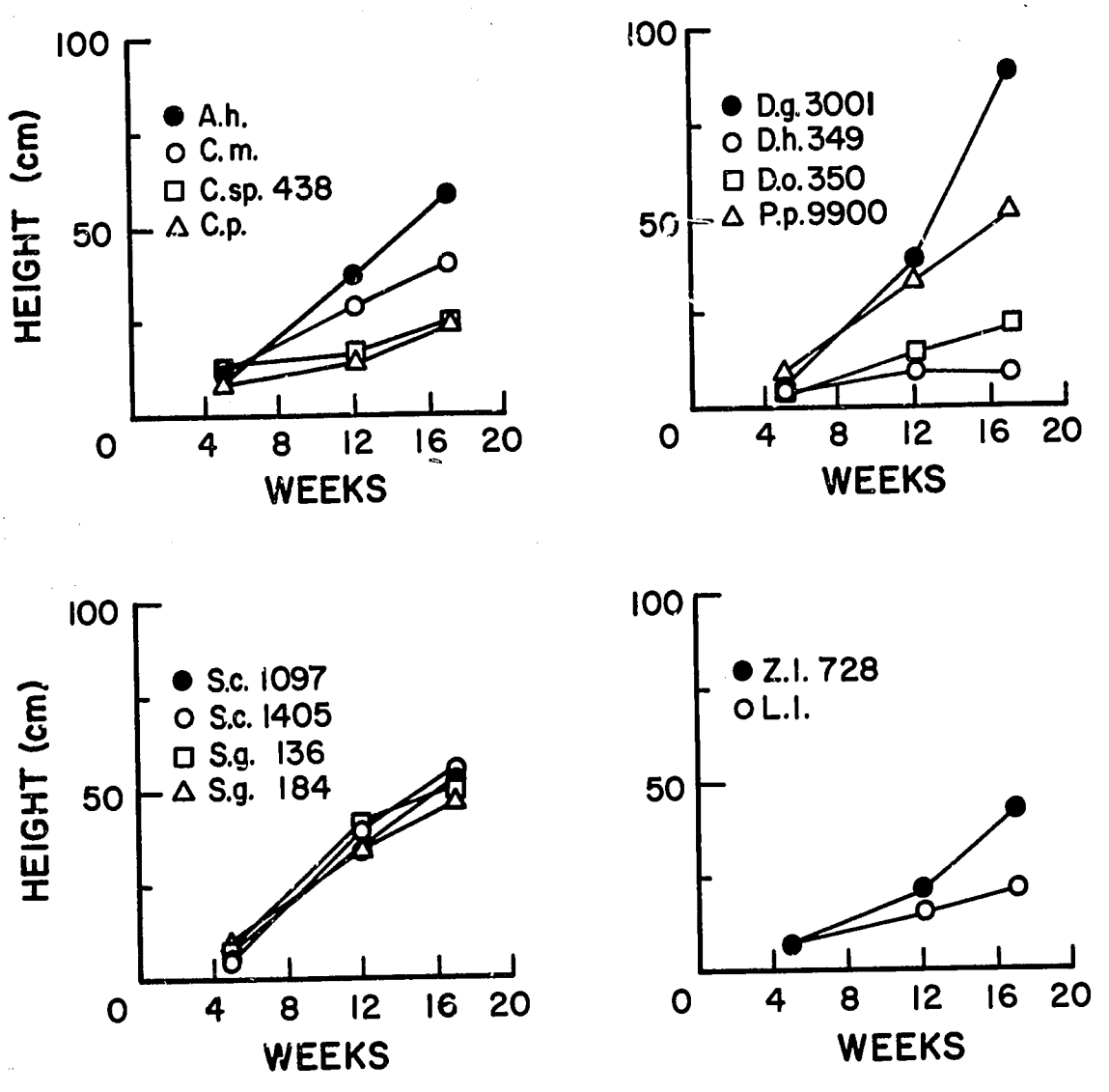


Figure 3.51:3. Height of legumes in adaptive trial at Yurimaguas. (See figure 3.51:1 for decoding species names.)

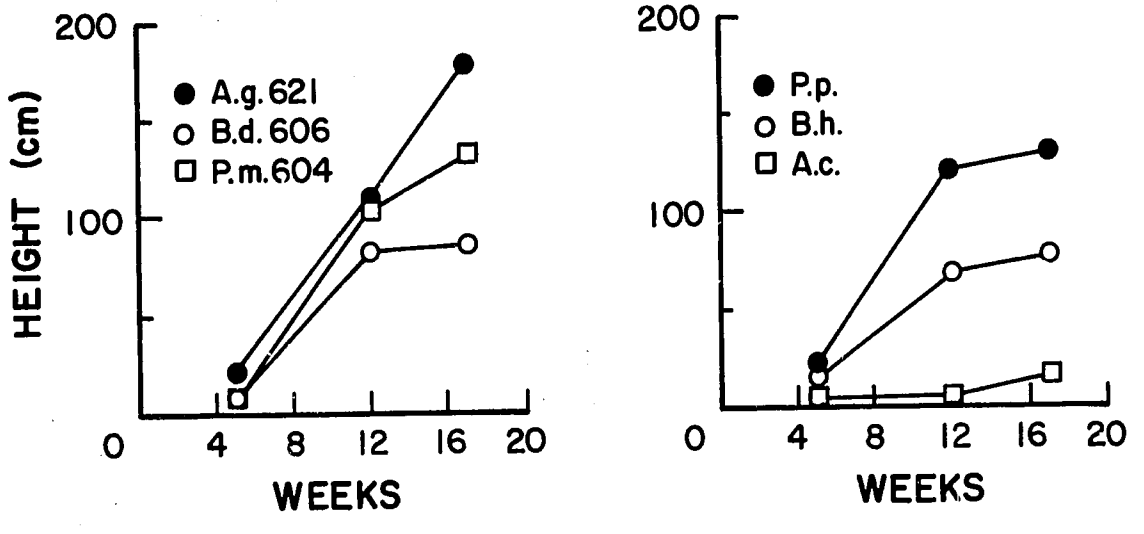


Figure 3.51:4. Height of grasses in adaptive trial at Yurimaguas. (See figure 3.51:2 for decoding species names.)

3.52 Grass-legume pastures under grazing

M. Ara, P. A. Sanchez and D. E. Bandy

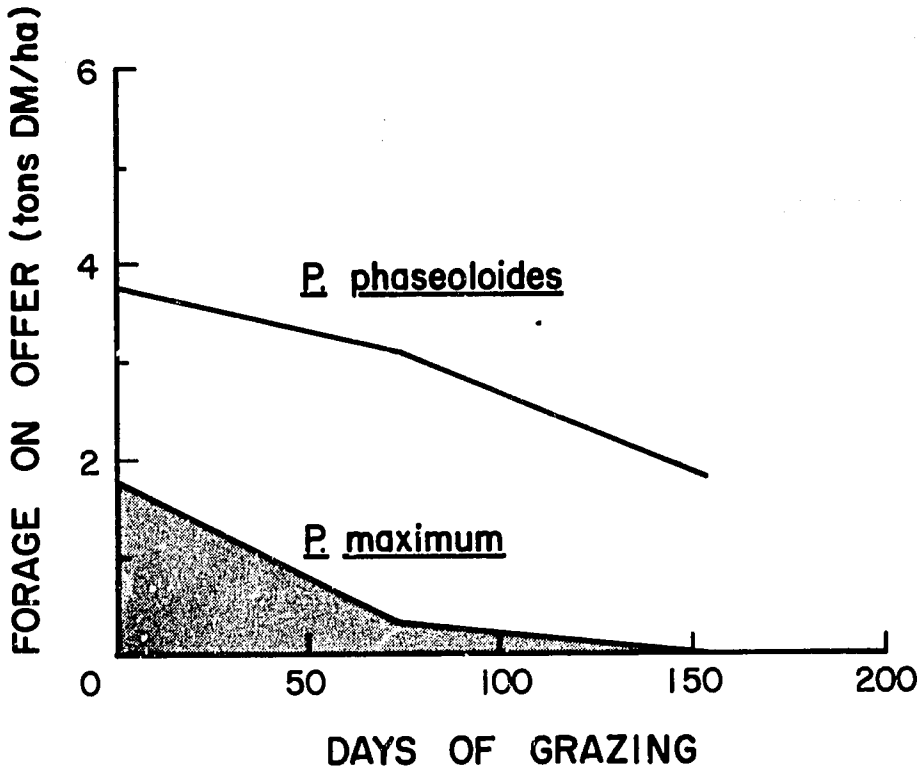
The first grazing experiment was established in 1980 to assess productivity of the most promising grass-legume associations in terms of animal performance and persistence of species under grazing. The experiment consisted of 3 grasses and 4 legumes in 5 grass-legume associations as follows: Andropogon gayanus 621 with Stylosanthes guianensis 136-184, Centrosema sp 438 and Pueraria phaseoloides, separately; Brachiaria decumbens 606 with Desmodium ovalifolium 350 and Panicum maximum with P. phaseoloides.

Each paddock had 4.5 has with two repetitions, in a completely randomized block design. Grasses were planted in twin rows 50 cm apart same as legumes, the result being alternate sequence of 2 rows of grasses and 2 rows of legumes. Fertilizers were applied at planting at the rate of 22 P, 41 K, 10 Mg and 250 Ca kg/ha to all plots. All fertilizers were broadcast with the exception of P which was applied 50% broadcast and 50% banded. All asociations were evaluated under continuous grazing at 4.4 beasts per hectare.

Brachiaria decubens - Desmodium ovalifolium and Panicum maximum - Pueraria phaseoloides associations established faster than all Andropogon gayanus based associations. Andropogon gayanus, being less vigorous than other grasses in the initial phase, suffers from competition of very aggressive legumes, especially from Pueraria phaseoloides. Consequently, B. decumbens and P. maximum based associations were ready for grazing earlier than A. gayanus based associations and animal performance data for A. gayanus associations are only partially available.

Forage-on-offer data from grazing start through 150 days for two grass-legume associations are presented in Figure 3.52:1. It is clear that in the condition of continuous grazing at the stocking rate chosen for the experiment, there was a declining proportion of the grass in the mixture. This was particularly observed in the case of P. maximum-P. phaseoloides association in which P. maximum represented only 1% of the total dry matter after 240 days grazing. In the case of B. decumbens-D. ovalifolium association there was also a decline in forage on offer with time for both species, but at the end of the 240 day period B. decumbens was still 23% of the mixture.

Liveweight gains and percent grass in the mixture for these two grass-legume associations are presented in Figure 3.52:2. Results show good animal performance on grass-legume associations, the problem being the lack of persistence of the balance of the association under continuous grazing with the fixed stocking rate selected for the experiment. The differential acceptability of the grass and the legume in the association contributes also to the lack of stability of the mixture in the conditions of the experiment.



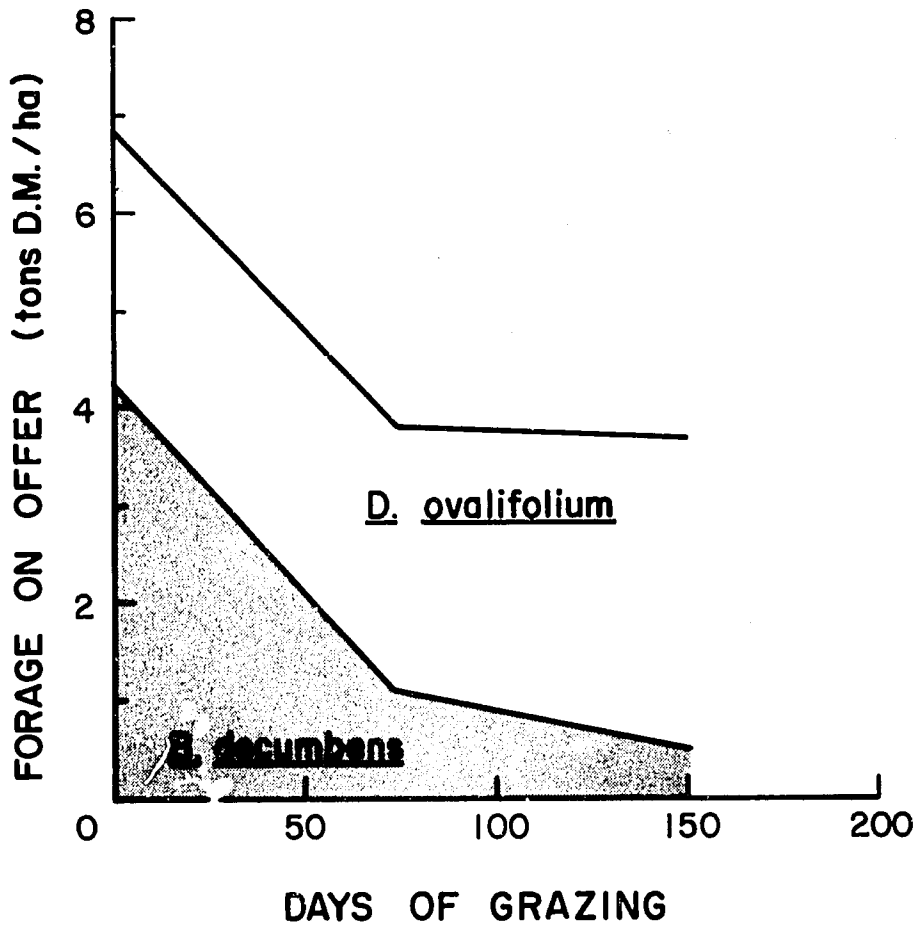
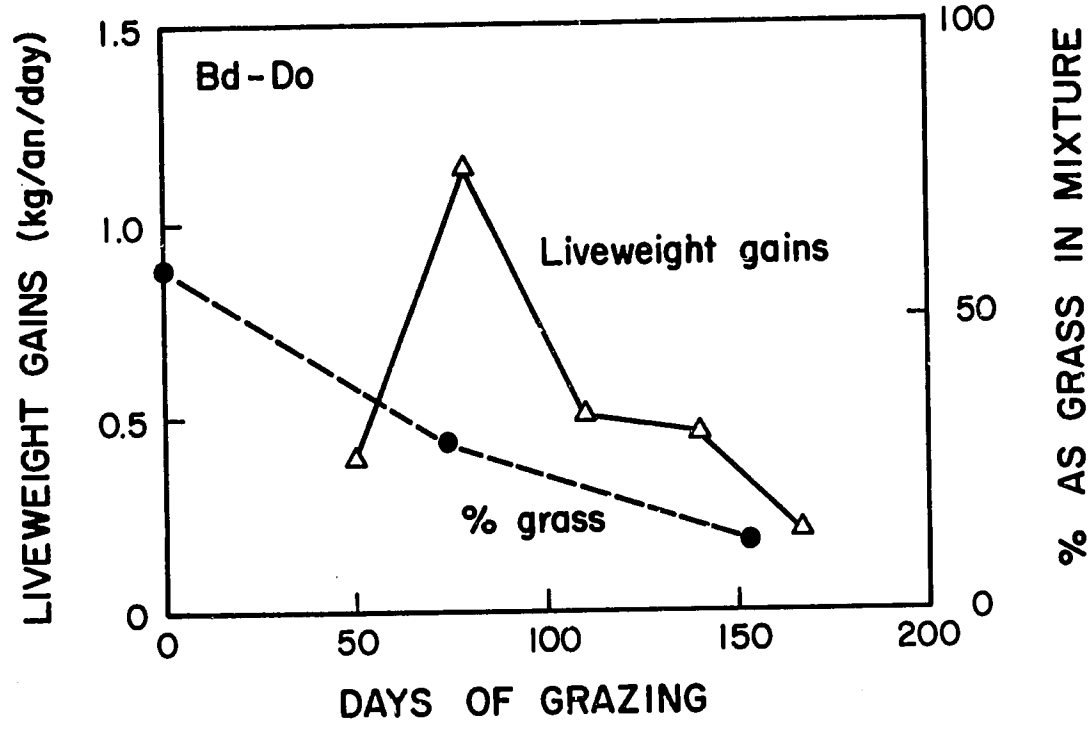


Figure 3.52:1. Available forage of two grass-legume mixtures during 150 days of grazing. Yurimaguas, Peru.



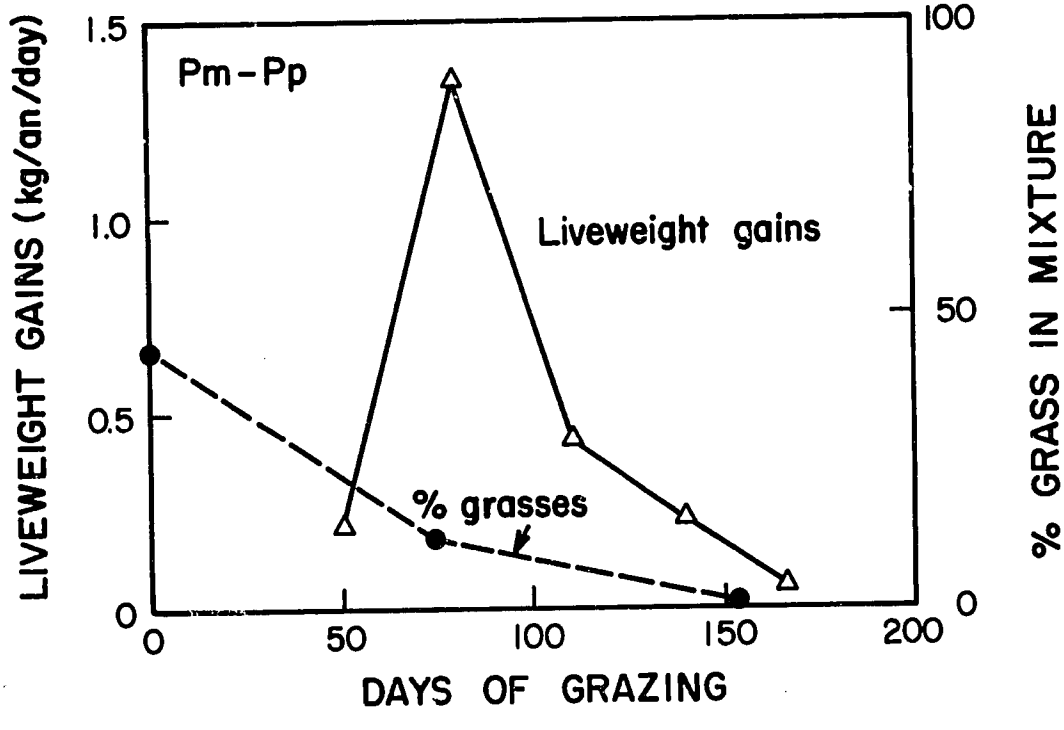


Figure 3.52:2. Stability of the grass and liveweight gains during 150 days of grazing B. decumbens - D. ovalifolium and P. maximum - P. phaseoloides mixed pastures. Yurimaguas, Peru.

3.53 Reclamation of degraded pastures

M. Ara, P. A. Sanchez and D. E. Bandy

The lack of persistence of *P. maximum* pasture under present management practices in most commercial farms of the Yurimaguas region and other humid tropical regions is a great concern for farmers, development planning institutions and credit agents. In most cases *P. maximum* pastures are degraded after a few years grazing, with sparse unproductive native grasses and forest regrowth taking over the *P. maximum* pasture. The result is large areas of unproductive, cleared areas and severe erosion hazard. These areas can be put into production by substitution of present vegetation or improvement of present pasture plus incoporation of new species. The result would be a newly productive pasture at a lower cost by comparison to those established in recently cleared areas and also, a lower rate of annual forest clearing.

An agreement was developed with EMPRESA GANADERA AMAZONIA to start experimental work on pasture renovation. The plan calls for minimum fertilizer inputs, plus legume introduction into pure *P. maximum* stands, with minimum or zero tillage in those areas most exposed to erosion hazard. Partial or total substitution of *Brachiaria decumbens*-*Desmodium ovalifolium* associations for degraded *P. maximum* pastures will also be tested.

Experimentation with flooded rice on alluvial soils, primarily Inceptisols, on the Yurimaguas Station produced excellent rice production.

3.6. Lowland Rice Production on Alluvial Soils

D. E. Bandy and J. R. Benites

In the region of Yurimaguas there are alluvial areas which have more fertile soils than the common ones. They are located close to rivers, and are flooded for a length of time that goes from a few weeks to six months. Some of these are flooded only occasionally. Most of these soils classify as Inceptisols (Aquic Dystropepts) and are considered very valuable by farmers of the region. These soils are slightly acid, with no aluminum toxicity and high Ca, Mg and K and available P. Tables 3.6:1 and 3.6:2 present their top-soil chemical characteristics. Chemical analysis of other soil horizons are not available yet but it is possible that some of these soils could meet requirements to be classifed as Alfisols (Typic Tropaqualfs).

Due to the importance of rice on the economy of the region and the interest in expanding rice production, there has been interest, recently, in developing rice under irrigation on these areas. An irrigated rice research project had been initiated in 1981 by agreement between the Regional Direction for Agriculture and Foods (CORDELOR) and North Carolina State University. Results presented here correspond to 1981 activities within this project.

3.61. Varietal selection

D. E. Bandy and J. R. Benites

Table 3.61:1 shows grain yield of twenty rice varieties which have been selected for planting in Ultisols, cultivated under irrigation.

Yields go from 0 to 7.5 ton/ha. The ten best varieties have been selected for 1982 experiments: Ceysroni, IR 6115, TOX 340, IR 7790, IR 4-2, TOX 514, Colombia 1, ARC 10372, TOX 515 and CR 1113 which were more productive than Carolino, the local variety.

Yield and some agronomic characteristics of 26 rice varieties under multiplication and evaluation are presented in Table 3.61:2. Yields go from 1.5 ton/ha for IR 8192-115-2 up to 7.8 ton/ha for IR 9411-5-3-3, while the local check yielded 2.6 ton/ha. It is interesting to point out the high yield obtained with IR 4-2 (7 ton/ha). This variety has been successfully used at San Ramon Experiment Station during the last 10 years, as an upland rice with no irrigation.

Most promising varieties in terms of yield were also resistant to *Pyricularia*, *Rhizoctonia*, *Rhynchosporium* and *Helminthosporium*.

Table 3.61:1. Chemical characteristics of top-soil layer (0-15 cm) of some alluvial soils on the Shanusi river, Yurimaguas.

Soil	pH	P	Extractable acidity	Ca	Mg	K	Zn	Mn	Fe	Cu	O.C.	Effect. CEC	Base sat'n.
	1:1(H_2O)	ppm	---------- meq/100 cc ----------				---------- ppm ----------				-------- % --------		
A	5.0	6.1	1.07	33.50	10.71	0.31	10.4	117.1	91.8	1.8	1.6	43.09	96
B	5.4	4.6	9.79	36.27	9.04	0.34	7.04	121.0	45.4	2.0	1.5	46.44	98
C	5.7	15.8	0.07	42.06	10.23	0.37	11.37	70.3	112.5	2.65	1.3	52.74	100
D	5.4	15.1	0.17	37.82	9.39	0.35	7.76	58.8	123.3	2.53	1.3	47.74	99
E	5.3	12.5	0.37	37.41	8.92	0.35	7.20	61.0	86.9	2.27	1.3	46.06	99
F	5.3	7.3	0.91	31.23	8.45	0.39	11.59	64.3	48.0	2.15	1.5	40.99	98
G	5.4	3.8	0.44	34.13	9.75	0.34	7.88	121.8	67.0	1.89	1.3	44.67	99
H	5.2	3.4	0.52	35.60	10.15	0.27	6.99	113.1	33.1	2.15	1.4	46.54	99
I	5.3	7.0	0.42	33.61	9.60	0.27	7.33	56.8	67.5	2.59	1.4	43.95	99
J	5.5	8.1	0.48	35.11	8.58	0.33	5.89	83.6	57.6	2.59	1.4	49.25	99
K	5.2	5.3	1.13	32.33	7.98	0.39	5.71	112.3	57.6	2.59	1.5	41.85	97
L	5.1	3.5	1.29	24.86	6.45	0.29	5.61	110.6	130.0	1.96	1.3	32.91	93

Table 3.61:2. Chemical characteristics of underlaying layer (15-20 cm) of some aluvial soils on the Shanusi river, Yurimaguas.

Soil	pH	P	Extractable acidity	Ca	Mg	K	Zn	Mn	Fe	Cu	O.C.	Effect. CEC	Base sat'n.
	1:1(H_2O)	ppm	meq/100 cc				ppm				%		
A	4.7	2.8	5.59	36.01	7.54	0.22	4.26	81.7	84.2	2.27	0.8	41.61	84
B	4.9	2.5	5.27	30.98	9.04	0.29	5.10	89.7	70.1	3.41	0.5	45.59	88
C	5.1	13.0	0.98	40.04	10.78	0.33	3.64	45.2	27.4	3.47	0.5	52.13	94
D	5.3	10.0	0.97	34.13	9.25	0.27	4.43	43.0	101.4	3.6	0.5	44.56	99
E	5.2	5.8	1.03	33.91	9.26	0.27	9.92	54.7	102.7	2.97	0.5	44.47	98
F	5.0	5.0	2.38	27.62	8.54	0.30	4.59	81.2	104.0	2.97	0.5	38.84	94
G	5.2	4.5	1.55	34.36	10.10	0.33	4.45	69.8	42.8	2.33	0.5	46.34	96
H	5.1	1.6	4.52	32.01	10.28	0.24	5.02	91.3	48.0	2.90	0.4	47.05	90
I	5.1	2.9	3.34	31.92	10.53	0.25	6.90	80.4	29.0	3.10	0.4	46.05	93
J	5.1	5.0	3.47	34.48	9.70	0.26	3.92	68.7	68.8	3.41	0.3	47.91	93
K	4.9	4.0	5.01	29.39	8.17	0.26	5.39	86.1	83.1	3.91	0.5	42.78	87
L	4.9	2.5	5.42	25.14	7.17	0.24	5.41	85.0	101.4	3.22	0.4	38.95	81

Table 3.61:3. Grain yield and vegetative growth parameters of several upland rice varieties growing under irrigation.

Varieties	Yield	Days to maturity	Plant height	Lodging	Number of heads
	t/ha		cm	%	
Ceysvoni	7.50	122	1.20	0	23
IR 6115	6.83	122	1.30	30	18
TOX 340	5.88	110	1.35	0	17
IR 7790	5.58	114	1.15	0	22
IR 4-2	5.25	123	1.20	0	22
TOX 514	5.25	120	1.20	50	21
Colombia 1	5.17	122	1.40	0	13
ARC 10372	4.85	106	1.55	100	12
TOX 515	4.48	106	1.10	0	13
CR 1113	4.42	105	1.30	0	13
Carolino	4.42	113	1.80	50	14
Moroberekan	4.00	115	1.75	0	10
IR 3880	3.83	114	1.30	0	15
IR 9671	3.33	124	1.25	100	19
CICA 8	2.83	124	1.10	0	17
IR 3262	2.83	122	1.30	0	15
IR 10781	2.83	128	1.15	0	15
INTI	2.83	123	1.40	0	9
OS 6	0	124	1.60	100	15
Unknown African Variety	0	113	1.65	100	11

Table 3.61:4. Multiplication of promising varieties and germplasm evaluation order.

Introduction Number	Varieties	Nad. 90%	Pyricularia oryzae (leaf)	Helmin. oryzae	Rhin. oryzae	Lodging	Plant height	Number of tillers	Number of Panicles	Vegetative cycle	Yield
		days				%	cm	----- perm^2 -----		days	kg/ha
1	B 922-C-MR-118	116	5	3	3	-	116	220	196	122	2,567
2	B 1050 C-MR-7-1	116	4	2	3	-	131	164	148	122	6,362
3	B 2039C-KN-7-2-5-3-1	109	5	2	2	-	135	328	208	114	3,977
4	IR 36	120	4	2	4	-	95	540	492	114	2,735
5	IR 2061-522-6-9	100	3	3	3	90	105	468	292	107	5,235
6	IR 3880-10	116	3	2	4	-	143	264	208	122	4,250
7	IR 4215-301-2-2-6	118	3	4	3	-	144	268	264	122	5,567
8	IR 4219-35-33	116	3	3	3	-	149	380	152	122	3,780
9	IR 4227-164-1-1-1-1	110	2	3	3	95	186	280	264	114	2,492
10	IR 5629-64-3	114	5	2	2	-	118	552	456	118	3,290
11	IR 5677-17-3-1	118	4	2	4	-	138	244	140	122	3,500
12	IR 4-2 (Testigo)	116	5	2	2	-	101	500	392	122	7,000
13	CICA 8 (Testigo)	116	6	3	3	-	92	320	172	122	1,750
14	IE 5716-45-1	103	5	2	2	-	106	312	228	109	1,750
15	IR 5817-45-3	116	4	2	3	-	147	332	244	122	5,500
16	IR 5852-93-3-1-1-1	118	3	3	2	-	141	372	192	122	2,380
17	IR 5853-198-1-2	118	4	3	3	-	129	532	236	122	2,340
18	IR 7790-18-1-2	116	3	2	2	-	124	388	316	122	3,162
19	IR 7963-30-2-3	111	4	3	4	-	105	436	372	116	5,000
20	IR 8072-18-1-2	116	3	3	2	-	163	224	204	122	4,555
21	IR 8192-155-2	118	3	2	2	-	138	220	124	122	1,500
22	Local check	107	4	4	4	95	176	316	252	114	2,612
23	IR 9411-5-3-3	107	4	3	2	85	115	412	348	114	7,750
24	IR 9849-72-3	116	3	3	3	-	147	368	324	122	5,000
25	IR 11418-15-2	111	4	3	2	100	112	304	244	116	4,125
26	Carolino Blanco (Testigo)	111	2	2	1	80	183	180	172	116	3,722

3.62. Soil tillage and planting methods

D. E. Bandy and J. R. Benites

Two varieties, INTI and IR 4-2 were planted in two soil conditions: "Fangueo" (wet, muddy soil) and "seco" (drained soil). In both cases two planting techniques (transplanted seedlings and germinated seed) were used. On dry soil, two planting methods were also used: mechanical planting by single row, hand-pushed seeder (Planet Junior) and by hand, using a planting stick ("tacarpo"). Results presented in Table 3.62:1 show: 1) variety IR 4-2 outyielded INTI under all planting methods and soil conditions, probably due to resistance to Pyricularia and overturning, 2) in both soil conditions transplanting technique by means of seedlings was better than direct planting. This was attributed to less weed competition due to higher initial vigor of transplanted seedlings, 3) direct planting using pre-germinated seed did not give satisfactory results, 4) direct planting by planting stick was better with IR 4-2 but this variety was not better than INTI when both were planted with "Planet Junior." This was probably due to the variation of depth of planting by manual method, using the planting stick.

The lowest yield was obtained when planting pre-germinated seeds on wet soils, using varieties INTI (1 ton/ha) and IR 4-2 (3.2 ton/ha). This was probably the result of using high seeding rates (100 kg/ha) which promoted lodging in these two varieties. This planting technique will be tested again with seeding rates of 60 and 80 kg/ha.

Table 3.62:1. Effect of seed bed preparation and planting system on rice yield of INTI and IR 4-2 varieties grown under irrigation at Yurimaguas, Peru, 1981.

Planting System	Varieties		Planting System Average
	INTI	IR 4-2	
	t/ha		
		Wet soil tillage	
Transplanting	5.05	7.89	6.47
Pre-germinated seed sown	1.10	3.17	2.13
		Dry soil tillage	
Transplanting	7.02	8.34	7.68
Pre-germinated seed sown	3.93	6.27	5.10
Direct planting by Planet Junior	5.18	5.21	5.20
Direct planting by planting stick	3.05	6.96	5.00
Variety Average	4.22	6.31	

3.63 Soil fertility and plant nutrition

D. E. Bandy and J. R. Benites

N Experiment

The experiment consisted of four N levels (0, 50, 100 and 200 kg N/ha) and four split applications: all at planting; 1/2 at planting and 1/2 flowering stage; 1/2 at tillering stage and 1/2 at flowering and finally, 1/3 at planting, 1/3 at tillering and 1/3 at flowering. All N treatments were tested on two different tillage methods, wet (puddled) and dry.

Results presented in Table 3.63:1 show that there was a negative response to N in this first crop in the experimental site. This is probably due to the high organic matter content of these soils and probably to the mineralization of the organic matter in water-logged soil conditions. Applied N levels decreased yield by promoting lodging and Pyricularia attack. This was especially true on the dry tilled soil where the high N rates caused severe yield reductions.

P Experiment

Four levels of P (0, 11, 22, and 44 kg P/ha) and three P sources (triple superphosphate, ordinary superphosphate and rock phosphate) were tested in the experiment. The variety used was INTI and no response to P was observed in the experiment. Results are presented in Figure 3.63:1. Soil analysis showed high available P content and this was probably enhanced by flooding conditions in these acid soils.

3.64. Other studies

D. E. Bandy and J. R. Benites

New experiments are now in progress and could provide valuable information on other nutrient requirements of rice growing under irrigation in these fertile soils. Special attention is given to Ca: Mg: K ratio in soils and the effect of micronutrients on rice yields.

Water-logging has important effects not only in increasing yields by means of suppressing water stress but by controlling weed competition and increasing nutrient availability. New experiments have been planned to study the effect of various water management systems on rice yields.

Weed competition is expected to increase in the conditions of continuous rice cropping under flooding and thus, new experiments including the use of pre-emergence and post-emergence herbicides are now planned. At the same time, the amount of available seed of the most promising varieties (IR 4-2, PNA 261, and PNA 221) is being increased with the purpose of providing basic seed for multiplication and further studies.

Table 3.63:1. Effects of N levels and split application on grain yield of INTI rice variety with two soil tillage techniques, under irrigation.

Nitrogen level	Soil tillage		
	Wet	Dry	Average
kg/ha	t/ha		
	At Planting		
0	7.70	7.08	7.39
50	6.40	5.01	5.71
100	4.03	2.92	3.48
200	4.58	1.56	3.07
	1/2 Planting, 1/2 Flowering		
0	6.65	6.42	6.54
50	3.41	6.32	4.87
100	5.13	2.62	3.88
200	4.33	3.60	3.97
	1/2 Clustering, 1/2 Flowering		
0	6.30	6.71	6.51
50	6.54	7.27	6.91
100	4.75	4.26	4.51
200	5.09	2.70	3.90
	1/3 Planting, 1/3 Clustering, 1/3 Flowering		
0	5.77	6.41	6.09
50	6.25	5.99	6.12
100	4.52	3.41	3.97
200	5.89	1.23	3.56
Soil Tillage Average	5.46	4.60	

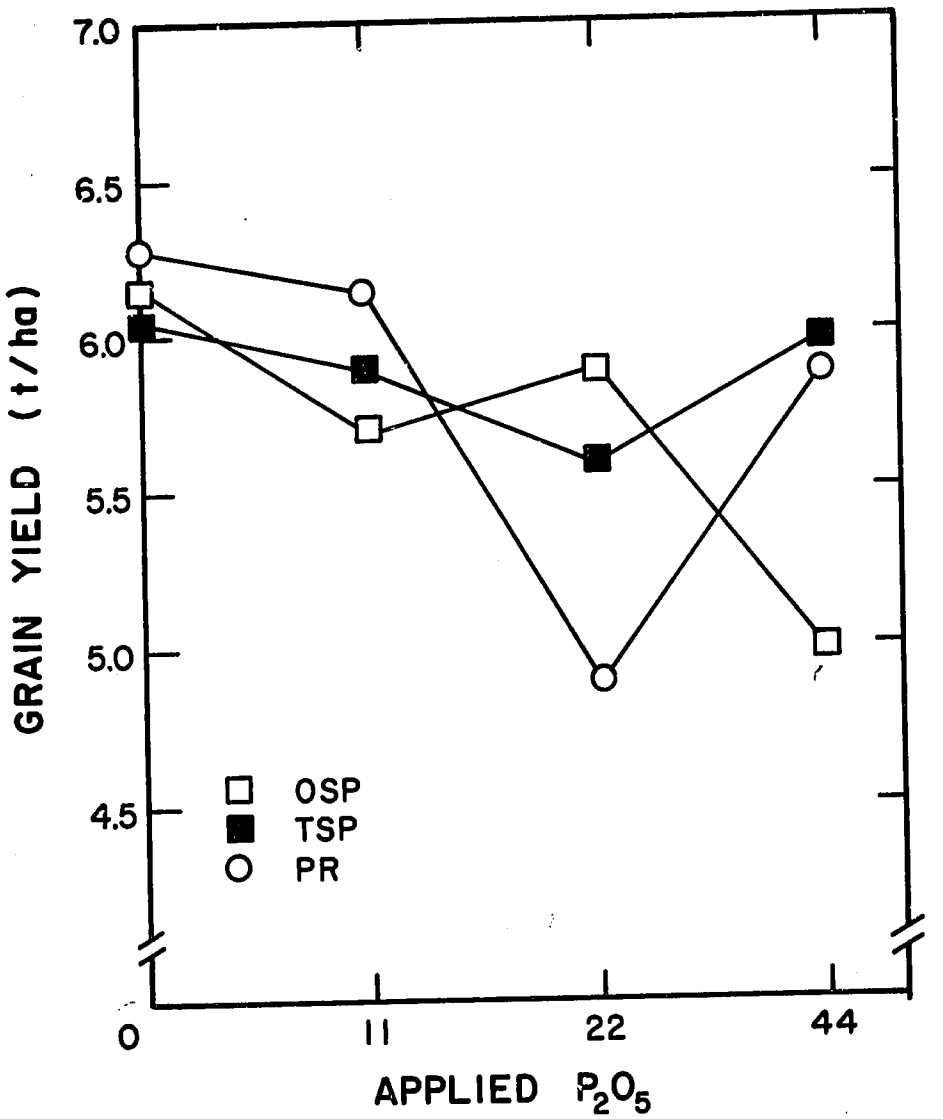


Figure 3.63:1. Effect of phosphorus on grain yield of rice grown under irrigation. INTI variety, Yurimaguas, 1981.

4. ECONOMIC EVALUATION

4.1 Economic Analysis of Agronomic Data

D. Hernandez and A. J. Coutu

A component of the economic analysis is an examination of two basic sets of data. One set of data comes from the experiments at the research station in Yurimaguas and the other set is from the extrapolation trials on the land of local farmers in the Yurimaguas area. The objective was to identify the most profitable cropping patterns given family labor, capital and nutritional constraints among production options that specify various rotation and intercropped systems, fertilizer levels and cultivation practices. In this component as well as all others in the analysis the focus is on labor utilization without mechanization over varying but low levels of owned or borrowed capital.

A base or control run was established in which input and output prices and yields were determined and capital levels, interest rates, wages, availability of labor and nutritional requirements were set. Table 4.1:1 shows resource constraints for three selected situations. Using the base run as a moderate estimate of potential net revenue, a less conservative and a more conservative run were made. In the less conservative run there was more family labor available for the agricultural work, otherwise all the other constraints remained the same as in the base estimate. In the most conservative run the yields were decreased 50 percent, the interest rate, wages and fertilizer prices were increased 100 percent from the base and the total available capital was lowered. Estimates of net revenue under three resource conditions are presented on Table 4.1:2.

The base run which is a relatively moderate to conservative estimate, earns the farmer a net revenue of S/.1,130,659. By increasing the amount of available family labor the farmer's net revenue will be S/.1,291,794, an increase of S/.261,135. Even taking the most conservative estimate, the farmer's net revenue is still S/.237,759 with an investment of only S/.25,000.

Table 4.1:1. Definition of resource constraints on the base, least conservative and most conservative situations, Yurimaguas.

Constraints	Base	Least conservative	Most conservative
Product prices (world prices adjusted for	Control	Same	Same
Fertilizer prices transfer costs)	Control	Same	100% increase
Other input prices	Control	Same	Same
Owned capital (soles)	50,000	50,000	25,000
Borrowed capital (soles)	50,000	50,000	0
Wages: Male (soles per hour)	50	50	100
Female (soles per hour)	38	38	76
Teen (soles per hour)	25	25	50
Child (soles per hour)	13	13	26
Interest rate (soles per hour)	.64	.64	1.28
Availability of family labor for agricultural activities:[1]	---- hrs./day/person ----		
Male	2.50	4.50	2.50
Female	1.60	1.80	1.60
Teen	1.25	2.20	1.25
Child	.93	1.09	.93
Yields	100%	100%	50% decrease
Nutritional Requirements[2]	Control	Same	Same

Table 4.1:1 (Continued)

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[1]The amount of available family labor is defined by the estimated size of the family and the activities defined as agricultural related. In this study, the family is estimated to consist of one child, 0-9 years old; 2 teens, 10-14 years old; 2 adult females, one 15-19 years old and the other 20 years plus. Agricultural activities are defined in the base and most conservative runs as tillage, general care of crops, clearing, planting, cultivating, keeping birds away, harvesting, and time spent living at the chacra. On the least conservative run, agricultural activities consisted of collecting food, hunting, fishing, poultry care, site selection, cultivating, keeping birds away, clearing, planting, living at the chacra, food preservation and mutal labor. The actual labor time coefficients were derived from Dr. Anthony Stocks doctoral thesis, The Invisible Indians, A History and Analysis of the Relations of the Cocamiros of Loreto State, Peru.

[2]The nutritional requirements were divided into four categories: calories, proteins, fats, and carbohydrates. By meeting the required levels of these four elements, a balance diet could be achieved. The levels were set for a seven member family as defined above per year. The required levels were determined with the aid of Dr. L. W. Aurand, professor in the Food Science Department at N. C. State University, Raleigh.

Table 4.1:2. Estimates of potential farm organizations and net incomes under alternative resource conditions.

Resource Use	Base	Least Conservative	Most Conservative
Farm size (ha)	1.675	2.167	1.47
Quantity of goods produced (kg)			
Rice	8286	9556	2671
Corn	3587	4644	1900
Peanuts	4696	5456	737
Soybeans		86	488
Cassava flour	32	164	257
Net revenue (soles)	1,130,659	1,391,794	237,759

These results are sensitive to a number of resource constraints such as factor prices, family size, yield levels, and capital levels. The data in Table 4.1:3 suggest the sensitivity of the base resource constraints to capital. Note that farm size is still small and that rice and peanuts dominate the cropping system. A substitution of soybeans for peanuts has little effect on net revenues and labor utilization. All crops are grown in varying rotations and intercropping sequences.

Table 4.1:3. Estimates of potential farm organizatins and net incomes under base conditions as borrowed capital levels change.

Resource Use	Capital (soles)		
	50,000	200,000	600,000
Farm size (ha)	1.675	3.029	6.568
Quantity of goods produced (kg)			
Rice	8286	16,163	39,059
Corn	3587	4,141	1,415
Cassava flour	32		
Net revenue (soles)	1,130,659	1,905,238	3,809,625

The second data set is from the on-farm trials. These experiments have the same nutritional and labor constraints as those set for the

research station experiments. However, there is a difference on the input and product prices as these are the most recent prices in Yurimaguas. The prices used for the data from the research station are world prices adjusted from transport costs. Also the wages are higher in the on-farm data, 600 soles/day versus 400 soles/day; in the latter the cost of feeding the workers was not included. These constraints were fixed and the capital levels were varied. The change in the capital levels caused a change not only in net revenues but also in the system used. When the total capital level was S/.25,000 the net revenue was S/.843,308 and only Input Level II was used, i.e. improved seed and cultivation (Table 4.1:4). As the total capital level increased to S/.50,000, half the cropped land was farmed using Input Level II and the other half using Input Level III, i.e. improved seed cultivation, lime and fertilizer. Finally, with a total capital level of S/.100,000 the net revenue is S/.1,555,132 and only Input Level III is used. These preliminary results suggest very high rates of return to additional capital. Also this rotation as compared with two others yields higher returns to family labor.

Table 4.1:4. Estimates of the most profitable farming system at varying capital levels using only family labor.

	Capital levels (soles)[1]		
	25,000 0	25,000 25,000	50,000 50,000
Enterprise mix	---------- hectares ----------		
Corn-peanuts-corn: Input Level II	1.059	.783	
Corn-peanuts-corn: Input Level III		.482	1.45
Total farm size	1.059	1.265	1.45
Quantity of goods produced (kg)			
Corn	6,930	9,843	14,237
Peanuts	1,441	1,848	2,360
Net revenue (soles)	843,308	1,135,258	1,555,132

[1]Top capital line is owned and bottom is borrowed.

These small farm net income prospects appear very favorable but are also very sensitive to changes in the resource conditions that vary among potential migrants. The data in Table 4.1:5 illustrate the sensitivity to capital and labor resource situations.

Table 4.1:5. Some estimates of the sensitivity of farm structure and net farm income as labor and capital levels are altered.

Resource situations	Farm size	Net farm income	Add to net revenue per added unit of:		
				Male labor	Female labor
Change capital:[1]	Ha.	Soles	Capital		
S/.100,000	1.675	1,130,659	5.31		
Add S/.50	2.095	1,395,104	5.14		
Add S/.100,000	3.029	1,905,238	5.08		
Add S/.400,000	6.568	3,809,625	4.41		
Change labor availability:[2]					
Just male	.544	322,332		743	
Add female	.828	529,969		905	845
Add teen	.927	619,468		911	1362
Add child	1.087	719,828		794	1575

[1]Total family labor and hired labor.

[2]At S/.50,000 of capital.

A separate analysis of similar sets of data was performed using a partial budgeting method and a linear programming mode given representative family farm resource restriction. Sensitivity tests were made for both modes.

The central economic questions centered on whether the agronomic data on continuous cultivation options gives economic encouragement to existing farmers, to migrants from rural or urban areas, to credit agencies on loan potentials, to public development agencies on infrastructural enhancements and to private factor and product market developers. In general the economic analyses for the selected crops were very favorable with respect to existing slash/burn systems in the Yurimaguas area. The very limited analysis of resource use options in other locations also supports a thrust in the Yurimaguas area. Some more specific conclusions were:

1. That the labor intensive three crops a year continuous production system is economically viable over a wide range of factor prices, capital levels and family labor force compositions.

2. That the most sensitive factor impacting economic viability is the ability to transfer experimental results to on-farm conditions. A twenty pecent yield reduction from expeirmental plots to farm plots is profitable relative to existing systems but at a fifty percent transfer loss the potentials for continuous cultivation systems is limited.

3. That the risks of loaning or borrowing capital for annual operational expenses are relatively low. Under an array of resource situations the data suggest returns to additional capital varying from 2 to 3 times existing rates with some estimates ranging up to 10 to 15 times existing rates.

4. That the possibilities for landless people to migrate into the area as farmers or initially as seasonal hired labor are encouraging. The data suggest that the profitability of hiring labor at rates 2 to 4 times the existing rates holds over a wide range of resource situations.

5. That the most profitable fertility levels are well below those agronomic determinations of levels yielding near maximum production levels. The data suggest that profitability is greater when fertilizer levels are roughly one-half of the agronomically determined complete fertilizer levels.

6. That family nutrition minimums would be satisfied by most of the more profitable crop and cropping systems. The data set was limited but did force a crop mix that met nutritional conditions for sustained work in the Yurimaguas area of high rainfall, temperatures and humidity.

7. That the economic viability of these small farms would likely be improved with the introduction of small scale machines. The high added values per unit of additional labor and capital suggests substitution options.

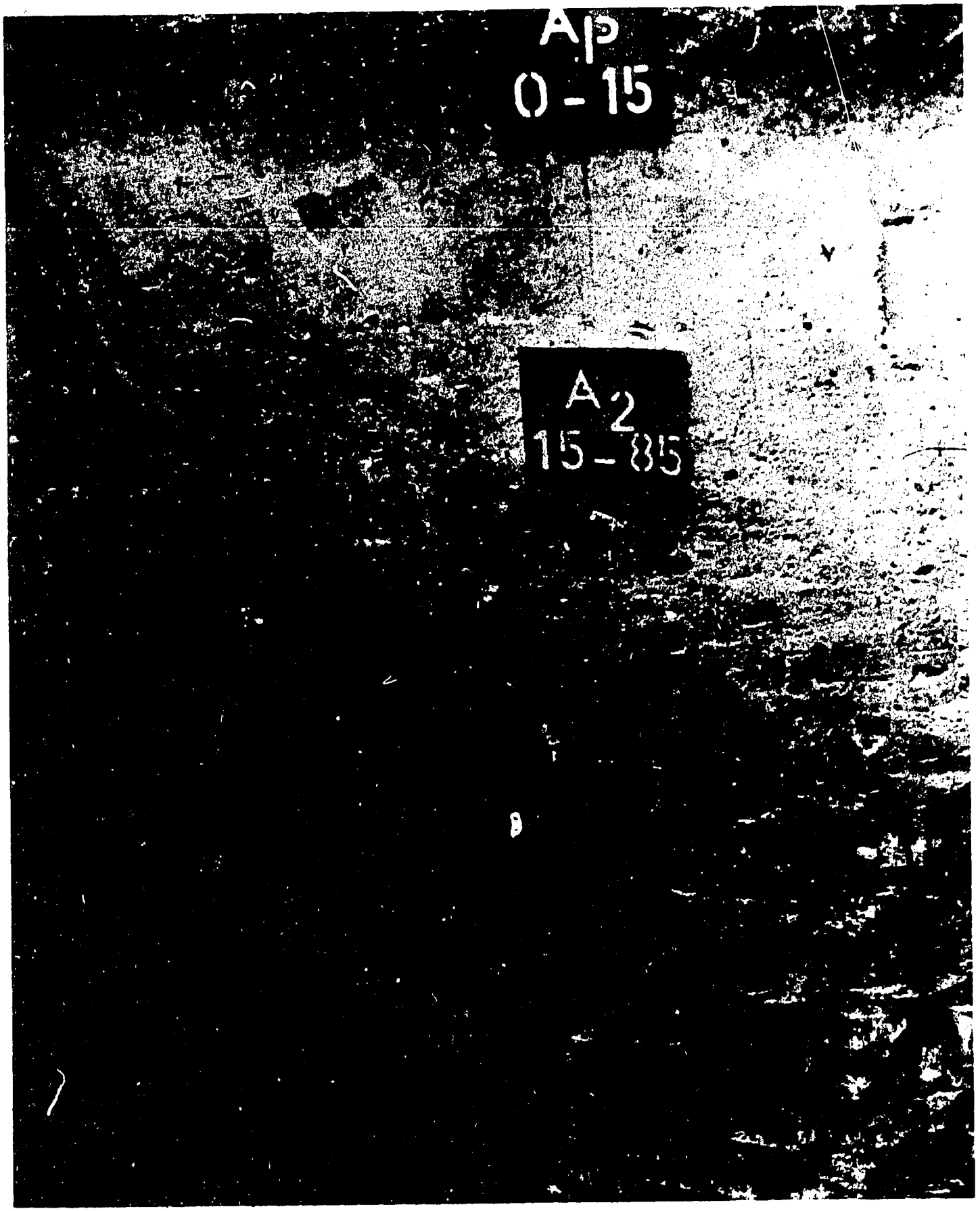
The economic analysis also points to some important areas for additional work. A most important reservation relates to the capacities of factor and product market supplies given increased regional supply. Similarly the question of fixed factor and product price levels could be an important economic consideration in the absence of supply response information in competing production areas.

The agronomic data are incomplete on alternative levels and timing of soil preparation options with respect to liming and phosphate levels. Similarly the data set on organic mulching conditions could be improved and may have important economic consequences.

In subsequent analyses, another important issue relates to nutritional conditions. The data base for such an analysis should include other commodities such as fruits, vegetables, animals and agro-forestry options.

As indicated earlier in this summary, there appear to be some economically viable options relating to machinery adapted to small family farms. Additional analyses on stationary threshers and small tractors with land preparation, cultivation and transport capabilities are suggested.

5. SOIL CHARACTERIZATION



The profile of one of the soils on the Yurimaguas Station. This one is classed as an Arenic Paleudult, fine-loamy, siliceous, isohyperthermic.

5.1 Lateral Water Movement in Oxisol-Ultisol Transition

A. C. Moniz, S. W. Buol and S. B. Weed

Very often Ultisols are as weathered as Oxisols having similar mineralogical and chemical properties. The general pattern of soil distribution is Oxisol profiles occurring on nearly level surfaces while Ultisol profiles occurring adjacent to these surfaces on side slope. Although those soils are believed to be far apart as far as soil genesis is concerned, this could be not exactly true. A close relationship between those two soils is indicated by those profiles having argillic horizon on the top of an oxic horizon as found in some areas in Brazil. This kind of association was studied in detail in two sites Itatiba and Moji-Guacu located in the State of São Paulo. The study carried out is designed to a) characterize the morphology and chemical properties of soils having features of both oxic and argillic horizons; b) to develop a model to explain both factors and processes involved in the formation of argillic horizon in soil material with oxic horizon properties.

In the toposequences of both study areas a blocky structure was observed to develop above the granular structured oxic material and thicken gradually downslope (Figures 5.1:1 and 5.1:2). The blocky structure is formed by desiccation and is referred to here as compressed or consolidated according to soil mechanics terminology. A compressed layer located above a soft layer of similar chemical and mineralogical composition has to be formed by desiccation. Soil materials are compressed because of a stress developed between grains of a soil caused by pore water tension produced by desiccation.

A double-water flow model best explains the formation of the compressed layer and the formation of soil structure as well as providing a dynmaic interpretation of the chemical weathering observed (Figure 5.1:3). Water, the essential component in the formation of the compressed layer by desiccation, is supplied by the lateral- and/or base-water flow. Lateral-water flow near the soil surface begins as the slope becomes steeper and affects mainly the upper part of the toposequence. This has been predicted by Zaslavsky and Rogowski (1969) based on a theoretical analysis of the effect of lateral-water flow.[1] Base-water flow represents a more constant water supply because its catchment includes surrounding areas while the lateral-water flow catchment is limited to the precipitation that falls on a particular slope.

In the Itatiba toposequence lateral-water flow seems to coincide exactly with the compressed layer and a sharp boundary is observed between the subangular blocky structure of the lateral flow zone and

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[1]Zaslavsky, D. and A. S. Rogowski. 1969. Hydralic and morphologic implications of antisotropy and infiltration in soil profile development. Soil Sci. Soc. Amer. Proc. 33:594-599.

the oxic horizon underneath. In both toposequences, the upper boundary of the base-water flow runs along the lithologic discontinuity between the colluvial layer of the oxic material and the underlying altered saprolite. In the footslope of both the Itatiba and the Moji-Guacu toposequences both lateral- and base-water flows are joined, resulting in the formation of a thicker and more compressed layer. In these sites with high moisture content and a slow rate of drying, medium or coarse blocky structures of weak to moderate grade are formed as compared to the drier sites higher in the toposequence which have a stronger grade of structure with smaller ped size.

The transformation of the fine granular structure of the oxic soil material into subangular blocky structures of the compressed layer occurs due to a plastic deformation induced by the alternate wetting and drying cycles. As the soil material develops a certain amount of cohesion due to the cluster of fine aggregates, desiccation cracks form during the drying cycle. These desiccation cracks are the rough precursor of ped surfaces which are smoothered and developed by the building up of compressive stress during the swelling of the entire soil mass during the wetting cycle. In this condition, only the high points of two adjacent surfaces touch each other, representing a small fraction of the total surface area. At these contact points pressure is extremely high even under light pressure plastic deformation and plastic deformation occurs as soon as yield strength is reached. The coarse, mainly sand, fractions in contact between aggregates migrate inward leaving a surface containing mainly fines. These clayey surfaces undergo a gradual reorientation of clay particles into parallel arrangement.

The soil volume change that occurs during alternate wetting and drying results in a decrease of porosity and the formation of a permanent compressed layer. In a close arrangement of uniform quartz spheres, a bulk density of 1.96 g/cc would be achieved. This value approaches the lower limit of volume change or shrinkage limit for sand materials. No single value of bulk density could be assigned for the shrinkage limit because it varies with the texture. As the clay content increases, the bulk density decreases because clay size particles are more resistant to compaction. The most compacted soils on the footslope of both the Itatiba and Moji-Guacu toposequences are approximately half of full compaction.

Excluding most Oxisols and other soils with very low bulk density, a large number of soils have been compressed by desiccation in varying degrees. This is a widespread phenomenon that occurs in large areas of the earth, even in dry and semi-dry regions, because soil material usually undergoes compression regardless of the presence of other soil-forming processes.

The type and degree of soil structure development are controlled by the rate of drying and texture as well as the degree of consolidation. The following sequence of structures is expected with an increase in compaction: (Figure 5.1:4). Included in the prismatic and columnar structures are the fragipans, one of the most compressed soil

horizons known, which are very close to the shrinkage limit. The brittleness of fragipans is due to apparent cohesion because strength is provided by capillary tension.

The local plasma concentration on ped surfaces is better developed in more compressed soils on the footslope of the Itatiba and Moji-Guacu toposequences, respectively. The local plasma concentration is favored by the long periods of time the soil material stays moist and expanded. In this condition of reduced shear strength shrinkage cracks are closed for longer periods of time resulting in the formation of strongly oriented argillans due to the inward migration of larger particles.

A high content of smectite with high crystalline swelling, as well as an abundant supply of water, favors an extremely high compression. This results in clay orientation within the matrix, instead of on the ped surface. There is evidence that clay arrangement, starting at the ped surface when compression is low, extends inside the ped when compression is increased. The following sequence of fabrics is expected in highly compressed clayey soils: First, the insepic or mosepic plasmic fabric, still having argillans, is formed with low shrink-swell potential. Second, the masepic or omnisepic plasmic fabric, with argillans absent, is formed with shrink-swell potential of more than 4%.

The transition between the blocky structure of the compressed layer and the underlying granular material is more abrupt in clayey textured material of the Itatiba site than in the Moji-Guacu site. This probably reflects greater concentration of lateral water flow in the smaller pores of the clay material than the coarse pores of the sandier material.

To better understand how the surfaces of A horizons are formed over compressed layers, we need to look into the properties of compressed layer, considering that the A horizon will be derived from it. The shear resistance observed in soil samples is due to the genuine cohesion or capillary tension. In sandy materials, both genuine cohesion and capillary tension are small. The genuine cohesion of the compressed clayey material is of small magnitude but its capillary tension is very high. Consequently, it has significant strength because of its high effective stress. The cohesion that clayey material seems to have and its strength transmitted by capillary tension are named "apparent cohesion."

The apparent cohesion is readily removed as soon as the soil sample is saturated (slaking test). This destroys the surface menisci and neutralizes the capillary tension, with consequent swelling of the soil mass. As the apparent cohesion is neutralized, the soil material falls apart in a matter of minutes or hours.

The tendency of aggregates of the compressed layer to break down is neutralized inside the pedon <u>in situ</u> because every ped is confined in all directions by neighboring peds. However, in the vicinity of the soil surface, there is space for the aggregates to partially slake.

Hence, the surface horizons are developed not only by the addition of organic matter but mainly by the degradation of the upper part of the compressed layer.

The structure of the clayey compressed layer in the Itatiba footslope (pedons 1213 and 1214) is water unstable, breaking down completely during the slake test both without and with vacuum (4 mm Hg) with the former reacting faster but with similar final results. The aggregates of the medium-textured compressed layer from the Moji-Guacu site are more water stable than those from the Itatiba site.

The presence of organic matter retards wetting and increases the stability of aggregates. Although organic matter seems to counterbalance the tendency of the aggregates from the A horizons from the Itatiba and Moji-Guacu sites to break down during the slaking test, its contribution to the stability of the structure of the A horizon is only partial if any. Pore stress is still present inside the aggregates. Although somewhat depleted of clay and DCB-extractable Fe, the upper part of the compressed layer (A horizon) has a) the highest amount of double-acid extractable Fe, Mn, Zn, Cu and P, b) the highest amount of water dispersed clay for the Itatiba soils; for the Moji-Guacu soils, it was observed in the compressed subsoil instead, c) the high amount of very fine colloidal water-dispersed Fe, in proportion to the DCB-extractable Fe, for the Moji-Guacu soils; for the Itatiba soils, it was observed in the compressed subsoil instead, and d) the highest active iron ratio (Fe_o/Fe_d). These results show that both Fe and clay have been removed from the top of the compressed layer and are still the most available components to be removed.

The bulk of the clay removed from the surface horizon of the compressed layer does not remain in the system. The clay contents remain nearly constant from the top of the B horizon to depths of 500 and 400 cm respectively in pedons 1217 and 1218 in the Moji-Guacu site (Figure 5.1:15). This is an indication that soil materials have been removed by creeping, which seems to be a natural pathway for the selective removal of fines. In addition, a partial solubilization of the clay from the surface horizon could be occurring.

Creeping and lateral-water flow seem to be closely related because they have the same general direction. The lateral water flow probably is one driving force of the slow lateral removal of fines from the upper part of solum.

Soils having surface horizons depleted of clay and Fe oxides are not restricted to soils with argillic horizons. It seems to be a widespread phenomenon observed in Oxisols from Africa as well as from large areas of Brazil such as the eastern Amazon basin. The instability of the surface horizon of Oxisols is explained by the presence of a thin compressed layer, as observed on nearly level crests of both the Itatiba and Moji-Guacu toposequences and many other Oxisols around Campinas, São Paulo State.

The red to yellow color transformation upward in the profile as well as downslope in toposequences is widespread regardless of the soil type and indicates a concentration of goethite due to the dissolution of hematite. The increase in moisture content upward in the profile could be an important factor in the same sense that it is important downslope, in addition to the effect of organic matter. The increase in the surface area of Fe oxides in the order Oxisols < Ultisols < Alfisols in both the Itatiba and Moji-Guacu sites is another indication that physical properties are controlled by the amount of moisture present, which also promotes compression of soil material. The more compressed soils have larger surface areas associated with their Fe oxides.

The concept of double-water flow, initially applied to the study of soil morphology and compressed layer, can be further developed to explain the chemical and mineralogical data from both the Itatiba and Moji-Guacu sites.

In the Itatiba toposequence as a consequence of the action of both lateral- and base-water flow, there occurs a 40 percent increase in the DCB-extractable Fe downslope, an even greater increase in DCB-extractable Mn content, and an increase in content of exchangeable bases. The latter is responsible for the formation of Alfisols (pedon 1214) in the concave footslopes where there is a concentration of both lateral- and base-water flow.

Pedon 1218 on the footslope of the more sandy textured Moji-Guacu toposequence has Fe removed rather than concentrated as compared to the other pedons located in the upper part of the toposequence. The sandy nature of both the colluvial layer and the underlying weathered in situ sandstone supplies less Fe and bases while at the same time allowing greater percolation, thereby clearly explaining the difference between the clayey Itatiba and sand Moji-Guacu sites.

To better understand the general trends of weathering processes, the alterations occurring at the interface of the fresh rock-saprolite have to be considered for three reasons: a) the base-water flow could be close enough to the surface of soil to affect the solum development; b) if the base-water flow is deep, it is going to affect only the soils in the footslope, and c) it is a reference point for studying the chemical and mineralogical reactions within the profile as well as along the toposequences.

Several chemical data show an intense removel of Fe, Mn, and Si as well as alkaline-earth metals at the rock-saprolite interface. Very often the removal of a particular element, as calculated, does not remain vertically constant. The addition of some elements (Fe, Mn, Si) subsequent to initial weathering occurs to partially compensate for earlier removal. This is accomplished by the base- and/or lateral-water flow which brings those constituents from adjacent upslope areas where they are being released. Iron is lost from the rock-saprolite interface because the clay formation is not fast enough to cope with the release of iron from the primary mafic minerals.

The resilication, observed upward in the soil profiles also occurs downslope in both the Itatiba and Moji-Guacu toposequences. This corresponds to the resilication observed in the direction Inceptisols > Ultisols in the Atibaia region near Itatiba and in similar geomorphology. The resilication of gibbsite formed in the early stages of weathering as well as any other soil gibbsite is an important process in tropical regions because it counterbalances the allitization process and prevents the soil material from becoming essentially gibbsitic.

An alternate desilication-resilication is occurring vertically in the soil profile as well as horizontally along any toposequences. Although eventually not strictly precise, the geochemistry of less mobile elements and minerals tends to occur upward in a vertical section in a fashion similar to that observed laterally in a downslope direction. Roughly, it is similar to Walker's Law of succession of facies. The gradual change of soil color, which becomes more yellowish both upward in the profile and downslope in the toposequence, is a visual indication of the trends described.

It can be visualized that soil materials undergo two general cycles. After deposition of colluvial material on nearly level surfaces, desilication predominates under a humid climate, resulting in the formation of Oxisols or soil material of oxic composition. As the superficial sediments are dissected by stream valleys, the relief becomes steeper and lateral- and/or base-water flow promotes resilication on the lower slopes. The compressed layer resulting from desiccation is formed under these conditions.

Although it has not been explicitly recognized, it should be pointed out that the weathering intensity at depths could fall into at least two general types: a) the weathering intensity increases toward the surface, and as a consequence the weathering stage of the colloids tends to advance in the same direction and b) the weathering intensity is high throughout the profile and even higher in the proximity of the weathering front.

In summary, lateral-water flow and base-water flow are the most important factors in the formation and development of different types of soil structure as well as in chemical and mineralogical transformations that occur during the soil development in the Oxisol-Ultisol transects studied.

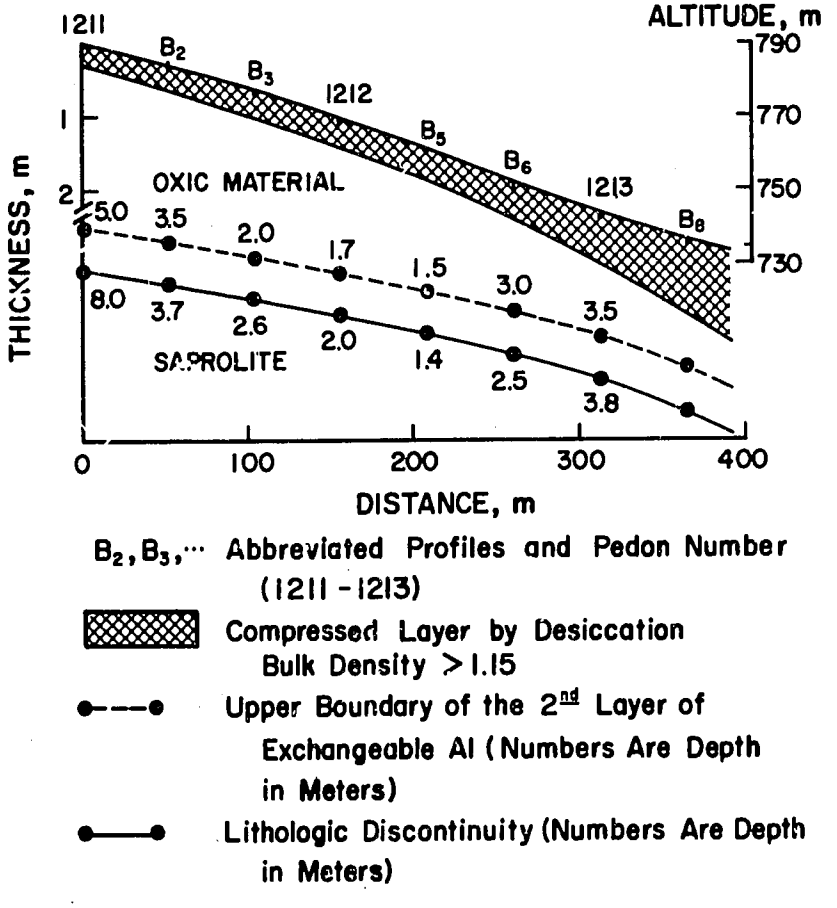


Fig. 5.1:1. Cross section of transect B in the Itatiba toposequence indicating the thickness of the compressed layer by desiccation, the upper boundary of the 2nd layer of exchangeable aluminum and the lithologic discontinuity.

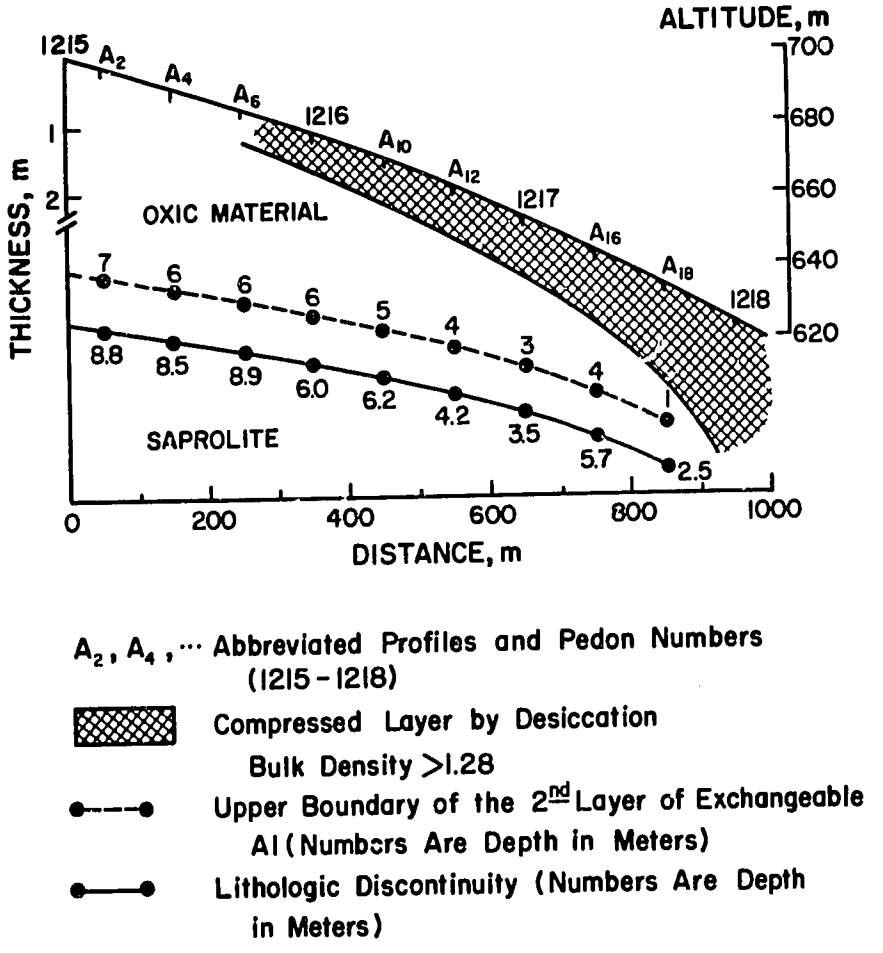


Fig. 5.1:2. Cross section of transect A in the Moji-Guacu toposequence indicating the thickness of the compressed layer by desiccation, the upper boundary of the 2nd layer of the exchangeable aluminum and the lithologic discontinuity.

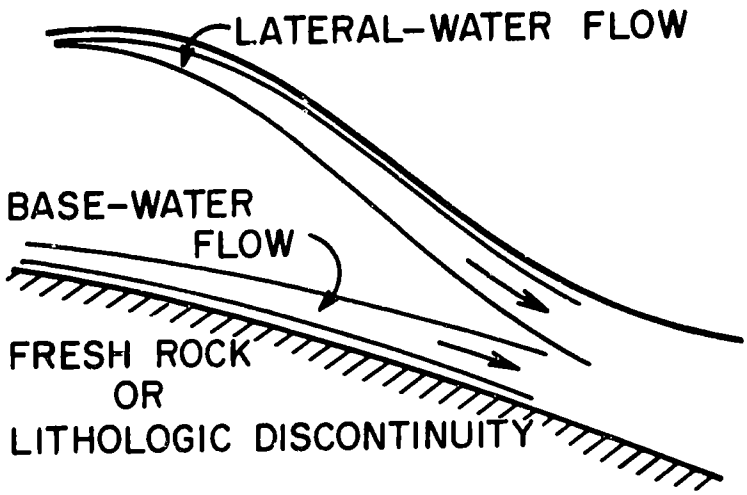


Fig. 5.1:3. Direction of the double-water flow along the slope.

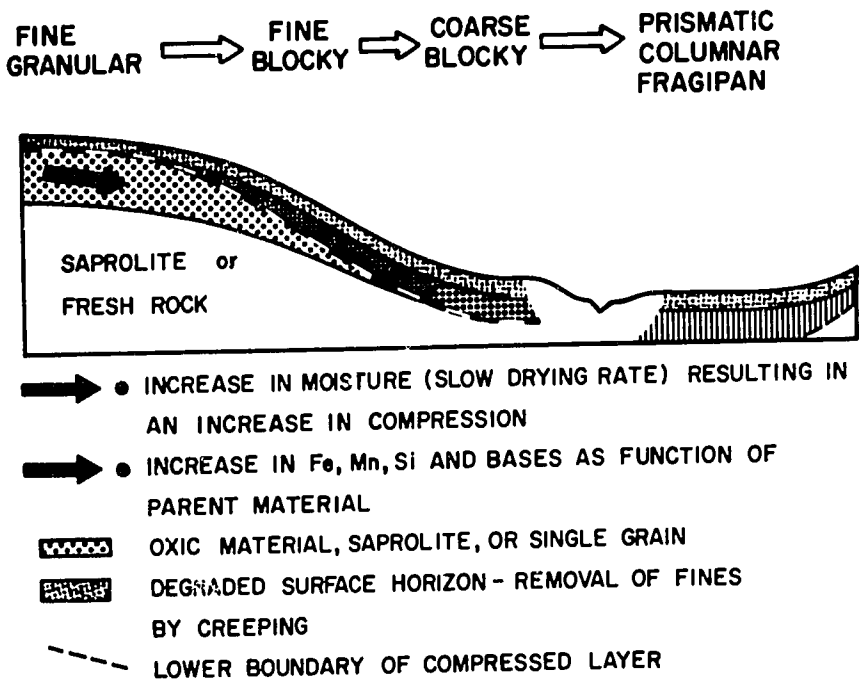


Fig. 5.1:4. Distribution of different types of soil structure as result of increase in moisture downslope as well as the direction of lateral translocations of Fe, Mn, Si and bases.

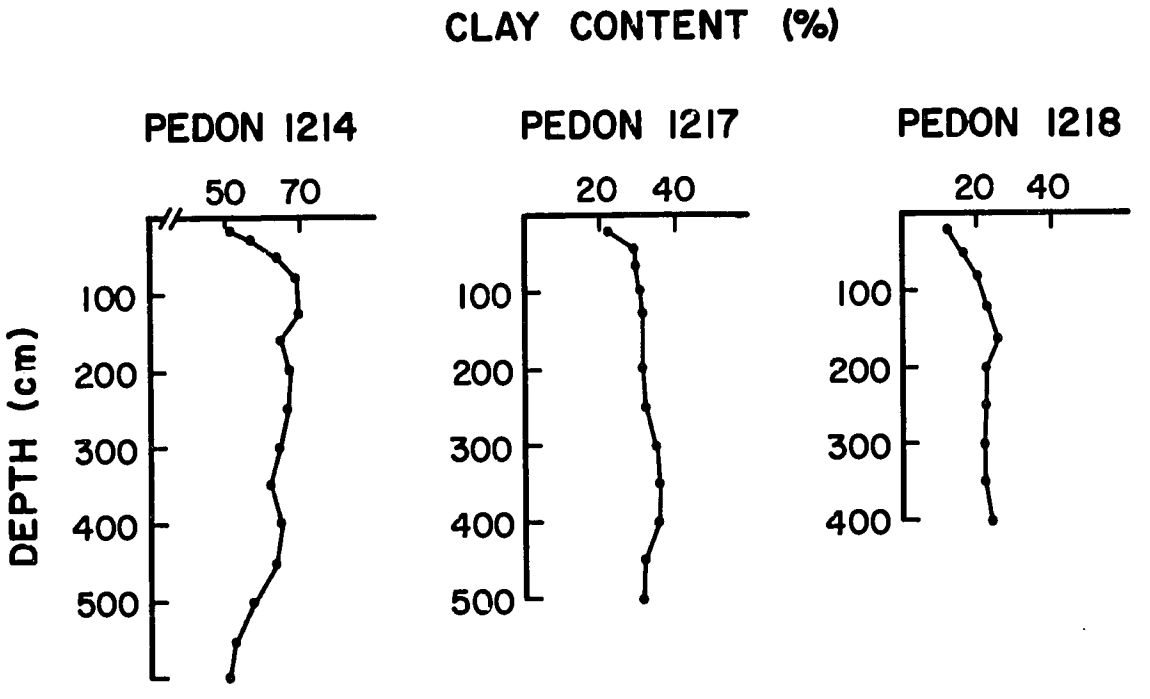


Fig. 5.1:5. Clay distribution of a Typic Paleudalfs (pedon 1214) from Itatiba and a Typic Paleudults (pedons 1217 and 1218) from Moji-Guacu, São Paulo State.

5.2 Field Assessment of P Fixation by Allophane

A. Alvarado and S. W. Buol

The "x" modifier had been used in the Fertility Capability Classification System to indicate the high phosphorus fixation capacity of soils with allophane (Andepts, Andolsols, etc.). Allophane presence is identified by means of the Fieldis and Perrott technique, based on the reaction of amorphous aluminosilicates with NaF.

$$Al_2\ Si_2O_5\ (OH)_4 + NaF \rightleftarrows Al_2\ Si_2O_5\ (OH)_{4-x} + NaOH$$

This reaction releases OH^- increasing the pH of the solution proportionally to the concentration of allophane. Since P fixation is also mainly determined by the content of amorphous aluminosilicates, the hypothesis that the former could be a predictor of the later was developed and tested.

Soil samples of Andepts from Guatemala (14) and Costa Rica (45), from A horizons (39) and B horizons (20) were collected and analyzed for this purpose. P fixation studies were carried out using from 0 up to 6000 µg P/g soil from which linear models were developed. The degree of regression obtained between the amount of P added vs the amount of P extracted were used to calculate the amounts of P fixed as follows:

$$\%\ P\ fixed = (1-b)\ 100$$

$$b = \frac{P\ extracted}{P\ added}$$

A highly significant correlation was found between the P fixation values and the amount of amorphous aluminum extracted with ammonium oxalate (Fig. 6.1:1). The samples separated in two groups, with a critical value of 2.3% amorphous aluminum equal to a P fixed value of 80%.

The pH in NaF also correlated highly significantly with amorphous aluminum content. In this case, a linear model gave the best fitness (R^2 = 0.62), as can be observed in Fig. 6.1:2.

A highly significant positive correlation was obtained between pH in NaF and P fixed (Fig. 6.1:3). In this figure, the amount of P needed to increase by 10 µ P its amount in solution is included. The soils over pH 10.7 and more than 90% P fixed are those that require large amounts of P fertilizer to satisfy the crop needs.

A field technique using spot ceramic plates, 1N NaF, and 0.04% thymolphthalein was developed to estimate the critical point (pH 10.6). The development of a blue color in the mixed solution after 10 minutes from a small amount of soil treated with an eye dropped full of NaF and 3 drops of the indicator will identify those soils that fixes more than 90% P.

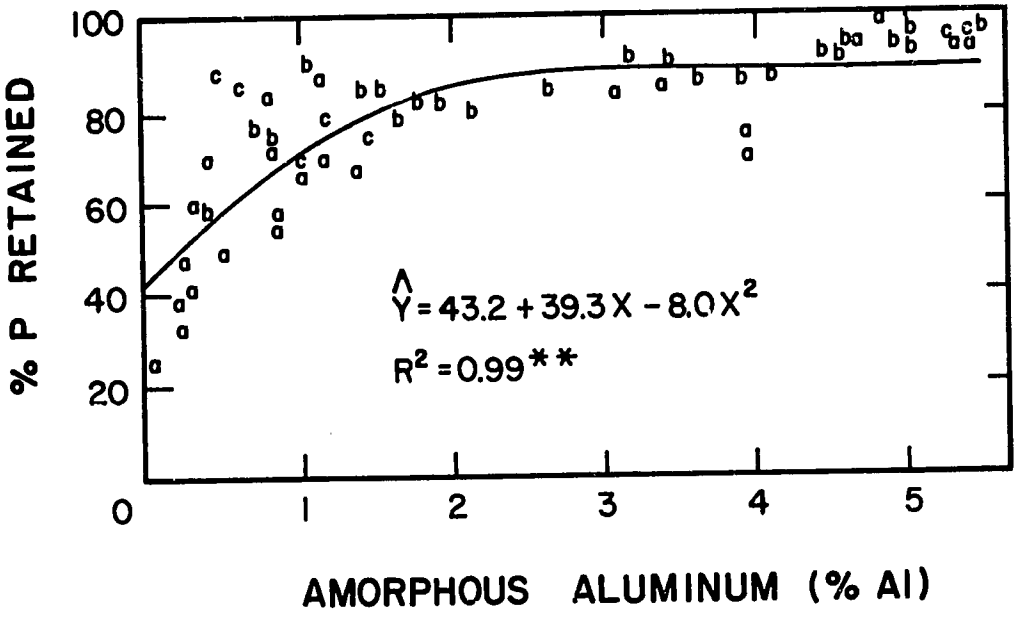


Figure 5.2:1. Relationship between P retention and ammonium oxalate extractable aluminum (equation in Figure is for the quadratic segment of the model; a = Group mean Al/(Al+Si) = 0.88; b = Group mean Al/(Al+Si) = 0.85; c = Group mean Al/(Al+Si) = 0.74).

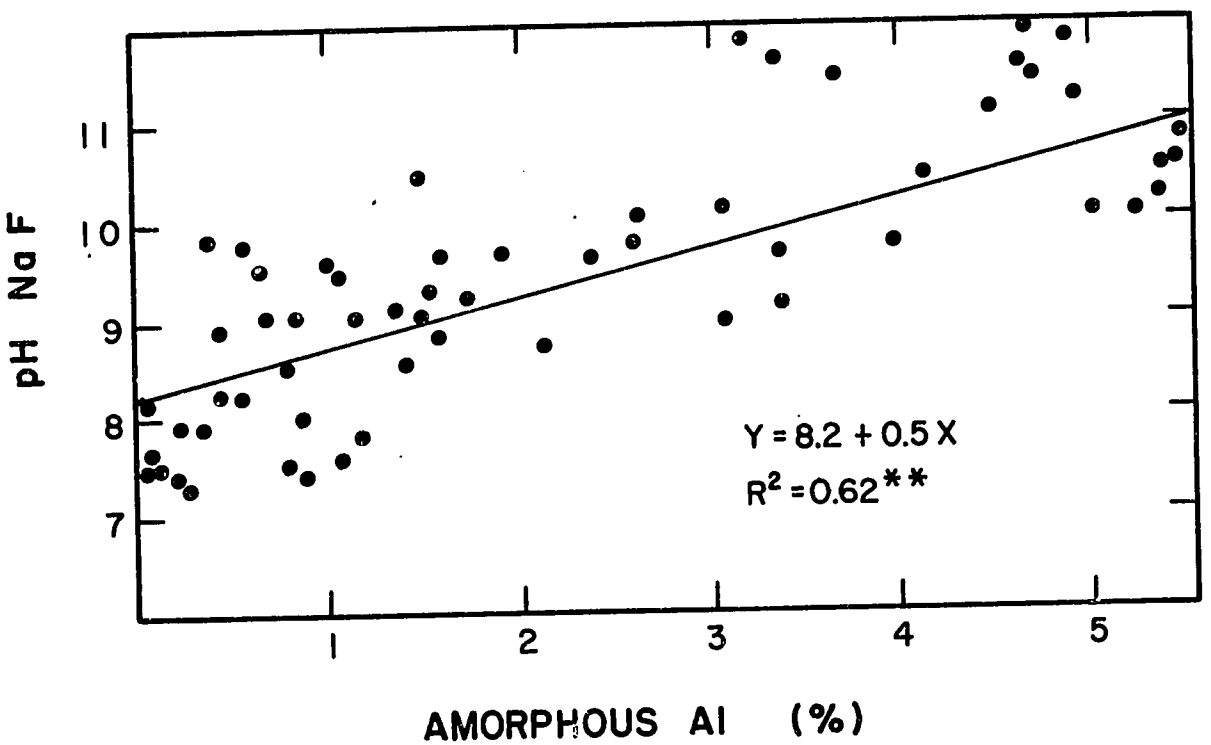


Figure 5.2.2. Relationship between amorphous Al and pH in NaF.

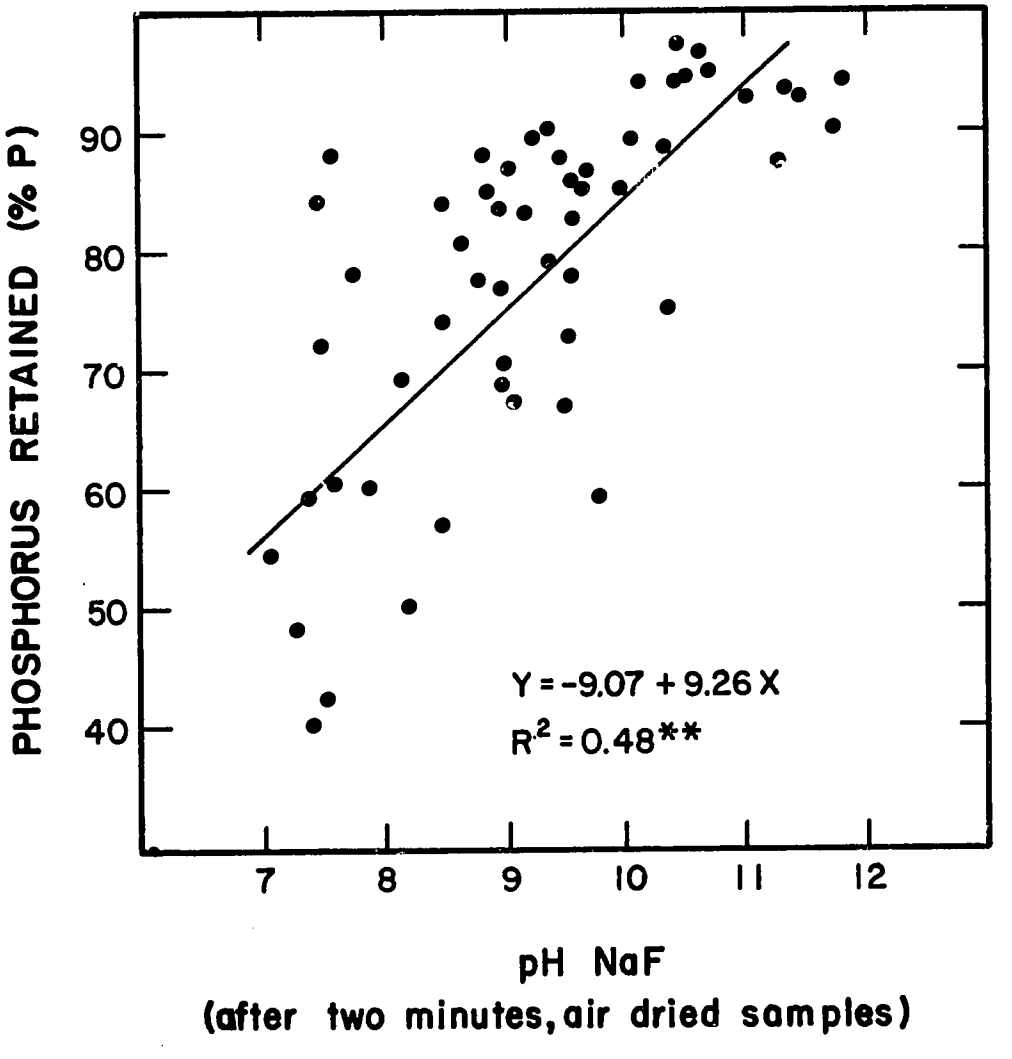


Figure 5.2.3. Relationship between P retained, pH in NaF (after two minutes using air dried samples) and P needed to provide 10 μg extractable P/g soil by the International Soil Fertility Evaluation and Improvement Program technique (1972).

In addition to published information, results are conveyed through many means such as Dr. Dale Bandy talking with Peru's Minister of Agriculture Nils Ericcson and other Peruvian leaders at the Yurimaguas Station.

6.1 Publications

B. I. Monar

The following papers were published by program staff in scientific journals, books or theses from mid-1980 through 1981:

Benites, J. R. 1981. Nitrogen response and cultural practices for corn-based cropping systems in the Peruvian Amazon. 153 pp. Ph.D. Thesis.

Bentley, C. F., R. J. Dudal, S. Arlosoroff, P. Buringh, J. Dobereiner, D. J. Greenland, W. D. Hopper, J. P. Jrabovsky, H. Lueken, P. A. Sanchez and L. D. Swindale. 1980. Soils. In: Agricultural Production, Research and Development Strategies for the 1980's. The Rockefeller Foundation, New York, pp. 6-15.

Buol, S. W. and J. J. Nicholaides. 1980. Constraints to soil fertility evaluation and extrapolation of research results. pp. 425-435. In: M. Drosdoff and W. Rockwood (eds.) Priorities for Alleviating Soil-Related Constraints to Food Production in the Tropics. IRRI/ Cornell University. Invitational paper presented at World Soils Constraints Conference. June 4-8, 1979. IRRI, Los Baños, Philippines.

Buol, S. W. and W. Couto. 1981. Soil Fertility-Capability Assessment for Use in the Humid Tropics, pp. 254-261. In: D. J. Greenland (ed.). Characterization of Soils. Clarendon Press.

Cochrane, T. T., J. G. Salinas and P. A. Sanchez. 1980. An equation for liming acid mineral soils to compensate for crop aluminum tolerance. Trop. Agric. 57:133-140.

Hiebsch, C. K. 1980. Principles of intercropping: Effects of nitrogen fertilization, plant population and crop duration on equivalency ratios in intercrop vs. monoculture comparisons. 101 pp. Ph.D. Thesis.

Kamprath, E. J. 1980. Soil Acidity in Well Drained Soils of the Tropics as a Constraint to Food Production. pp. 173-187. In: Soil Related Constraints to Food Production in the Tropics.

Lins, I. D. 1980. The on-farm test program as viewed by agents of the northeast agricultural extension district of North Carolina. 43 pp. M. Ag. Thesis.

Naderman, G. C. and P. A. Sanchez. 1980. Soil fertility and moisture studies in the Cerrado of Brazil. In: H. B. Obeng and P. K. Kwakye (eds.). International Soil Science Society Conference on Savanna Soils and their Management. Soil Science Society of Ghana, Kumasi, Ghana. pp. 113-132.

Nicholaides, J. J., H. F. Chancy, H. J. Mascagni, Jr., L. G. Wilson and D. W. Eaddy. 1980. Potassium and phosphorus fertilization of sweet potatoes. pp. 10-24. In: D. Cassel (ed.). Soil Sci. Soc. N.C. 1979 Proc., Raleigh, NC.

Nicholaides, J. J. 1981. Rondonia rural development project: Soil management implications for annual crop production. World Bank/International Finance Corporation. Washington, D. C. 9 pp.

Mombiela, F., J. J. Nicholaides and L. A. Nelson. 1981. A method to determine the appropriate mathematical form for incorporating soil test levels in fertilizer response models for recommendation purposes. Agron. J. 73:937-941.

Moniz, A. C. 1980. Formation of an Oxisol-Ultisol transition in São Paulo, Brazil. 209 pp. Ph.D. Thesis.

Paredes, J. R. and S. W. Buol. 1981. Soils in an Aridic, Ustic, Udic, Climosequence in the Maracaibo Lake Basin, Venezuela. Soil Sci. Soc. of Amer. J. 45:385-391.

Sanchez, P. A. 1980. The subhumid tropics: technology and management strategies for rainfed agriculture. In: Proceedings, Agricultural Sector Symposia. The World Bank, Washington, D. C. pp. 35-65.

Sanchez, P. A. and T. T. Cochrane. 1980. Soil constraints in relation to major farming systems of tropical America. pp. 107-139. In: Priorities for Alleviating Soil-Related Constraints to Food Production in the Tropics. International Rice Research Institute, Los Baños, Philippines.

Sanchez, P. A. and G. Uehara. 1980. Management considerations for acid soils with high phosphorus fixation capacity. In: F. E. Khasawneh, E. C. Sample and E. J. Kamprath (eds.). The Role of Phosphorus in Agriculture. Amer. Soc. of Agron., Madison, Wisconsin. pp. 471-514.

Sanchez, P. A. 1981. Soils in the Humid Tropics. pp. 347-410. In: Blowing in the Wind: Deforestation and Long Range Implications, Studies in Third World Societies. Williamsburg, Virginia.

Sanchez, P. A., R. K. Perrin and S. W. Buol. 1981. Concepts of Program Design for Soils Research and Information Transferral in Developing Countries.

Sanchez, P. A. and J. G. Salinas. 1981. Low Input Technology for Managing Oxisols and Ultisols in Tropical America. Advances in Agronomy 34:279-406.

Sanchez, P. A. 1981. Soil Management in the Oxisol Savannas and Ultisol Jungles of Tropical South America. pp. 214-252. In: D. J. Greenland (ed.). Characterization of Soils.

Smyth, T. J. and P. A. Sanchez. 1980. Effects of lime, silicate and phosphorus application to an Oxisol on phosphorus sorption and ion retention. Soil Sci. Soc. Amer. J. 44:500-505.

Smyth, T. J. and P. A. Sanchez. 1980. Niveis criticos de fosforo para arroz de sequeiro em um Latossolo dos Cerrado. Rev. Bras. Ciencia Solo 4:88-92.

Smyth, T. J. 1981. Agronomic comparisons between phosphate rock and superphosphate in soils of the Cerrado of Brazil. 143 pp. Ph.D. Thesis.

Van Diepen, J. C. 1980. Corn response to different tillage practices in selected North Carolina Soils. 102 pp. M.S. Thesis.

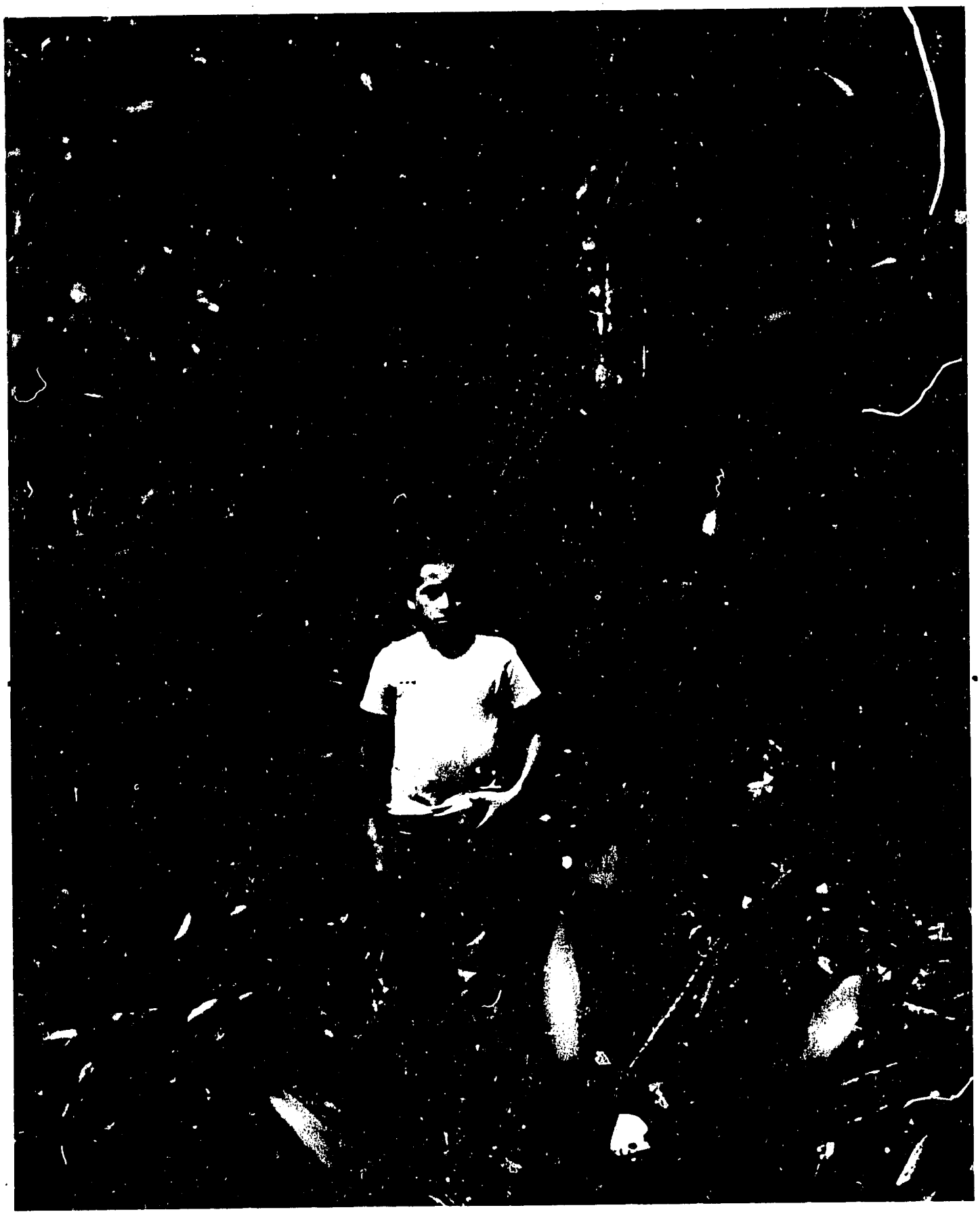
6.2 Mailing List

D. M. Silsbee

Requests for publications increased by 8.8% on our Tropical Soils Research Program mailing list during the period of 1980-1981. This raises the total listing of individuals and institutions on our mailing list to 1,983 scientists, administrators, private companies, students and libraries which receive this service free of charge in 102 countries around the world.

Any individual or institution requesting this service is eligible to be placed on the mailing list of the Tropical Soils Research Program.

Farmers in the region are now beginning to use and benefit from the Yurimaguas improved technologies developed by the Program.



When continuous cultivation becomes a reality in the Amazon basin, less rainforest will have to be cleared.