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CROP PRODUCTION AND LAND POTENTIAL OF BENCHMARK SOILS OF LATIN AMERICA

Contract AID/ta-C-1158

ANNUAL RESEARCH REPORT
for the period
1 October 1978 to 30 September 1979

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DEPARTMENT OF AGRONOMY AND SOILS
COLLEGE OF AGRICULTURAL SCIENCES
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MAYAGUEZ, PUERTO RICO

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REPORT SUMMARY

A. 1. Project Title and Contract Number: Crop Production and Land Potential of Benchmark Soils of Latin America - AID/ta-C-1158

2. Principal Investigator, Contractor and Mailing Address:
F. H. Beinroth Univ. of Puerto Rico Department of Agronomy and Soils
College of Agricultural Sciences
Mayaguez, Puerto Rico 00708

3. Contract Period (as amended): 1 January 1975 to 31 December 1980

4. Period covered by Report: 1 October 1978 to 30 September 1979

5. Total AID funding of contract to date: $2,110,555.00

6. Total expenditures and obligations through previous fiscal year: $1,101,538.55

7. Total expenditures and obligations for current year: $346,412.60

8. Estimated expenditures for next fiscal year: $420,600.00

B. Narrative Summary of Accomplishments

The objective of the Benchmark Soils Project is to demonstrate that agroproduction technology can be transferred among tropical countries on the basis of soil classification. To verify the transfer hypothesis, a series of crop production and soil management experiments are conducted in various countries by this contract and a parallel project of the University of Hawaii.

The soils selected for experimentation by the University of Puerto Rico project are highly weathered, red upland soils of the subhumid tropics defined as Eutrustox in the U.S. Soil Taxonomy. Six experiment sites in such soils were established, three in Puerto Rico and three in Minas Gerais, Brazil. Following previously developed standard procedures, a total of 31 transfer, 5 variety and 9 management experiments with maize and soybeans were completed or begun during FY 79.

Maize yields obtained in the transfer experiments were generally good to excellent. But statistical analyses of the field data revealed considerable variability, both within and among sites and from season to season. While this is to be expected in view of divergences in past management and other site variables, it renders the transfer test difficult. Encouragingly, the R^2 values for regression analyses by different models indicate that there was no segregation of sites along country lines. However, P-statistic analyses showed sizeable differences between observed and predicted yields, stressing the need for considerably more modelling work. At this point, there is no strong statistical evidence either for or against the transfer hypothesis. It is nonetheless expected that further field experimentation and refined statistical analyses will corroborate the hypothesis, at least in essence.

Management experiments focused on irrigation, plant population density, minimum tillage, liming, and variety trials. These studies were designed to fill gaps in the knowledge about the management of Eutrustox and to generate information of local applicability.

Dissemination of project rationales and results at workshops and seminars, and through brochures and a regularly published newsletter lead to a growing international acceptance of the concepts under study. In addition, various manuscripts have been prepared for publication in scientific journals.

INTRODUCTION

This is the fourth annual report on the Benchmark Soils Project of the University of Puerto Rico which became effective in January 1975 under contract AID/ta-C-1158 as a companion project to a similar AID contract of the University of Hawaii.

The report covers the period from 1 October 1978 to 30 September 1979 and deals mainly with the accomplishments achieved during that time. Emphasis is placed on the presentation of the results of field experiments and their statistical interpretation relative to the project hypothesis. No effort is made to reiterate at length the basic rationale of the project or the generalities regarding research strategy and experiment methodology, but pertinent referenced statements are included. For more detailed information on these aspects, previous annual reports and two joint progress reports on the Benchmark Soils Project published by the University of Hawaii (PRBSP-01-8/78 and PRBSP-02-9/79) should be consulted.

An administrative and fiscal report containing a complete account of expenditures and a budget forecast for FY 80 was submitted to the AID Contract Office in January 1980. Fiscal data are, therefore, not reported here.

It should be pointed out that the present report has been prepared primarily for AID review and is not intended for wide circulation. However, the Universities of Hawaii and Puerto Rico will again join efforts to prepare a combined report of appealing form and substance which will be published and distributed in 1980.

REFERENCE BACKGROUND

I. General

Agricultural production capacity in the less-developed countries (LDCs of the tropics must be expanded by increases both in the yields per hectare and in the area of cultivated land to meet present and future food demands. While there is no fundamental reason why these demands cannot be met, the record so far has been less than reassuring. Dudal (1978) estimates that during the 20-year period ending in 1977 the area of cultivated land in the world increased by 135 million hectares which corresponds to about 10 percent of the land resources still available for cultivation and to only about 9 percent of the land currently in agricultural use. In the same period, however, the world's population increased by 40 percent. Distressingly, the expansion of cultivated lands in the LDCs in particular is far lagging behind

that required by the increase in population there. If the LDCs are to increase per capita food availability by at least 1 percent per year, they need to expand their food production over the next 25 years by an average rate of about 3 to 4 percent per year and increases in yield need to average about 2.5 percent per year.

The growth in resource productivity must be guided by wise land-use decisions and based on sound methods of soil and crop management. Because biological phenomena, such as crop production, have to be studied in and cannot be separated from the ecosystem where they occur, the task of developing an advanced technology for tropical agriculture must therefore be accomplished primarily in the tropics. However, the traditional, empirical approach to improving crop performance --agricultural experimentation-- is both expensive and time-consuming. And many LDCs lack the manpower, capital and institutional capacity to conduct all of the research needed. It thus stands to reason that they should capitalize on experience gained elsewhere under conditions of similar ecology and factor endowment.

Kellogg (1967) "fully expects that 'some day' the most productive agriculture of the world will be mostly in the tropics, especially in the humid parts." There has been enough imaginative soil and agronomic work to show in a few places that this is not beyond our capacity. The knowledge base required to transform agriculture in the tropics from a natural resource based enterprise to an industry founded on science and technology is now gradually being generated through research and development in many agencies and areas. Although there has been a lag in the large-scale dissemination and systematic application of this knowledge, transfers of applicable agrotechnology are of such critical importance to the agricultural and economic development of agrarian LDCs that they must now be facilitated.

In the context of this perspective and on the basis of the rationales elaborated below, the Benchmark Soils Project contends that soil classification is a suitable vehicle for and an essential element of the process of agrotechnology transfer.

II. Project Rationale

Many authoritative statements can be found in the literature that allude to the fact that soil classification, in conjunction with soil surveys, provides an effective basis for knowledge transfers. Of the various systems of soil classification in use, Soil Taxonomy (Soil Survey Staff, 1975) is best suited for practical interpretations as it was conceived with this end in mind.

After 20 years of preparation, Soil Taxonomy was published by the USDA Soil Conservation Service in 1975. It is an attempt at a comprehensive taxonomic classification of soils and constitutes the most elaborate and most quantitative system developed to date. Although basically an American system, Soil Taxonomy is gradually becoming the internationally accepted classification for scientific communication, and more and more pedologists, particularly in the Third World, are talking to each other in terms of this system. It is also used, either in lieu of or parallel to, national systems of soil classification, notably in Southeast Asia and in Latin America.

Like most taxonomic systems, Soil Taxonomy is a multicategoric system. Each category is an aggregate of taxa, defined at about the same level of abstraction, with the smallest number of classes in the highest category and the largest number in the lowest category. In order of decreasing rank, these categories are order, suborder, great group, subgroup, family, and series.

The soil family constitutes a condensed scientific statement that integrates the knowledge about a narrowly defined group of soils and their environment. Soil families are, within a given subgroup, differentiated primarily on the basis of soil characteristics that provide classes having relative homogeneity in properties important to plant growth and indicative of soil-water-root relationships. Soils classified in the same family should, therefore, have nearly the same management requirements, a common response to cultural practices, and a similar potential for crop production.

This assumption is basic to the Benchmark Soils Project and a test of its validity is the principal concern of the Project. If proven correct, Soil Taxonomy, together with soil resource inventories, can emerge as a powerful tool in the process of agrotechnology transfer and provide a framework for mobilizing and utilizing existing soil management and crop production knowledge.

III. Project Purpose and Objectives

The purpose of the Benchmark Soils Project (BSP) is to test an innovative approach to agrotechnology transfer in the tropics and develop a methodology designed to assist LDC's in appropriately utilizing their land resources for increased and better quality food production by bypassing key constraints. Principal among the constraints prevalent in LDC's are insufficient capital, scarcity of qualified research personnel, and lack of time to close the widening gap between agroproduction and food requirements.

The primary research objectives of the BSP are:

1. To demonstrate that soil management and crop production knowledge can be directly transferred among tropical countries at the family level of Soil Taxonomy, and

2. To establish that the behavior of tropical soils and their potential for food production under various levels of management inputs can be predicted on the basis of soil taxonomic units.

Implicit in these objectives are the substantiation of the value of soil survey and classification for land use planning and the testing of the validity of the established taxonomic criteria. For a limited number of soil families, the BSP further attempts to indicate management alternatives conforming to the economic decision environment of small farmers in tropical LDC's.

IV. Research Design and Methodology

The strategy to test the project hypothesis consists basically of conducting a series of identical experiments in soils of the same family and monitering crop performance. The research design and methodology was developed in concurrence with the recommendations of the Workshop on Experimental Design (Silva and Beinroth, 1975) and in close coordination with the University of Hawaii. In the Project design distinctions are made between two types of experiment sites, designated primary and secondary sites, and three kinds of experiments referred to as transfer experiments, variety trials and management experiments.

Primary sites are experiment locations where the three kinds of experiments explained below are conducted and which are completely instrumented for collection of pertinent weather data. At each primary site the following weather parameters are monitored: (1) ambient temperature and relative humidity recorded continuously with standard hygrothermographs, (2) daily maximum and minimum ambient temperatures, (3) rainfall recorded continuously or daily, (4) accumulated daily solar radiation, (5) daily wind run, (6) pan evaporation (optional), and (7) maximum-minimum soil temperatures at 5, 15, 20 and 50 cm depths. To the extent possible, instrumentation is according to U.S. Weather Bureau Standards.

Secondary sites are experiment locations where only transfer experiments are conducted. They are required to increase the number of experiment sites per soil family in order to have sufficient data for a statistically valid estimate of the

effect of uncontrolled variables on crop yields. Secondary sites may differ from primary sites in that they exhibit variations in soil properties important to plant growth, such as pH or base saturation, within the range permitted by the definition of the soil family. If located at some distance from the primary site, secondary sites may also have different weather conditions. In this case they are equipped with the standard instrument shelter, hygrothermograph, rain-gauge and solar radiometer. At secondary sites situated closer to the respective primary sites, only rainfall is recorded, as other weather parameters are not likely to vary significantly over short distances.

Transfer experiments are soil fertility trials designed especially to generate the data necessary to test the hypothesis set forth above. Their design is the 5^2 partial factorial modification by Escobar as described in a paper by Laird and Turrent and presented at the Workshop on Experimental Design. Currently the two variables on Eutrustox are phosphorus and nitrogen at 5 levels each with 13 of the 25 total possible treatment combinations and 3 "control" treatments. These 16 treatments are replicated at least 3 times; thus, there are 48 plots in each experiment. Such transfer experiments are conducted on all primary and secondary sites. In order to eliminate, or at least minimize, the effect of the natural moisture variable, trickle irrigation systems are installed for all transfer experiments. Tensiometers are used to determine the frequency of water applications. Soil moisture is maintained at or near optimum levels throughout the growth period. Both maize and soybeans have been used as test crops in earlier transfer experiments, but only maize is now used. Varieties known to be well adapted are planted in the transfer experiments at each location.

Variety trials are conducted at the primary sites to assure that a well adapted and productive variety is grown in the transfer experiments at all locations. Also, to make the yield data among sites more comparable, the test crop varieties of each site of the network are included in the variety trials at each primary site.

In the variety trials a split-plot design is employed, each variety being grown with phosphorus treatments at two levels. With all other controllable conditions at or near optimum, this provides a measure of each variety's requirement for and capacity to respond to applied phosphorus.

Management experiments have the purpose to provide information on economic and efficient practices, and information for subsequent soil interpretations and land evaluation. Whereas the procedures for conducting the transfer experiments must

be virtually identical at all sites, the design of the management experiments is more flexible and allows the BSP to respond to host country priorities and local farmer needs. A philosophic framework for the management experiments was developed at the first annual coordination meeting of the BSP projects in 1976. Particular attention is paid to experiments on costly inputs and high energy use cultural practices, such as irrigation, fertilization and tillage.

Field operations, and data collection and processing follow standardized procedures to ascertain compatibility of results throughout the network. Working in close cooperation with the University of Hawaii, a set of guidelines was developed and is continuously revised so that laboratory and field experiment procedures can be as nearly identical as possible within the constraints confronted at the various experiment sites of each project. These guidelines are sufficiently detailed to insure comparability of data obtained at all sites. All field operations such as land preparation, pest control, irrigation, cultivation and harvesting are considered, as well as field plot designs and data observations. Special attention has been given to the standardization of climatological data collection. Each of the experiments is statistically analyzed in consultation with the project's statistics experts. The University of Hawaii assumed the responsibility for the overall analyses.

V. Network of Experiment Sites

A. Soils

The soils selected for experimentation belong to the clayey, kaolinitic, isohyperthermic family of Tropeptic Eutrustox. This family was chosen because it is common to Puerto Rico and Hawaii and thus provides the required link between the two Benchmark Soils Projects.

Eutrustox are well-drained, red upland soils occurring under savanna or deciduous forest vegetation in subhumid tropical regions. They are slightly acid to neutral, have an appreciable supply of bases and moderate to high base saturation in the subsoil. Among their adverse properties are a limited water holding capacity, a tendency to compact when cultivated with heavy equipment, and phosphorus deficiency. Their main constraint for agricultural use is the insufficiency of soil moisture for more than three months per year. Although not the most common kind of Oxisols, they are extensive in tropical South America and Africa. They represent important soil resources preferred for immediate development over other Oxisols on account

of their high base saturation status.

B. Experiment Sites

In theory, the locations for field experimentation should be randomly selected from all the units of the population of soils comprised in the stated soil family. In the project, however, random sampling is not feasible, primarily because only a limited number of countries can be involved. On the basis of preliminary investigations involving literature surveys and consultations, the search was concentrated on Brazil, Colombia, the Dominican Republic, Jamaica and Venezuela.

In spite of extensive field and laboratory studies, the desired family of Eutrustox could only be identified in the northern part of the state of Minas Gerais in Brazil. Other potential locations had to be eliminated because the soils failed to meet the specific family criteria or because of adverse logistic conditions. Experiment sites were, therefore, established in Puerto Rico and in Brazil.

In Puerto Rico, one primary site and one secondary site were installed in 1975 on the grounds of the Isabela Agricultural Experiment Substation of the University of Puerto Rico located in the northwestern corner of the Island. An additional secondary site is on a private farm nearby.

In Brazil, one primary and two secondary sites were established in 1976 and 1977, respectively, in an area adjacent to the Sao Francisco River in northern Minas Gerais known as the "Distrito Agro-Industrial de Jaiba". This 300,000-hectare scheme was recently developed and is now being opened for colonization by small farmers. The BSP sites are thus well located from the point of view of local impact and utilization. The primary site near Jaiba comprises 6 ha and is on a new experiment farm operated by the project's cooperating agency, EPAMIG. The two secondary sites of 3 ha each were set up on private land near the Jaiba site. At all three locations, 60-m-deep water wells had to be drilled to allow irrigation.

The Puerto Rico project thus operates six sites. Together with the two sites of the Hawaii project, the BSP Eutrustox network includes eight sites in three widely separated regions -- Oceania, South America and the Caribbean.

ACCOMPLISHMENTS

I. General Scope of Work

With all six experiment sites in Puerto Rico and Brazil fully operational, project activities during the report period were concentrated on agronomic field work. Particular emphasis was placed on transfer and management experiments. Table 1 shows the number of field experiments conducted during FY 79 and since project implementation by crop, kind of experiment and country. A detailed timetable of the experiments carried out in Puerto Rico and Brazil is presented in Appendix A.

Table 1. Experiments completed or begun during FY 79 and life-of-project

Experiment	Crop			
	Maize	Soybean	Other	Total
Transfer				
Puerto Rico	13 (28) *)	(5)	-	13 (33)
Brazil	18 (24)	(1)	-	18 (25)
Variety				
Puerto Rico	(5)	-	-	(5)
Brazil	3 (10)	2 (5)	-	5 (15)
Management				
Puerto Rico	3 (8)	(3)	-	3 (11)
Brazil	4 (6)	(1)	2 (3)	6 (10)
	41 (81)	2 (15)	2 (3)	45 (99)

*) Numbers in parentheses indicate total number of experiments completed or begun to date.

Field experimentation followed the research methodology and design developed jointly with the University of Hawaii. Although these procedures were essentially established in previous years, refinements in the method of phosphorus determination were made in 1978 and 1979 in accordance with the recommendations of coordination meetings of the two Benchmark Soils Projects.

The yield and most crop phenology data of all experiments were statistically analyzed at UPR's Agricultural Experiment Station. In addition, the project's statistics consultant, Dr. Larry A. Nelson, scrutinized the data relative to the project hypothesis.

Continuing efforts were made to strengthen the existing linkages and to establish new contacts. Dissemination of project concepts and results was accomplished through technical papers, seminars and periodical publications.

As detailed in the administrative report, 8 professionals, 9 nonprofessionals and a varying number of field laborers and students were engaged in project activities during the report period. (The current regular project staff is listed in Appendix B). In FY 79, the total work effort amounted to about 290 man-months.

II. Testing the Transfer Hypothesis

A. Results of Transfer Experiments

1. General

As explained in the BSP Annual Research Report for FY 78, the transfer experiments are designed specifically to generate data for testing the technology transfer hypothesis. They are conducted with maize as the test-crop and with two controlled variables, phosphorus and nitrogen levels. Initial plantings of transfer experiments are followed in the same plots by residual transfer experiments, whereby a measure is obtained of maize response to residual phosphorus left in the soil after the initial transfer experiment is harvested. No additional phosphorus is applied to residual trials but nitrogen treatments are repeated at the same levels used for the initial plantings. Both the initial and residual transfer experiments provide data for use in testing the transfer hypothesis.

The data presented in this section are from the transfer experiments harvested during the period from 1 October 1978 to 30 September 1979. For simplification of presentation, the experiments are grouped by seasons and as initial and residual transfer experiments.

The following is a largely descriptive account of the experiment results and their agronomic interpretation. A statistical evaluation is given in the subsequent section.

2. Results of dry season experiments

a. Initial transfer experiments

During the 1978 dry season, maize grain yields increased sharply with phosphorus applications up to the +.85 levels of P in initial transfer trials at the primary (Parana) and secondary #2 (Bahia) sites at Jaiba, MG, Brazil. Tables 2 and 3 show grain yield responses to P (at the highest N level) from 1895 to 7786 and

Table 2

Maize, Pioneer hybrid 304C dry season yields from initial transfer experiment (BSP B-22) planted June 20 and harvested December 15, 1978 at Jaiba, MG, Brazil, primary (Paraná) site.

P kg/ha	Coded P Treatment Level	Grain Yield, kg/ha[1/]					
26.6	+.85		7551		7718		7786
20.2	+.40			7034		7247	
14.4	"O"	7267	5485		5007		5024
8.6	-.40			3746		3373	
2.2	-.85		1741		1292		1895
0	-1	655			853		
	Coded N Treatment Level	-1	-.85	-.40	"O"	+.40	+.85
	N kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

Table 3

Maize, Pioneer hybrid 304C dry season yields from initial transfer experiment (BSP B-26) planted June 19 and harvested December 5, 1978 at Jaiba, MG, Brazil, secondary site #2 (Bahía).

P kg/ha	Coded P Treatment Level	Grain Yield, kg/ha 1/					
53.3	+.85		7849		8436		8453
40.3	+.40			7543		7713	
28.8	"O"	8805	7233		8072		7155
17.3	-.40			6467		6827	
4.3	-.85		4337		3952		4144
0	-1	1396			3049		
	Coded N Treatment Level	-1	-.85	-.40	"O"	+.40	+.85
	N kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

and 4144 to 8453 kg/ha for these two Brazil sites, respectively. A similar degree of yield increase with applied P was observed across all levels of N. At the Brazil secondary site #2 (Ceará) there was response to P, although much less, and the yield curve began to level off at lower levels of P. Conversely, among initial transfer experiments conducted during the 1978-79 dry season at Isabela, Puerto Rico there appeared no well defined response to P (Tables 4, 5, 6 and 7).

With the possible exception of Puerto Rico secondary site #2 (Calero), it appears likely that a reserve of residual P from previous fertilizer applications at the Puerto Rico sites is adequate for one or more crops of maize. However, some earlier transfer experiments at adjacent sites have clearly demonstrated positive yield responses to P, indicating a potential for yield increase and a limited soil P reserve. At the Calero site yields were restricted by other constraining factors to such an extent that, even if reserve soil P and N were low, a clear response could not be demonstrated. More recently, lime x phosphorus level experiments and blanket applications of lime to transfer trials have shown yield responses that implicate low pH as a partial cause of the low yield ceiling at Calero and possibly also on some smaller units within the Puerto Rico primary site (Ramal).

Only at the Ramal site was there a clear positive yield response to nitrogen; the yield range in that initial transfer experiment was from 4436 to 7678 kg/ha as shown in Table 5. There was possibly a mild increase in yield with N applications at the Puerto Rico secondary site #1 (Cerro), but no effect at all was observed at the Calero site. In Brazil none of the sites responded to nitrogen fertilizer in FY 79.

Apparently, at the BSP sites in Brazil, sufficient soil N is available for at least one or more cropping seasons, as the sites are all on essentially virgin land. In Puerto Rico all BSP sites have been cropped for many decades and available soil N depends largely on recent cropping history including all aspects of management, especially fertilizer application. For these reasons the effects of N treatments have been quite variable in Puerto Rico.

b. Residual transfer experiments

Residual transfer experiments conducted during the dry season in Brazil showed a response to P similar to that described above for initial transfer trials, although maximum yields for the two sites that responded most strongly, Paraná and Bahía, were relatively low, 5361 and 6734 kg/ha, respectively. Tables 8 and 9 present

Table 4

Maize, Pioneer hybrid 304C dry season yields from initial transfer experiment(BSP B-24)planted June 20 and harvested November 29, 1978 at Jaiba, MG, Brazil, secondary site #1 (Ceará).

P kg/ha	Coded P Treatment Level	Grain Yield, kg/ha[1/]					
7.6	+.85		7949		8194		8595
5.8	+.40			7932		8319	
4.1	"O"	8331	8117		7449		7747
2.5	-.40			6239		7424	
0.6	-.85		7348		7125		7659
0	-1	7097			6523		
	Coded N Treatment Level	-1	-.85	-.40	"O"	+.40	+.85
	N kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

Table 5

Maize, Pioneer hybrid 304C, dry season yields from initial transfer experiment (BSP PR-37) planted December 6, 1978 and harvested April 19, 1979 at Isabela, Puerto Rico, primary (Ramal) site.

P, kg/ha	Coded P Treatment Level	Grain Yield, kg/ha[1/]					
43.3	+.85		4841		6450		7462
32.8	+.40			4977		6629	
23.4	"0"	4916	5062		6923		7678
14.0	-.40			6694		7222	
3.5	-.85		4436		6794		6984
0	- 1	4931			5876		
	Coded N Treatment Level	-1	-.85	-.40	"0"	+.40	+.85
	N, kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

Table 6

Maize, Pioneer hybrid 304C, dry season yields from initial transfer experiment (BSP PR-38) planted December 6, 1978 and harvested April 17, 1979 at Isabela, Puerto Rico, secondary site #1 (Cerro).

P, kg/ha	Coded P Treatment Level	Grain Yield, kg/ha[1/]					
32.5	+.85		7387		7640		7556
24.6	+.40			6329		7383	
17.6	"0"	6265	7429		8115		7647
10.5	-.40			7489		7946	
2.6	-.85		7617		7110		7577
0	- 1	6989			8342		
	Coded N Treatment Level	-1	-.85	-.40	"0"	+.40	+.85
	N, kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

Table 7

Maize, Pioneer hybrid 304C, dry season yields from initial transfer experiment (BSP PR-39) planted December 12, 1978 and harvested April 24, 1979 at Isabela, Puerto Rico, secondary site #2 (Calero).

P, kg/ha	Coded P Treatment Level	Grain Yield, kg/ha[1/]					
32.5	+.85		3599		2900		3077
24.6	+.40			2724		4084	
17.6	"0"	3217	4248		2181		2379
10.5	-.40			3035		3687	
2.6	-.85		3250		3577		3268
0	- 1	4286			3815		
	Coded N Treatment Level	-1	-.85	-.40	"0"	+.40	+.85
	N, kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

Table 8

Maize, Pioneer hybrid 304C, dry season yields from residual transfer experiment (BSP B23, following B19) planted June 16 and harvested December 14, 1978 at Jaiba, MG, Brazil, primary (Paraná) site.

P kg/ha 2/	Coded P Treatment Level	Grain Yield, kg/ha 1/					
36.0	+.85	5061	5361		4692		3748
25.9	+.40			3869		3730	
18.7	"O"		3681		3428		3480
11.5	-.40			2487		2220	
2.9	-.85		2984		2039		1959
0	-1	1533					1968
	Coded N Treatment Level	-1	-.85	-.40	"O"	+.40	+.85
	N kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates

2/ Phosphorus was applied only to the initial transfer experiment.

Table 9

Maize, Pioneer hybrid 304C dry season yields from residual transfer experiment (BSP B-27, following B-21) planted June 19 and harvested December 2, 1978 at Jaiba, MG, Brazil, secondary site #2 (Bahía).

P kg/ha 2/	Coded P Treatment Level	Grain Yield, kg/ha 1/					
57.0	+.85	6641	6734		6429		6725
43.2	+.40			5876		5898	
30.8	"O"		4622		5701		5407
18.4	-.40			4832		3691	
4.6	-.85		3799		2221		3176
0	-1	2819					3141
	Coded N Treatment Level	-1	-.85	-.40	"O"	+.40	+.85
	N kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ Phosphorus was applied only to the initial transfer experiment.

mean grain yields for these two P-responsive sites. At the Brazil Ceará site there was no clear P effect apparent (Table 10). Tables 11, 12 and 13 show mean grain yields from dry season residual transfer trials in Puerto Rico at the Ramal, Cerro and Calero sites, respectively. As at the Paraná and Bahía sites in Brazil, maximum yields in Puerto Rico for the dry season residual experiments were lower than for the initial experiments conducted during the same period. However, only at the Puerto Rico Ramal site was there evidence of a mild positive response to residual P; and that increase was not very consistent across all N levels.

None of the Brazil dry season residual trials reflected any noticeable N treatment effect on maize grain yields. Also, the Calero site in Puerto Rico was non-responsive to applied N. On the other hand, there was a marked increase in yield with N applications up to the +.4 N level and possibly the +.85 level at both the Ramal and Cerro Puerto Rico sites.

3. Results of wet season experiments

a. Initial transfer experiments

Maize grain yields during the wet seasons in Brazil (Tables 14, 15 and 16) and Puerto Rico (Tables 17, 18 and 19) were similar to the preceding dry period yields except at the Bahía secondary site in Brazil and the Cerro secondary site in Puerto Rico where, in both cases, dry season yields were much higher. Mean yields for +.85 P treatments (across all N levels) during the dry season were 8246 and 7528 kg/ha (Tables 3 and 6) for Bahía and Cerro sites, respectively; wet season yields were 4387 and 6076 kg/ha (Tables 16 and 18), respectively, for the same sites.

Table 19 reveals wet season initial transfer experiment yields on the Puerto Rico Calero site to be higher than dry season maize yields, (Table 7) on the same site. This yield increase is thought to be caused by a blanket application of lime one month before the wet season experiment was planted on that site. Lime was applied uniformly to new experiment areas at both the Calero and Ramal sites for the 1979 wet season crop to reduce micro-site variability and to remove possible soil pH related yield constraints.

At the Bahía secondary site in Brazil the wet season initial experiment showed only weak response to P (Table 16) and in Puerto Rico there was only weak and erratic or no response to P on the three sites, (Tables 17, 18 and 19). At the other two Brazil sites, Paraná and Ceará, applied P resulted in moderate to strong grain yield increases, (Tables 14 and 15). This was the first time at Ceara that a marked

Table 10

Maize, Pioneer hybrid 304C dry season yields from residual transfer experiment (BSP B-25, following B-20) planted June 17 and harvested November 22, 1978 at Jaiba, MG, Brazil, secondary site #1 (Ceará).

Grain Yield, kg/ha 1/

P kg/ha 2/	Coded P Treatment Level	-1	-.85	-.40	"O"	+.40	+.85
		Coded N Treatment Level					
		0	14	54	90	126	166
		N kg/ha					
19.0	+.85	7683	7321		7139		8809
14.4	+.40			6807		7655	
10.2	"O"		6477		7037		7410
6.2	-.40			6644		7434	
1.6	-.85		6417		7073		7005
0	-1	7659					5871

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ Phosphorus was applied only to the initial transfer experiment.

Table 11

Maize, Pioneer hybrid 304C, dry season yields from residual transfer experiment (BSP PR-34, following PR-27) planted November 17, 1978 and harvested March 21, 1979 at Isabela, Puerto Rico, primary (Ramal) site.

P kg/ha 2/	Coded P Treatment Level	Grain Yield, kg/ha 1/					
56.7	+.85		2481		4430		6598
42.9	+.40			3933		5439	
30.6	"0"	1401	1133		4919		6408
18.3	-.40			4288		6717	
4.7	-.85		972		4790		6045
0	- 1	813			5152		
	Coded N Treatment Level	-1	-.85	-.40	"0"	+.40	+.85
	N, kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ Phosphorus was applied only to the initial transfer experiment while nitrogen was applied at the rates indicated to both initial and residual experiments.

Table 12

Maize, Pioneer hybrid 304C, dry season yields from residual transfer experiment (BSP PR-35, following PR-30) planted November 11, 1978 and harvested March 19, 1979 at Isabela, Puerto Rico, secondary site #1 (Cerro).

P, kg/ha 2/	Coded P Treatment Level	Grain Yield, kg/ha 1/					
23.2	+.85		4247		5348		6662
17.6	+.40			4302		6588	
12.5	"0"	1659	2632		5766		6506
7.6	-.40			5603		6134	
2.0	-.85		4424		5634		7274
0	- 1	3040			6351		
	Coded N Treatment Level	-1	-.85	-.40	"0"	+.40	+.85
	N, kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ Phosphorus was applied only to the initial transfer experiment while nitrogen was applied at the rates indicated to both initial and residual experiments.

Table 13

Maize, Pioneer hybrid 304C, dry season yields from residual transfer experiment (BSP PR-36, following PR-33) planted November 21, 1978 and harvested March 27, 1979 at Isabela, Puerto Rico, secondary site #2 (Calero).

P, kg/ha 2/	Coded P Treatment Level	Grain Yield, kg/ha 1/					
42.5	+.85		1735		1155		2214
32.2	+.40			2139		1959	
23.0	"0"	1264	1152		2557		1732
13.8	-.40			2113		2016	
3.5	-.85		1244		2754		2607
0	- 1	2074			2008		
	Coded N Treatment Level	-1	-.85	-.40	"0"	+.40	+.85
	N, kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ Phosphorus was applied only to the initial transfer experiment while nitrogen was applied at the rates indicated to both initial and residual experiments.

Table 14

Maize, Pioneer hybrid 304C wet season yields from initial transfer experiment (BSP B-36) planted January 9 and harvested June 16, 1979 at Jaiba, MG, Brazil, primary (Parnaã) site.

Grain Yield, kg/ha 1/

P kg/ha	Coded P Treatment Level	-1	-.85	-.40	"O"	+.40	+.85
53.3	+.85		6302		6288		6815
40.3	+.40			6353		6266	
28.8	"O"	5122	4653		5508		5812
17.3	-.40			4454		4106	
4.3	-.85		1665		1962		2683
0	- 1	633			810		
	Coded N Treatment Level	-1	-.85	-.40	"O"	+.40	+.85
	N kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

Table 15

Maize, Pioneer hybrid 304C wet season yields from initial transfer experiment (BSP B-38) planted January 12 and harvested June 12, 1979 at Jaiba, MG, Brazil, secondary site #1 (Ceará).

Grain Yield, kg/ha 1/

P kg/ha	Coded P Treatment Level	-1	-.85	-.40	"O"	+.40	+.85
		N kg/ha					
		0	14	54	90	126	166
26.6	+.85		7607		~~9605~~ 7357		8239
20.2	+.40			6655		7410	
14.4	"O"	7753	6725		7594		6657
8.6	-.40			5838		6502	
2.2	- 85		5318		5338		4131
0	- 1	4062			4544		

1/ Adjusted to 15.5% moisture, means of 3 replicates.

Table 16

Maize, Pioneer hybrid 304C wet season yields from initial transfer experiment (BSP B-40) planted January 10 and harvested June 12, 1979 at Jaiba, MG, Brazil, secondary site #2 (Bahía).

P kg/ha	Coded P Treatment Level	Grain Yield, kg/ha[1/]				
53.3	+.85		4446		3620	5094
40.3	+.40			4795	4811	
28.8	"0"	4846	2569		5586	5095
17.3	-.40			2831	4264	
4.[illegible]	-.85		2378		3200	3931
0	- 1	1510			4357	
	Coded N Treatment Level	- 1	-.85	-.40	"0"	+.40	+.85
	N kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

Table 17

Maize, variety X304C, wet season yields from initial transfer experiment (BSP PR-45) planted May 18 and harvested September 7, 1979 at Isabela, Puerto Rico, primary site (Ramal).

P, kg/ha	Coded P Treatment Level	Grain Yield, kg/ha[1/]					
83.1	+.85		6023		6995		6407
62.8	+.40			7032		7458[2/]	
44.8	"O"	6143	5719		7368[2/]		6637
26.9	-.40			6121		7123	
6.8	-.85		5252		6633		7101
0	- 1	5549			6292		
	Coded N Treatment Level	-1	-.85	-.40	"O"	+.40	+.85
	N, kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ These data, 7368 and 7458, represent means of only 2 replicates (I and II).

Table 18

Maize, variety X304C, wet season yields from initial transfer experiment (BSP PR-44) planted May 17 and harvested September 6, 1979 at Isabela, Puerto Rico, secondary site #1 (Cerro).

P, kg/ha	Coded P Treatment Level	Grain Yield, kg/ha[1/]					
41.9	+.85		6020		5763		6444
32.4	+.40			7233		7878	
22.6	"0"	5290	5551		5974		6552
13.7	-.40			6601		6948	
3.3	-.85		6124		6190		6634
0	- 1	4218			6683		
	Coded N Treatment Level	-1	-.85	-.40	"0"	+.40	+.85
	N, kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

Table 19

Maize, variety X304C, wet season yields from initial transfer experiment (BSP PR-48) planted May 30 and harvested September 10, 1979 at Isabela, Puerto Rico, secondary site #2 (Calero).

P, kg/ha	Coded P Treatment Level	Grain Yield, kg/ha[1/]					
39.8	+.85		4852		5758		6021
30.0	+.40			5088		4428	
21.4	"O"	4906	5027		4981		4972
12.9	-.40			4390		4942	
3.3	-.85		3620		4310		5243
0	- 1	4252			4995		

	Coded N Treatment Level					
	- 1	-.85	-.40	"O"	+.40	+.85
	N kg/ha					
	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

treatment effect was demonstrated; there is apparently an already relatively high soil fertility status over most of that site area. Yields have been fairly uniform and high for most experiments at Ceará.

There was apparently a mild positive yield response to N at the Cerro site in Puerto Rico and possibly also at the Paraná site in Brazil during their respective wet seasons. All other sites in Brazil and Puerto Rico were, at best, only slightly and erraticly responsive to N treatments.

b. Residual transfer experiments

Wet season residual transfer experiment yields in Brazil were low in 1979, possibly in part because of late planting that year. Mean + 85 P treatment maize grain yields were 2544, 4287 and 5362 kg/ha for Paraná, Ceará and Bahia sites respectively (Tables 20, 21 and 22); mean dry season yields for the same treatments in 1978 were 4905, 7738 and 6632 kg/ha, respectively, for the same three Brazil sites (Tables 8, 9 and 10). Conversely, Puerto Rico 1979 wet season residual experiment yields were higher than 1978-79 dry season residual trial yields; +.85 N treatment means across all P levels were 7445, 8205, 8223 and 4676 kg/ha for Ramal, Cerro (2 experiments, first and second cycle residual) and Calero, respectively, during the wet season (Tables 23, 24, 25 and 26) vs. 6350, 6814 and 2184, respectively, for the same sites during the preceding 1978-79 dry season (Tables 11, 12 and 13).

With wet season residual experiments there was only mild to moderate response shown to residual P and that was at only two sites, Paraná and Bahía, in Brazil and the Cerro site in Puerto Rico. Experiments at all other sites reflected no or erratic previous P treatment effects.

Nitrogen treatments produced sharp yield increases in wet season residual trials at Ramal and Cerro sites in Puerto Rico. At Calero, however, the N treatment effect was mild and at all three sites in Brazil it was nil.

B. Results of Statistical Analyses*

1. General

During the report period major emphasis was placed on the statistical analysis of the results of all transfer experiments relative to the project hypothesis. These studies were conducted by Dr. L. A. Nelson of the Department of Statistics, North Carolina State University (NCSU) under a subcontract from the UPR-BSP.

*This section is based largely on a report by Dr. L. A. Nelson, statistical consultant to the UPR-BSP.

Table 20

Maize, Pioneer hybrid 304C wet season yields from residual transfer experiment (BSP B-37, following B-22) planted January 16 and harvested July 10, 1979 at Jaiba, MG, Brazil, primary (Paraná) site.

Grain Yield, kg/ha[1/]

P kg/ha[2/]	Coded P Treatment Level	-1	-.85	-.40	"0"	+.40	+.85
		N kg/ha					
		0	14	54	90	126	166
26.6	+.85		2550		2758		2325
20.2	+.40			2273		3161	
14.4	"0"	2148	1705		1126		1499
8.6	-.40			1341		1234	
2.2	-.85		595		733		1071
0	- 1	583			562		

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ Phosphorus was applied only to the initial transfer experiment; N was applied to both, initial and residual, trials.

Table 21

Maize, Pioneer hybrid 304C wet season yields from residual transfer experiment (BSP B-39, following B-24) planted January 15 and harvested July 6, 1979 at Jaiba, MG, Brazil, secondary site #1 (Ceará).

P kg/ha 2/	Coded P Treatment Level	Grain Yield, kg/ha 1/					
7.6	+.85		4232		3903		4727
5.8	+.40			4281		4420	
4.1	"O"	4856	4735		4780		3032
2.5	- 40			2922		4207	
0.6	-.85		4737		4434		4908
0	- 1	4833			3817		
	Coded N Treatment Level	- 1	-.85	-.40	"O"	+.40	+.85
	N kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ Phosphorus was applied only to the initial transfer experiment; N was applied to both, initial and residual, trials.

Table 22

Maize, Pioneer hybrid 304C wet season yields from residual transfer experiment (BSP B-41, following B-26) planted January 12 and harvested July 6, 1979 at Jaiba, MG, Brazil, secondary site #2 (Bahía).

P kg/ha 2/	Coded P Treatment Level	Grain Yield, kg/ha 1/					
53.3	+.85		5705		5498		4883
40.3	+.40			4370		3426	
28.8	"O"	4856	4157		4418		2863
17.3	-.40			2937		3138	
4.3	-.85		2847		2211		2511
0	- 1	1369			2500		
	Coded N Treatment Level	- 1	-.85	-.40	"O"	+.40	+.85
	N kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ Phosphorus was applied only to the initial transfer experiment; N was applied to both, initial and residual, trials.

Table 23

Maize, variety X304C, wet season yields from residual transfer experiment (BSP PR-43 following PR-37) planted May 3 and harvested August 29, 1979 at Isabela, Puerto Rico, primary site (Ramal).

P kg/ha 2/	Coded P Treatment Level	Grain Yield, kg/ha 1/				
43.3	+.85		2254	6365		7026
32.8	+.40		4540		6733	
23.4	"O"	2287	1894	6218		7626
14.0	-.40		5057		7486	
3.5	-.85		2011	6838		7683
0	- 1	2099		6376		
	Coded N treatment Level	- 1	-.85	-.40	"O"	+.40	+.85
	N, kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ Phosphorus was applied only to the initial transfer experiment while nitrogen was applied at the rates indicated to both initial and residual experiments.

Table 24

Maize, variety X304C, wet season yields from residual transfer experiment (BSP PR-41 following PR-38) planted May 2 and harvested August 27, 1979 at Isabela, Puerto Rico, secondary site #1 (Cerro).

P, kg/ha 2/	Coded P Treatment Level	Grain Yield, kg/ha 1/					
32.5	+.85		5664		7129		8519
24.6	+.40			4434		6892	
17.6	"O"	2602	3849		7498		8426
10.5	-.40			6598		7763	
2.6	-.85		4660		6662		7671
0	- 1	2805			6958		
	Coded N Treatment Level	-1	-.85	-.40	"O"	+.40	+.85
	N, kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ Phosphorus was applied only to the initial transfer experiment while nitrogen was applied at the rates indicated to both initial and residual experiments.

Table 25

Maize, variety X304C, wet season yields from 2nd residual transfer experiment (BSP PR-42 following PR-30 and PR-35) planted May 2 and harvested August 27, 1979 at Isabela, Puerto Rico, secondary site #1 (Cerro).

P, kg/ha 2/	Coded P Treatment Level	Grain Yield, kg/ha 1/					
23.2	+.85		2898		6379		7115
17.6	+.40			4036		7718	
12.5	"O"	902	1823		4479		9321
7.6	-.40			5086		7233	
2.0	-.85		3173		6160		8232
0	- 1	1678			~~4519~~		
	Coded N Treatment Level	-1	-.85	-.40	"0"	+.40	+.85
	N kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ Phosphorus was applied only to the initial transfer experiment while nitrogen was applied at the rates indicated to both initial and residual experiments.

Table 26

Maize, variety X304C, wet season yields from residual transfer experiment (BSP PR-46 following PR-39) planted May 25 and harvested September 11, 1979 at Isabela, Puerto Rico, secondary site # 2 (Calero).

P, kg/ha[2/]	Coded P Treatment Level	Grain Yield, kg/ha[1/]					
32.5	+.85		3872		4015		4848
24.6	+.40			4372		4955	
17.6	"O"	2708	3952		3703		4524
10.5	-.40			4647		4360	
2.6	-.85		3302		4824		4657
0	- 1	3469			5038		
	Coded N Treatment Level	-1	-.85	-.40	"O"	+.40	+.85
	N, kg/ha	0	14	54	90	126	166

1/ Adjusted to 15.5% moisture, means of 3 replicates.

2/ Phosphorus was applied only to the initial transfer experiment while nitrogen was applied at the rates indicated to both initial and residual experiments.

Before starting the actual test of transferability, a considerable amount of data analyses was performed with the objective to determine the degree of variability of the data, means, relationships among variables, and other parameters. Also, the computer program developed with support from the UPR-BSP at the University to run the models which test the P-statistics was put in operation at NCSU after some initial difficulties were overcome.

The results of 24 maize transfer experiments, 14 from Puerto Rico and 10 from Brazil, were used. Treatment means, P main effect means, N main effect means, and Country x Season means are reported in Tables 27a, 27b, 27c, and 27d, respectively.

Second order response surfaces were fitted to the data from the 13 treatments for each of the 24 experiments. The means ranged from 1952 to 8330 kg/ha. The coefficients of variation ranged from 5.63 to 42.18 per cent.

In general, the P linear was significant for all Brazil experiments. The P quadratic term (denoting curvature of response) was significant in only 3 of the Brazil trials. There was much less tendency to obtain P response in Puerto Rico--this occurred only in two experiments. In both of these dry season experiments, PR-20 and PR-21, the response was not curvilinear but rather linear.

Nitrogen response occurred in 10 out of the 14 transfer trials in Puerto Rico. In four of these cases, the response to N was curvilinear; in the other 6 it was linear. This N response occurred both in dry season and wet season experiments. Significant interaction between P and N occurred only in 2 trials, PR-21 and PR-27. Significant N response occurred in only two experiments in Brazil and then both had significance only at the 5 per cent level. Both of these were residual transfer experiments and were conducted during the dry season. There were no significant interactions between P and N in any of the 10 Brazil experiments.

The R^2 values for the quadratic model fitting in the 2 variables ranged from .12 to .98 (Brazil and Puerto Rico locations). In general, the quadratic model tended to fit slightly better in the case of the Brazil locations as judged by overall R^2 value.

For further statistical analyses leading to the test of transfer, experiments having a coefficient of variation of more than 20 per cent were eliminated. (These were experiments PR-23, PR-33, PR-34, PR-36, PR-39, B-23, and B-27). The instability created from this highly variable data if included in the transfer analyses would make the test of transfer very difficult to conduct on an impartial basis.

Table 4. Treatment Mean Maize Yields by Site for Benchmark Soils Transfer Experiments, Brazil and Puerto Rico[1]

Coded level	P	-.85	-.85	+.85	+.85	-.40	-.40	+.40	+.40	0	-.85	+.85	0	0	
	N	-.85	+.85	-.85	+.85	-.40	+.40	-.40	+.40	0	0	0	-.85	+.85	
Site	Season	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	General Mean
PR-19	W	5120	5235	4595	4810	4656	4616	5607	4557	5033	4750	4513	4237	4846	4783
PR-20	D	4033	6043	6252	7536	6360	6398	6456	7140	7055	5902	6958	6465	6790	6415
PR-21	D	7976	8409	7499	9122	8290	8471	7982	8611	8597	7392	9391	7547	9005	8330
PR-23	D	2753	4572	4129	5158	3559	3063	3888	3344	2839	3311	4735	2377	4934	3742
PR-27	W	4053	4327	3657	5550	4352	5427	4445	6141	6261	5396	5497	3852	5488	4956
PR-30	W	6793	7874	5925	7905	7025	7746	6492	7590	6976	7394	7167	6379	8503	7290
PR-31	W	2215	6198	2303	6827	4431	5768	4806	5544	5322	5791	5181	2366	6910	4897
PR-33	W	3701	4885	4667	4587	4405	4993	5177	4405	5457	4626	5089	3523	3981	4575
PR-34	D	472	6045	2481	6598	4288	6717	3933	5439	4919	4790	4430	1133	6408	4473
PR-35	D	4424	7274	4247	6662	5603	6134	4302	6588	5766	5634	5348	2632	6506	5471
PR-36	D	1244	2607	1735	2214	2113	2016	2139	1959	2557	2754	1155	1152	1732	1952
PR-37	D	4456	6334	4841	7462	6694	7222	4977	6629	6923	6794	6450	5062	7678	6319
PR-38	D	7617	7577	7387	7556	7489	7946	6529	7383	8115	7110	7640	7429	7647	7479
PR-39	D	3250	3468	2222	3077	3035	5087	2724	4084	2181	3577	2900	4248	2379	3232
		4155	5807	4578	5933	5163	5731	4947	5658	5570	5575	5461	4172	5915	
B-9	D	3145	4034	6345	7323	5274	5386	5817	6574	5755	4741	6808	5513	6379	5692
B-10	W	2459	2791	5478	5328	5131	5043	4517	4352	4653	2140	5510	3677	4559	3955
B-20	W	5169	5552	6760	6522	6132	5537	6027	6517	5518	5467	6095	6072	5938	5958
B-21	W	2958	2251	4965	5135	3275	3684	4349	4402	4777	2082	5082	4616	4638	4051
B-22	D	1741	1655	7322	7786	5746	5573	7034	7247	5007	1282	7718	5485	5024	4992
B-23	D	2234	1392	5351	5748	2437	2220	3869	5730	3428	2039	4692	3681	3480	3360
B-24	D	7348	7659	7949	8595	6259	7424	7932	8319	7449	7125	8194	8117	7747	7700
B-25	D	6417	7005	7321	8809	6044	7434	6807	7655	7057	7073	7139	6477	7310	7171
B-26	D	3351	4134	7849	8453	6467	6527	7545	7713	8072	3952	8456	7253	7155	6783
B-27	D	5722	5176	6734	6728	4832	5691	5876	5848	5701	2221	6429	4622	5407	5008
		4561	5777	6885	6885	4975	4651	5650	5795	5445	3587	6204	5260	5491*	

*Brazil site means are weighted averages, i.e., weight of 4 for the 4 rep sites and weight of 3 for the 3 rep sites

[1]Maize yields expressed in kg/ha

Note: Site = experiment

Table 27b. Table of P main effect means (averaged over replications and N levels)

Site	Coded P level					Significance of P terms from ANOVA	
	-.85	-.40	0	+.40	+.85	linear	quadratic
PR-19	5032	4636	4705	4982	4573		
-20	5326	6379	6770	6798	6915	**	
-21	7926	8381	8383	8297	8671	**	
-23	3545	3301	3383	3616	4674		
-27	4593	4890	5200	5293	4895		
-30	7354	7386	7286	7041	7332		
-31	4735	5100	4866	5175	4770		
-33	4404	4699	4314	4791	4781		
-34	3936	5503	4153	4686	4503		
-35	5777	5869	4968	5445	5419		
-36	2202	2065	1814	2049	1701		
-37	6071	6958	6554	5803	6251		
-38	7435	7718	7730	6856	7528		
-39	3365	3361	2936	3404	3192		
B- 9	4173	5430	5916	6196	6825	**	
-19	2390	3087	4296	4435	5439	**	
-20	5328	5990	5843	6292	6459	**	
-21	2427	3475	4677	4476	5061	**	**
-22	1643	3560	5172	7141	7685	**	**
-23	2327	2354	3530	3800	4600	**	
-24	7377	6832	7771	8126	8246	**	
-25	6832	7039	6975	7231	7756		
-26	4144	6647	7487	7628	8246	**	
-27	3065	4262	5243	5887	6629	**	

†The reported means are unadjusted for differences in N levels used.

Note: Site = experiment

Table 27c. Table of N main effect means (averaged over replications and P levels) †

Site	Coded N level					Significance of N terms from ANOVA	
	-.85	-.40	0	+.40	+.85	linear	quadratic
PR-19	4584	5132	4765	4487	4964		
-20	5583	6408	6638	4513	6790	**	
-21	7674	8136	8460	8541	8845	**	
-23	3086	3714	3628	3204	4888	*	
-27	3848	4399	5718	5784	5122	**	**
-30	6699	6759	7179	7668	8094	**	
-31	2295	4619	5431	5656	6645	**	**
-33	3964	4791	5051	4699	4484		**
-34	1529	4111	4713	6078	6350	**	**
-35	3768	4953	5583	6361	6814	**	*
-36	1377	2126	2155	1988	2184		
-37	4780	5836	6722	6926	7375	**	
-38	7478	6909	7622	7665	7593		
-39	3699	2880	2886	3886	2908		
B- 9	5234	5546	5766	6080	5912		
-19	3865	3824	4101	3698	4159		
-20	5999	6105	5693	6177	5937		
-21	4173	3912	3980	4043	4011		
-22	4926	5390	4672	5110	4902		
-23	4009	3178	3386	2975	3062	*	
-24	7805	7086	7589	7872	8000		
-25	6738	6726	7409	7545	7741	*	
-26	6473	7005	6820	7270	6584		
-27	5052	5354	4784	4795	5103		

† The reported means are unadjusted for differences in P levels used.

Note: Site = experiment

Table 27d. Country by season maize yield means[+]

Country \ Season	Wet	Dry	Country Mean
Puerto Rico	5300	5268	5279
Brazil	4648	5815	5391
Season Mean	5010	5507	5328

[+]yields of maize expressed in kg/ha.

Table 28. Combined analysis of variance for the ten sites used in the combined analysis over sites including transfer studies (Model E)

Source	d.f.	SS	MS
Site	9	704,095,219.66	7,823,280.10 **
Reps in Site	22	44,681,558.36	2,030,979.90
Treatment	12	249,719,445.50	2,080,995.30 **
T × S	108	252,416,446.77	233,718.02 **
Error	264	164,989,702.81	62,496.10

Note: The above analysis was run on an analysis of variance program rather than a linear models program. The fact that 3 Brazil sites had 4 reps rather than 3 could cause some non-orthogonality between some of the sources of variation in the analysis of variance.

Also, the trials designated as transfer residual were eliminated from the combined analyses due to the fact that data were not yet available to quantify the amount of nutrient in the soil precisely for these transfer experiments. There were 8 of these residual transfer experiments, 5 of which had already been eliminated due to high coefficients of variation. Six other sites were eliminated in some runs because data were missing for certain relevant site variables.

A combined analysis of variance for the 10 experiments which were kept in the combined analyses for transfer is shown in Table 28. There was a significant interaction between experiments and treatments which probably is due to response to P only in Brazil and N only in Puerto Rico.

In attempting to combine data over experiments there are a number of approaches which one could use. For example, one could use pairs of sites which were similar with respect to properties which might affect yield response. Choosing nearly exact pairs in this manner would be "stacking the deck" so to speak because in practice one could not be assured that a well studied site in one country could be "matched" well in the other country which has not been studied as well. It would seem better to try to develop a general response model which would include not only controlled variables, P and N but also the uncontrolled variables which would seem to have caused among experiment variation. Since we know that the response was not uniform among experiments (e.g. some sites had linear response to P only, some quadratic response to P, some responded only to N, etc.) we are putting faith in the general second order model to adapt itself to a wide variety of response situations. Interaction terms of the type uncontrolled x controlled variables help in providing this adaptability.

2. Regression Modelling of Combined Data

Our desire was to fit a general second order response model to all experiments of Puerto Rico and Brazil combined to see if such a general model was flexible enough to fit a variety of response surface shapes and to help sort out those variables which are responsible for among site variation.

Data were available on the following variables:

1. Average Daily Precipitation (mm)
2. Average Max Daily Temperature
3. Average Min Daily Temperature

4. Average Daily Solar Radiation (Langley s)

5. Soil P (PPM)

6. Days to 50% tasseling (TAS)

7. Days to Physiological Maturity

8. Pest Ratings

9. % of Harvest Plants Lodged

Very high correlation existed between the following variables:

Days to 50% tasseling & temperature
Days to 50% tasseling & days to physiological maturity
Days to 50% tasseling & pest ratings
Temperature & pest ratings
Temperature & average daily solar radiation
Temperature & days to physiological maturity

These potential predictors were included in a number of models which combined data from all available experiments for which complete data were available. There were also attempts made to combine data for the two levels of season separately, for the two countries separately and for the four classes of country x season also separately.

The results of these combined regressions are reported in Table 29. In this table, R^2 values for various models (including different combinations of site variables) are reported. The number of sites varied from cell to cell because certain experiments would drop out if information on one of the variables included in the model were missing for those experiments. It is revealed in Table 29 that the fit for the model which predicted for all sites combined over Brazil and Puerto Rico was approximately equivalent to separate fits for the combined set of Brazil and the combined set of Puerto Rico sites. It was encouraging that there was not a segregation of sites along country lines as far as the R^2 for the general model was concerned.

After about 10-15 regression runs it was obvious that only the following site variables would contribute significantly to the among experiment variability and thus to the overall regression:

PPM phosphorus
Solar radiation
Days to 50% tasseling

Table 29. R^2 values for regression runs using different models both by Season, Country, Country × Season, and Overall

Model	Season		Country		Country × Season				No. of Sites
	wet	dry	PR	B	PR, wet	PR, dry	B, wet	B, dry	
A	.30	.49	.69	.39	.70	.94	.72	.75	
	(6)	(6)	(6)	(6)	(3)	(2)	(3)	(4)	12
B	.54	.61	.53	.73	.33	.94	.96	.84	
	(5)	(6)	(5)	(6)	(3)	(2)	(2)	(4)	11
C	.23	.48	.60	.36	.61	.91	.46	.67	
	(6)	(6)	(6)	(6)	(3)	(2)	(3)	(4)	12
D	.24	.49	.67	.38	.65	.92	.48	.75	
	(6)	(6)	(6)	(6)	(3)	(2)	(3)	(4)	12
E	.78	.70	.61	.99					
	(4)	(6)	(4)	(6)					10

E (all 10 sites) .54

F (all 10 sites) .62

G (all 10 sites) .62

H (all 10 sites) .62

I (all 10 sites) .69

J (all 10 sites) .75

Note: numbers in parentheses refer to numbers of sites.

Note: Site = experiment

Definition of models given in Table 29:

Model A = P N P^2 N^2 PN PPM TEMP P × PPM N × PPM P × TEMP N × TEMP PPM × TEMP;

B = P N P^2 N^2 PN SRAD PPM TAS;

C = P N P^2 N^2 PN PPM TEMP PPM × TEMP;

D = P N P^2 N^2 PN PPM TEMP TEMP × P TEMP × N TEMP × PPM;

E = P N P^2 N^2 PN PPM SRAD TAS PPM × P PPM × N SRAD × P SRAD × N TAS × P TAS × N;

F = P N P^2 N^2 PN PPM SRAD TAS PPM × P PPM × N SRAD × P SRAD × N TAS × P TAS × N SEASON;

G = P N P^2 N^2 NP PPM SRAD TAS P × PPM N × PPM P × SRAD N × SRAD P × TAS N × TAS SEASON P × SEASON N × SEASON;

H = P N P^2 N^2 NP PPM SRAD TAS P × PPM N × PPM P × SRAD N × SRAD P × TAS N × TAS SEASON P × SEASON × COUNTRY N × SEASON × COUNTRY;

I = P N P^2 N^2 NP PPM SRAD TAS P × PPM N × PPM P × SRAD N × SRAD P × TAS N × TAS SEASON P × SEASON × COUNTRY N × SEASON × COUNTRY;

J = P N P^2 N^2 NP PPM SRAD TAS P × PPM N × PPM P × SRAD N × SRAD P × TAS N × TAS SEASON COUNTRY SEASON × COUNTRY;

The temperature variables showed very little promise in explaining among site variation--solar radiation was much better.

The final set of 10 trials for which Model E (and subsequent variants of F, G, H, I, J) fit reasonably well were as follows:

B-9
B-20
B-21
B-22
B-24
B-26
PR-20
PR-21
PR-27
PR-30

The regression equation (Model J) had the following significant terms:

P linear
N linear
PPM phosphorus
Days to 50% tasseling
Solar Radiation
P linear x Days to 50% tasseling
N linear x Solar Radiation
Season
Country

The fact that season and country appeared in this list can be attributed to the fact that the dry season yields in Brazil were high as shown in Table 27d. This created a strong seasonal effect and a weak country effect.

3. Use of the Cady-Wood P-Statistic Approach

In the project the P-statistic is used as the transfer hypothesis test statistic. This prediction statistic is the ratio of the pooled transfer residual sum of square to the pooled ordinary residual sum of squares (Wood and Cady, 1979).

The fitting of the models described above was in preparation for fitting the Cady-Wood model. In other words we wanted to know what variables should be used in fitting the Cady-Wood model. We have started with Model E of Table 29 and added a Season term to it. This made 15 independent variables. The result was that for some observations there were large differences between observed and predicted values (in some cases, the difference between observed and predicted was on the order of 100 per cent). One cannot hope to have a low value of the P-statistic under such circumstances. There are two approaches which can be taken now. One is to search for a more appropriate general model which although it may differ in content from that which was considered "best" in the model exploration phase it may produce lower deviations of observed from predicted. This will be called "General Model Refinement."

A second approach is to divide the data into groups on the basis of response patterns and to try to develop prediction models which perform well in explaining variation within the individual groups. Studies which focus upon what variables cause the groups to differ in their response patterns will also be carried out.

4. Grouping of Experiments According to Response Pattern

The motivation for constructing groups according to response pattern came from Table 30 which we constructed from results of significance tests. Table 30 shows that the average maize yields for P-response-only and N-response only experiments is nearly the same but trials which responded to both nutrients had a much higher group mean yield. This group which responded to both nutrients included both Brazil and Puerto Rico experiments. One residual trial (B-23) having an average of only 3360 was eliminated from the average because it had a high coefficient of variation (as did a number of other residual transfer experiments).

The group mean maize yield for trials responding to neither N nor P was lower than that for the responders, especially if one includes experiments PR-36 and PR-39 in the average. In this group one could have either high yields denoting a site which did not need any more fertilizer (PR-38) or low yields indicating that some other factor (fertility or other) is controlling the yield potential and keeping yields low (PR-19). The average difference between the largest P mean and the -.85 P mean was 3647 kg/ha for the P-only response group and 412 kg/ha for the N-only response group. The average difference between the largest N mean and the -.85 N mean was 2546 kg/ha for the N-only response group and 396 kg/ha for the P-only response group.

Table 30. General Means Reported by Response Pattern Group†

Sites Responding to P Only	General Mean
B-19	3955
B-20	5958
B-21	4031
B-9	5692
B-22	4992
B-24	7700
B-26	6783
RT B-27	5008
Avg.	5515
Avg. uncircled	5587

Sites Responding to Both N and P	General Mean
PR-20	6415
†† PR-21	8330
RT B-23	3360
RT B-25	7171
Avg.	6319
Avg. uncircled	7305

Sites Responding to N Only	General Mean
RT PR-22	3742
†† PR-27	4956
PR-30	7290
RT PR-31	4897
PR-33	4575
PR-34	4473
PR-35	5471
PR-37	6319
Avg.	5215
Avg. uncircled	5787

Sites Responding to Neither N nor P	General Mean
PR-19	4783
RT PR-36	1952
PR-38	7479
PR-39	3232
Avg.	4362
Avg. uncircled	6131

Circled sites are those with coefficients of variation ≥ 20.

RT = Residual transfer

†Maize yields reported in kg/ha.

††These sites had a significant NP interaction.

Note: Site = experiment

If an analysis of variance is conducted for the P-response only group and the N-response only group, one finds that there is a significant P x Experiment interaction for the first group and a significant N x Experiment interaction for the second group. These interactions imply that within a group there is some interaction between yield response to a given nutrient and the site variables. The experiment to experiment variation within a group is almost of the same magnitude as the treatment to treatment variation and these are for the responders i.e., sites which show considerable response to one fertilizer nutrient.

Our goal will be to study the factors which explain among experiment variation within a group and to see if these are the same variables which explain among group variation. If the among experiment variation is of the same magnitude as the among group variation and is due to the same factors then we will focus all of our attention on the general model for our transferability tests. If the models are different for different groups and also between the within group and the among group variation, then the transferability tests will need to be conducted for individual groups separately.

5. Appropriate Models for Individual Groups

If one lists all P-main effect means for the Brazil sites in the P-only response group and then averages them over experiments in the group (Table 31) it is found that a quadratic response pattern is obtained. There is a tendency for yields to be somewhat higher for the +.85 level of P than for the +.40 but not enough so to suggest that a higher ordered polynomial is appropriate (e.g., a cubic model).

In like manner, if one lists all N- main effect means for the Puerto Rico sites in the N-only response group and then averages them over experiments in the group (Table 31) again a curve can be drawn through the points which would suggest a quadratic response pattern. Again, the +.85 N yield was somewhat higher than the +.40 N yield which might border on the suggestion of a cubic equation but one can only speculate what the yield would be if higher levels of N were used.

The shapes of the curves drawn from the N and P main effect means for the group of experiments which showed response to both N and P were very similar to those of the response curves suggested by the means of Table 31. There is an upswing in the curves at the highest level of the particular nutrient being graphed (i.e., +.85). Again the quadratic response surface would probably provide a good fit for this group in spite of the fact that there is evidence that the maximum yield has not yet been reached.

Table 31. Nutrient Main Effect Means Reported by Response Pattern Group†

Sites Responding to P Only (Certain Brazil Sites)

	Coded P level				
	-.85	-.40	0	.40	.85
Mean†† (8 sites)	3818	4910	5801	6273	6824

Sites Responding to N Only (Certain Puerto Rico Sites)

	Coded N level				
	-.85	-.40	0	.40	.85
Mean (8 sites)	3746	4898	5503	5797	6222

†Maize yields in kg/ha

††Means are unweighted for differences in numbers of replications per site.

Note: Site = experiment

6. Summary

a. The quadratic model generally gave a reasonably high R^2 for fit for individual experiments but there were usually a number of terms which were not significant. An interaction between N and P occurred in only two experiments. There were other experiments which were strictly P responders and others which were strictly N responders. A few sites responded to neither. Quadratic terms were not consistently significant even in the sites responding to a particular nutrient. Part of this may have been due to the fact that there was an upswing in the curves at the highest rate for both N and P which meant that the data curve was shaped like this: and a straight line would fit better than a curve having only one bend in it .

b. The Brazil sites all responded significantly to P. Only two of them responded to N. There was no interaction between P and N in any of the 10 Brazil experiments.

c. Blocking appeared to be effective in a number of experiments.

d. The combined analysis of variance for 10 experiments which had complete data on all site variables considered important in the transfer analyses showed significant Location, Treatment, and Treatment x Location effects.

e. Preliminary work on fitting a general Cady-Wood transfer model showed rather sizeable differences between some observed and predicted observations. Work will continue with this approach using a general model over the 10 experiments in hopes that model refinement will improve the predictions.

f. At the same time, another approach involving four groups of experiments will be carried out. Attempts will be made to fit models and transfer functions within the following groups: P-only Response; N-only Response; Both N and P Response. There is also a group called Neither N nor P Response. The idea is to see if separate models are required for the different groups or if a general model is flexible enough to fit all sites simultaneously. The latter is preferred from an operational point of view because it provides many more degrees of freedom for experiments and this permits the general model to contain more site variables.

g. Some review of the matter of data existing for soil P and N levels within sites seems in order. The fact that Puerto Rico had a sizeable N response and Brazil had a sizeable P response may suggest that deficiencies may have

existed at the sites prior to application so site estimates of the levels originally present would be quite helpful in predicting sites where response would take place.

h. Considerably more modelling work needs to be carried out before any conclusions can be drawn about the transferability of technology.

C. Tentative Conclusions

As discussed above, the results of the regression analyses for the Puerto Rico and Brazil experiments revealed that the fit for the prediction model was about the same for the Puerto Rico and Brazil experiments combined as it was for these sites individually. There was no segregation along country lines which is encouraging. But there were still sizeable differences between observed and predicted yields when the P-statistic model developed by Wood and Cady was used. The theory is that we can use site variables as interaction terms to explain why the response surfaces do not have the same shape or orientation. However, the sites variables, as presently used in the statistical models, fail to satisfactorily explain the differences among the means for the various sites. This indicates that considerably more modelling work is needed to improve the predictions. Thus, on the basis of the statistical work conducted to date, there is, at this point, no strong evidence either for or against the transfer hypothesis. The statistical research nevertheless indicates that there is reason to be cautiously optimistic that the transfer hypothesis will be substantiated within practical limits.

Table 32 shows the mean maize grain yield for compatible initial and residual transfer experiments from Puerto Rico and Brazil by seasons. The data indicate considerable variability as regards maize performance at the sites of one country, among the sites of the two countries, and during the wet and dry growing seasons. The fact that no clear and consistent trends are readily obvious, alludes to the complexity of the field results and the difficulty encountered in analyzing these data.

Table 32. Mean maize grain yields (kg/ha) for the +.85P/+.85N treatments of initial and residual transfer experiments from Puerto Rico and Brazil by seasons.

Site/Experiment	Puerto Rico		Brazil	
	Dry	Wet	Dry	Wet
Primary Site				
Initial	8292	5979	7555	6072
Residual	6598	6927	4507	2325
Secondary Site 1				
Initial	7546	7175	8595	7381
Residual	6662	7817	8809	4727
Secondary Site 2				
Initial	3077	5304	8453	5114
Residual	2214	4848	6725	4883

Some of the variability in yields can be explained by differences in soil properties. The high yields of the residual experiments at the secondary site 2 in Brazil (Ceará), for example, can most likely be attributed to the inherently high fertility of the soil at this site. (This soil has a surface horizon that almost qualifies for a mollic epipedon which is customarily associated with high soil fertility.) Conversely, the soil at the secondary site 2 in Puerto Rico (Calero) has an acid surface and a relatively low base saturation in the subsoil, both of which tend to depress yields.

On the other hand, it is not really clear at this time how exactly the climatic site variables shown in Table 33 influence maize yields. The data indicate noteworthy differences in the weather conditions prevailing in Brazil and Puerto Rico, reflecting a continental type of climate in Brazil and a maritime climate in Puerto Rico. Thus, minimum air temperatures during the dry season are significantly lower in Brazil and the temperature range there is about twice as large as in Puerto Rico. Also, the amount of solar radiation during the dry season in Puerto Rico is about 35 percent lower than during the wet season but only 10 percent lower in Brazil. Maize yields were consistently higher during the dry season in Brazil, while this was not the case in Puerto Rico. It may be speculated therefore that the lower mean minimum temperatures during the dry season in Brazil, probably in combination with lower disease incidence and insect damage during this season, account for the higher yields. In Puerto Rico, where the seasonal temperature differences are less pronounced, this trend is

Table 33. Site data from Brazil and Puerto Rico for ten transfers experiments.

EXPT. NO.	SEASON	SITE	YIELD MEAN	PPM[a]	TAS[d]	MAT[e]	TEMPERATURE (°C) MIN	MAX	SRAD[f]	TIME SPAN OF TEMPERATURE AND SRAD AVERAGES[g]		
B-9	Dry	PARANA	5692	.04[b]	83.0	192.0	14.23	32.61	448.13	7-29-77	to	9-29-77
B-20	Wet	CEARA	5958	.02[c]	66.0	157.0	22.42	35.04	467.82	12-24-77	to	2-24-78
B-21	Wet	BAHIA	4031	.01[c]	73.0	165.0	*	31.19	492.22	1- 1-78	to	3- 4-78
B-22	Dry	PARANA	4992	.04	88.5	162.0	14.35	32.46	433.83	8-16-78	to	10-17-78
B-24	Dry	CEARA	7700	.06	79.8	145.6	13.25	33.55	438.78	8- 7-78	to	10- 8-78
B-26	Dry	BAHIA	6783	.02	81.2	152.6	13.06	34.33	493.96	8- 7-78	to	10- 8-78
MEANS			5859	.03	78.6	162.4	15.46	33.20	462.46			
PR-20	Dry	CERRO	6415	.06	55.6	125.8	18.34	27.98	328.86	12- 9-77	to	2- 9-78
PR-21	Dry	RAMAL	8330	.04	56.2	124.5	18.08	29.37	319.83	1- 5-78	to	3- 8-78
PR-27	Wet	RAMAL	4956	.02	50.8	105.0	20.81	29.70	486.51	5-14-78	to	7-15-78
PR-30	Wet	CERRO	7290	.04	50.2	103.0	20.94	29.76	487.54	5-26-78	to	7-27-78
MEANS			6748	.04	53.2	114.6	19.54	29.20	405.69			

[a] PPM = Phosphorus in solution in parts per million (for partial control since there was no complete control)

[b] Average over complete and partial controls

[c] For complete control since this experiment had no partial control

[d] Days to 50 percent tasseling (averaged over all reps)

[e] Days to physiological maturity (averaged over all reps)

[f] Daily solar radiation in Langleys (averaged over time period indicated)

[g] One month before and after date corresponding to average No. of days to 50 percent tasseling

* No available data

not as obvious. Statistical analyses that include the climatic site variables are therefore now being conducted with the objective to explain the differences in maize performance at the various sites.

Variability within experiment sites, as indicated by plot data, is a distressing factor in both Puerto Rico and Brazil. Assuming equal weather conditions and equal soil and crop management at one experiment, this variability must be caused by the soil. In Puerto Rico, soil microvariability could be thought to be the effect of a long history of cultivation resulting in man-induced differences in fertility and soil physical conditions. To some extent this is certainly true. However, nearly the same yield variability was observed in Brazil although the soils there had not been cultivated before. Moormann and Van Wambeke (1978) pointed out that strong variability over very short distances is a characteristic of many soils of the tropics, particularly in soils with low activity clays such as Eutrustox. The low clay activity causes the soils to have a low buffering capacity for nutrients and a low effective water-holding capacity. Therefore, even small lateral variations in texture, organic carbon content, pH, etc. have a pronounced effect on crop performance. The situation encountered at the Puerto Rico and Brazil sites thus appears to be the rule rather than the exception.

It must also be realized that the soil family, although the lowest taxonomic category, still allows for variations in defined and undefined soil properties. For example, the base saturation in the major part of the subsoil of the Eutrustox must, by definition, be 50% or more and thus may conceivably range from 50 to 100%. Similarly, the clayey particle size class permits clay contents from 35 to 100%. It should further be remembered that in the case of the Eutrustox, the differentiating criteria for soil classification are applied in the so-called control section that starts below the plowed layer. Although the general properties of the surface soil are covariant with the subsoil properties, they may differ from soil to soil despite the fact that they belong to the same soil family. Such surface soil conditions include organic matter content, soil reaction, nutrient availability, soil texture, horizon thickness, and others. Some of this variability reflects the past cropping and management history of the soil. Fertilization with ammonium sulfate, for example, may result in residual acidity in the surface soil. Furthermore, although the general climate of the area where a soil family occurs is indicated in the soil moisture and temperature regimes, the actual weather conditions during a given growing

season, of course, cannot be inferred from the taxonomic unit with the degree of accuracy desirable for precise crop performance predictions.

Crop performance and soil management predictions could clearly be refined if they were based on information more specific than that contained in the soil family. In fact, Soil Taxonomy recognizes a categoric level below that of the soil family, the soil series. The differentiae used for series are mostly the same as those used for the classes in other categories to which the series belongs, but the range permitted is less than is permitted in the family or some other higher category. However, taken collectively, the number of possible distinctions is too large to be comprehended readily and to be incorporated in a key.

In addition, Soil Taxonomy has the flexibility to indicate soil characteristics that are not considered in taxa definitions but are important for a specific land use. The phases provide for a utilitarian classification that can be superimposed on the taxonomy at any categoric level to permit more precise interpretations and predictions. Thus, one may recognize an "acid surface soil phase" of the clayey, kaolinitic, isohyperthermic family of Tropeptic Eutrustox.

The most precise predictions, therefore, can be made on the basis of phases of soil series. However, it would clearly be unrealistic to use this level in the process of international agrotechnology transfers. First, such detailed information rarely exists for LDC's. Second, soil series are not rigidly defined, and different rationales for establishing series are used in different countries. As a consequence, the lowest categoric level of Soil Taxonomy that can be universally applied in a uniform and consistent manner is the soil family. It is for this pragmatic reason that the soil family is used in the Project.

While it is still too early to make conclusive statements about the validity of the project hypothesis, it is becoming evident that response of all soils of the Eutrustox network to treatment variables have a remarkably uniform trend which suggests that all members of the soil family have indeed a common response to management practices that is characteristic of this family and distinct from others. The yield potential of the Eutrustox studied also was quite similar and predictable under stated conditions of management. Further experimentation and the final statistical analysis are, therefore, expected to corroborate the project hypothesis, at lease in essence.

III. Management Experiments

A. General

Aside from available phosphorus and nitrogen, limited soil moisture is probably the most severe constraint inherent in the soil family under study. For this reason, moisture utilization studies have been emphasized in BSP management experiments in Puerto Rico and Brazil. Irrigation rate experiments have been and continue to be conducted in both Puerto Rico and Brazil by the BSP.

Other types of experiments less directly related to soil water management included plant population density and planting date trials. The use of maize and sorghum stover mulch in trials with these two crop species was tried. Multicropping begun in FY 78 and still underway is also indirectly related to soil moisture utilization, being an attempt to maximize the use of all natural resources available in a given space.

Phosphorus rate and placement, and liming experiments were also carried out. Two tillage experiments were conducted previously and another was completed in FY 79.

B. Puerto Rico

1. Irrigation rate x nitrogen level

In Puerto Rico three irrigation x nitrogen level experiments have been completed, one during the wet season and two during dry seasons. Another similar experiment will be conducted during the approaching dry season. The objectives of this study are (1) to compare the performance of maize when grown without irrigation during the dry and wet seasons in an area with an ustic soil moisture regime, (2) to determine the effect of supplemental irrigation on crop yield in both seasons, and (3) to study nitrogen-water interactions.

The Puerto Rico irrigation x nitrogen experiments were conducted using the line-source continuous variable method described by Hanks et al. (1976) but utilizing a trickle irrigation system instead of sprinklers. The first experiment had 24 levels of nitrogen from 0 to 230 kg/ha in 10-kg increments and 12 levels of water applied from 0 to approximately 20 mm of water per application. Irrigations were applied when tensiometer readings in the center plots showed 20 centibars or more

tension. The irrigation treatments were likewise applied not randomly but in a stepwise fashion across the nitrogen treatments. There were four replications. The second experiment was laid out in a similar manner, but only half as many treatment levels were utilized and there was no replication. The plot size was very small in the first trial, being only two plants. Since treatment gradients were almost continuous, there were no border effects between plots and large plots were, therefore, unnecessary. For subsequent experiments, plot size was increased to four rows 4 m long (3 x 4 m) and only the center two rows were harvested for yield measurements. Treatments were not replicated in the latter trials.

The maize yield data from this study for FY 79 are presented in Table 34. During the 1979 dry season there was a strong response to water applications and a mild response to nitrogen. The highest grain yield, 9252 kg/ha, was obtained with 160 kg/ha of N and the highest irrigation rate applied. Lowest yields were harvested from the plots receiving no water; these ranged from 4499 kg/ha without N to 6915 kg/ha with 160 kg/ha of N applied.

Tentative conclusions drawn from current and previous BSP wet season and dry season experiments are (1) that a reasonably high yielding crop of maize may be grown without supplementary water at Isabela during at least some dry seasons, (2) that during other dry seasons, however, maize yields may be improved considerably with appropriate supplemental irrigation and (3) that nitrogen deficiency can be a limiting factor moderately to severely restricting grain yields depending on cropping history, previous fertilizer applications and available soil moisture. Experimentation with supplemental water must be repeated over a number of seasons to provide reliable information as to crop requirements for irrigation in this area. Results of these trials will be analyzed statistically utilizing years as replications after one more planting season.

2. Normal tillage vs. minimum tillage

In a tillage experiment repeated at Isabela in FY 79 standard complete tillage was compared with a minimum tillage method of maize culture at various in-row plant spacings. The objectives of these experiments were (1) to evaluate the suitability of minimum tillage for maize production in Tropeptic Eutrustox in order to minimize soil erosion and compaction, (2) to evaluate three different plant population densities -- the standard used in transfer experiments, one lower and one higher --

Table 34.

Maize, Pioneer hybrid 304C, grain yields from nitrogen x irrigation experiment (BSP PR-40) planted December 14, 1978 and harvested April 30, 1979 at Isabela, Puerto Rico, secondary site #1 (Cerro).

Nitrogen, kg/ha	Grain Yield, kg/ha 1/					
	0	30	60	90	120	150
320-	4694	7194	6439	8109	7973	8287
160-	6915	6473	7194	6962	7557	9252
80-	5643	6309	7034	7290	7453	6085
40-	4525	5169	6996	6997	7101	8284
20-	5131	7019	6048	7446	6260	8173
0-	4499	6205	6048	7689	7471	6548

Irrigation time, minutes 2/

1/ Adjusted to 15.5% moisture.

2/ Water was applied through twin-wall trickle irrigation tubing with 8" x 40" hole spacings; treatment levels were determined by timing each application to deliver from 0 to approximately 20 mm of water per application.

and (3) to obtain a basis for evaluating the effect on maize yields of minimum tillage as practiced in the residual transfer experiments.

The experiment was established in a split-plot design with three replications. Tillage treatments, assigned to whole-plots, consisted of (1) complete tillage, plowing and discing twice followed by rotovating just before planting by hand, and (2) minimum tillage, weed control with paraquat and planting by hand with no other tillage. Later in the season weeds were controlled on all plots by shallow hoeing.

Plant spacings, sub-plot treatments were 20, 23 and 27 cm between plants within the row or 66,666, 57,971 and 49,383 plants/ha, respectively. Maize, Pioneer hybrid 304C, was used as the test crop.

The results of this study are presented in Table 35. Yield differences appeared consistently in favor of conventional tillage in this experiment; however, the data have not been statistically analyzed and definite conclusions should not be drawn at present. Plant spacing within the row had little, if any, effect on yields in the current, FY 79, experiment.

3. Pot studies

Because surface soil pH at the Calero secondary site in Puerto Rico is low, (pH 4.2 - 4.5) and maize response to phosphorus and nitrogen has been limited, several pot experiments were conducted with lime, micronutrients and phosphorus as variables. Objectives of these studies were (1) to determine whether soil pH on the Calero site was a constraint to maize growth, (2) to study the effect of micronutrients and (3) to observe the early plant growth response to P and lime applications separately and in combinations.

Results of the first experiment in which maize plants were grown for 34 days in pots of soil treated with lime at 0.8 meq Ca/100 g soil, are presented in Table 36. The strongest response was to the blanket application of complete fertilizer which was applied uniformly to all pots except one set of control pots without lime or fertilizer. Considering the limited growth period (34 days), there was a marked increase in maize dry matter production with lime applications up to 4 meq Ca/100 g soil which raised soil pH from 4.6 to 5.5.

In a second pot trial with lime and micronutrient levels varied, 4 meq Ca plus Zn and B produced the highest dry matter yield, 8.91 g/plant in 34 days

Table 35.

Maize, X304C, grain yields from a tillage X plant spacing experiment (BSP PR-49) conducted during June 4 to September 13, 1979 at the Isabela, Puerto Rico BSF primary site (Ramal).

Tillage treatment	In-row Spacing cm	Grain Yield, kg/ha[1/] Replicate I	II	III	Mean
Conventional	20	6204	5931	5128	5754
"	23	5701	5940	5865	5835
"	27	5604	6023	5817	5815
"	Mean	5836	5965	5603	5801
No tillage	20	5516	4934	5025	5158
"	23	5666	4805	5222	5231
"	27	5764	5403	3639	4935
"	Mean	5649	5047	4629	5108
Mean over all treatments		5742	5506	5116	5455

1/ Adjusted to 15.5% moisture.

Table 36.

Dry matter production of 34-day old maize (X304C) grown in pots of Coto clay soil[1/] treated with and without a blanket application of fertilizer and with 15 different levels of lime plus fertilizer.

Treatment meq Ca/100 g soil	Dry matter g/plant	
0	0.48	a [2/]
.26 + fertilizer	4.32	b
0 "	4.37	b
.39 "	4.51	b
.50 "	4.86	b c
2.86 "	5.20	b c
2.60 "	5.42	b c d
1.0 "	5.47	b c d
2.0, 3.0 "	5.52	b c d
4.29 "	5.57	b c d
7.0 "	5.84	b c d
8.0 "	5.95	b c d
5.0 "	6.16	c d
6.0 "	6.28	c d
4.0 "	6.91	d

Soil for this experiment was taken from the Isabela secondary site # 2 (Calero), soil pH 4.2 in H_2O

Treatments followed by the same letters are not significantly different at the .05 level of probability.

(Table 37). This yield was superior to dry matter production from pots without lime but not higher than other micronutrient combinations at the same, 4 meq Ca, lime level. Micronutrients alone appeared to have little, if any, influence on yield, while lime plus micronutrients showed considerable increase in maize growth. A comparison of the first two pot experiments conducted at the same time and location suggests that both micronutrients and lime were effectively increasing maize growth in the second pot trial.

A third pot experiment with various levels of phosphorus added to the soil produced significantly more dry matter when 43 kg/ha of P was added (Table 38); but apparent increases in yield with still higher P levels were not significant. Phosphorus and lime combinations were studied in a fourth pot trial. The data from this trial are presented in Table 39. Again, P alone increased dry matter production of 28-day old maize plants; however, the response to P was still greater when lime was applied at 2 to 4 meq Ca/100 g soil. The 4 meq Ca level at 4.08 g of P/pot was the most effective treatment in this experiment, although yield differences between the 2 and 4 meq Ca levels were not significant at any one level of P.

4. Lime x phosphorus

As a follow-up to the pot trials, a field experiment was conducted with lime and P variables. The objective of this experiment was to verify pot study maize responses to lime and lime-phosphorus combinations under field conditions and with plants grown to maturity. Early, during the silking stage, treatment effects on plant size and ear development were visible, but final grain yields showed no consistent treatment effects (Table 40). Hurricane David and tropical storm Frederick passed near and over Puerto Rico, respectively, as this experiment was approaching maturity and damages from these storms could easily have obliterated treatment effects on grain yields.

C. Brazil

1. Irrigation rate x crop variety

In cooperation with the Centro Nacional de Pesquisa de Milho e Sorgo (CNPMS) of Empresa Brasilera de Pesquisa Agropecuaria (EMBRAPA) and Purdue University and utilizing line-source irrigation experiments designed by Dr. Jack Keller of Utah State University, a moisture utilization model is being developed for maize and sorghum in Brazil. Three sets of experiments with maize and sorghum have been

Table 37.

Dry matter production above ground of 34-day old maize (304C) plants grown in pots of Coto clay soil 1/ treated with various micronutrient combinations.

Treatment			Dry Weight, g/plant				
Code	Lime meq Ca	Micronutrient	Rep. I	II	III	IV	Mean 2/
1	0	Mg + Zn + B	5.52	5.62	6.72	2.27	5.03 abc
2	0	Mg + Zn	5.56	4.97	5.73	2.06	4.58 abc
3	0	Mg + B	3.49	6.97	2.42	2.52	3.85 ab
4	0	Zn + B	7.86	3.17	2.48	1.09	3.65 a
5	4	Mg + Zn + B	8.60	8.02	8.03	5.77	7.61 cd
6	4	Mg + Zn	8.96	10.23	4.14	5.35	7.17 bcd
7	4	Mg + B	9.31	9.87	4.61	4.66	7.11 bcd
8	4	Zn + B	10.57	11.02	9.61	4.44	8.91 d

1/ Soil from the Isabela secondary site #2 (Calero) with ph 4.2 in H_2O.

2/ Means followed by the same letters are not significantly different at the 5% level of probability.

Table 38.

Dry matter production of 28-day old maize (X304C) grown in pots of Coto clay soil 1/ treated with various levels of phosphorus fertilizer.

Treatment P, kg/ha	Dry Matter g/plant
0	.48 a 2/
43	1.88 b
65	1.94 b
22	2.00 b
86	2.08 b
106	2.62 b

1/ Soil for this purpose was taken from the Isabela secondary site #2 (Calero), soil pH 4.2 in H_2O.

2/ Treatments followed by the same letters are not significantly different at the .05 level of probability.

Table 39.

Dry Matter production above ground of 28-day old maize (X304C) plants grown in pots of Coto clay soil treated with various combinations of lime and phosphorus.

Code	Treatment: Lime meq Ca	Phosphorus g/pot 2/	Blanket Fertilizer	Dry Matter, g/plant: Rep I	II	III	IV	Mean 1/
1	0	0	0	0.92	1.03	1.96	0.29	1.05 ab
2	0	0	+	1.05	0.73	0.43	0.09	0.58 a
3	0	.82	+	1.25	2.37	2.05	1.74	1.85 abcd
4	0	1.63	+	2.31	2.41	2.58	1.36	2.17 bcd
5	0	4.08	+	2.68	4.23	3.80	2.47	3.30 de
6	2	0	+	1.33	1.69	0.90	0.72	1.16 abc
7	2	.82	+	2.04	3.81	2.57	1.81	2.56 cd
8	2	1.63	+	3.87	7.77	4.20	3.41	4.81 fg
9	2	4.08	+	6.35	7.62	6.15	3.82	5.99 gh
10	4	0	+	2.14	2.33	1.56	1.23	1.82 abcd
11	4	.82	+	4.10	3.59	2.56	2.14	3.10 de
12	4	1.63	+	6.39	5.69	3.69	1.99	4.44 ef
13	4	4.08	+	7.50	9.60	7.17	5.59	7.47 h
14	6	0	+	3.30	2.58	2.03	1.35	2.32 bcd
15	6	.82	+	6.17	8.43	4.17	1.33	5.03 fg
16	6	1.63	+	4.86	7.36	3.62	5.64	5.37 fg
17	6	4.08	+	7.67	6.63	9.0	4.16	6.87 h

1/ Means followed by the same letters are not significantly different at the 5% level of probability.

2/ Pots utilized were 15 cm in diameter filled to approximately 15 cm with soil. Triple super phosphate was added to each pot at the rates indicated.

Table 40.

Maize, Pioneer hybrid 304C wet season yields from a lime x phosphorus fertilizer trial (BSP PR-47) conducted May 25 to September 12, 1979 near Isabela, Puerto Rico, secondary site #2 (Calero).

Treatment		Grain Yield, kg/ha[1/]			
Ca	P	Replicate			
me	ka/ha	I	II	III	Mean
0	0	4617	4039	5148	4601
0	20	4988	2749	5612	4450
0	50	5201	2686	4539	4142
3	0	3704	4829	4214	4249
3	20	4174	4118	4491	4261
3	50	4432	4155	3891	4159
6	0	4817	2723	4139	3893
6	20	3482	3855	4576	3971
6	50	5620	2718	6249	4862
6	100	5125	4108	4549	4594
9	0	4873	5146	4771	4930
9	20	3918	5375	2909	4067
9	50	4941	5812	3850	4868
9	100	3311	5344	5120	4597

1/ Adjusted to 15.5% moisture

completed. The data from the first experiments are being analyzed by Purdue University and are to be prepared for publication. The second and third set of experiments also with maize and sorghum were managed by CNPMS with BSP assistance at the field site. These second experiments included two varieties of each crop to examine possible varietal differential with respect to moisture requirements by the crop species. The CNPMS is analyzing those data. Another irrigation experiment with supplemental water x P-levels x plant population variables was established, though not harvested during FY 79.

2. Multicropping

A multicropping design with maize, beans, onions, carrots and a number of other food crops (Table 41) was initiated late in FY 78 and continued through FY 79. The purpose of this intensive cropping study is to examine ways to maximize food production throughout the year on a limited land area, as would be the need in small farm operations in the tropics.

The multicropping experiment is small, utilizing only a 20 x 20 m space, with three cropping cycles of combinations of 12 different food crop species. The design is a modification of a plan described by Hildebrand (Papendick et al., 1976, pp. 347-71). The trial is now in the third cycle. Some pertinent data are presented in Table 41 for the first and second cycles. A total cash value of $139.29 for the produce from the first crop cycle on the 20 x 20 m plot was estimated. It is supposed, however, that the produce from a small intensive system as this would generally not be sold; rather, it would more likely contribute to the diet of the family involved.

IV. Variety Trials

Variety trials conducted on the clayey, kaolinitic, isohyperthermic Tropeptic Eutrustox have demonstrated that a number of maize varieties are suitable for this family of soils on the sites tested. One variety, Pioneer's X304C, has been consistently high yielding, up to 9,782 kg/ha in Puerto Rico, and possesses sufficient desirable agronomic traits to make it useful as a test-crop at all sites. This hybrid has been observed to have a scarcity of brace roots which suggests that it may be susceptible to lodging, but no major problem occurred during the first several seasons it was used in variety trials and

Table 41.

Crop yields and their approximate economic values for an irrigated and intensively managed 400 m^2 plot multicrop experiment (BSP B-31) at Jaiba, MG, Brazil, primary site.

Crop/Variety	20m-rows No.	Plant/Harvest Dates	Yield per plot	Yield kg/ha	Unit value 1/	Total value 1/ Cr	Total value 1/ $ US
First planting:							
Raddish, Redondo verm. precoce	2	Aug 18,'78/Sept-Oct,'78	237 dz	—	3 Cr/dz	711	29.62
Onion, Red creole	12	Aug 18,'78/Jan 4,'79	29.2 kg	1622	20 Cr/kg	584	24.33
Carrot, Nantes superior	7	Aug 18,'78/Jan 10,'79	124 kg	11857	10 Cr/kg	1245	51.88
Garlic, local	6	Aug 21,'78/None harvested (poor germination)				—	—
Dry bean, Campesino	26	Sept 11,'78/Dec 28,'78	20.6 kg	515	15 Cr/kg	309	12.88
Maize, 111C (Cargill)	27	Sept 18,'78/Feb 24,'79	230.6 kg	5765	150 Cr/70kg	494	20.58
Total value, 1st planting						3343	139.29
Second planting:							
Dry bean, Carioca	24	Apr 10,'79/July 25,'79	60 kg	1500			
Maize, 111C (Cargill)	14	Apr 25,'79/Sept 18,'79	24.7 kg	617			
Squash, Abobora menina	5	Apr 25,'79/Aug-Sept,'79	186.6 kg	12440			
Cucumber --	5	Apr 25,'79/None harvested	--	--			
Squash, Zucchini	3	Apr 25,'79/ " "	--	--			

1/ Values used are rough approximations based on local market prices; no value estimates were available for the produce from the second planting. During the first cycle the currency exchange rate was approximately 24 cruzeiros per US dollar.

transfer experiments. Considerable lodging did occur during two storms, hurricane David and tropical storm Frederick, striking Puerto Rico in close sequence in August 1979; but no variety could have been expected to resist lodging under such circumstances.

Other hybrids have also produced quite well in both countries. IAC Phoenix 1110 was initially used in Brazil tests. This was followed by another hybrid, Cargill's variety 111, which also yielded well in variety trials at Jaiba. In Puerto Rico the first transfer experiments were planted to the Pioneer hybrid X306B. Since 1978 all transfer experiments at all Eutrustox sites including Hawaii have been planted to the Pioneer hybrid, X304C.

No further variety testing has been done by BSP in Puerto Rico. However, some maize variety testing has been continued in Brazil for in-country purposes.

A maize composite population improvement study initiated at Jaiba in FY 79 is to be carried through several planting cycles. Results from these trials will not be available until FY 80.

Two Brazil national maize variety trials, one of precocious selections and another of normal maturity selections, were conducted from November 1978 to May 1979 by the BSP EPAMIG/UPR staff at Jaiba. The early maturing selections gave yields ranging from 2312 to 7738 kg/ha, while normal-maturity material yielded from 2825 to 8825 kg/ha. These were replicated trials and the data from these experiments were sent to Centro Nacional de Pesquisa de Milho e Sorgo (CNPMS) at Sete Lagoas. These data are analyzed, interpreted and published along with the results of all other national maize variety trials conducted in Brazil during the year.

The third INTSOY international soybean variety trial in Brazil was planted in July 1978 and completed during FY 79. Grain yields ranged from 975 kg/ha for the variety Cobb to 1,920 kg/ha for the variety Calland. The yield data are summarized in Table 42. It is of interest that varieties appearing repeatedly in these trials have appeared from season to season in quite different order when ranked by grain yields. Another soybean variety trial planted in January 1979 with material supplied by International Plant Breeders (IPB) gave grain yields from 1457 to 4730 kg/ha for Jupiter and IPB selection 73-77 respectively.

Table 42.

Soybean grain yields from the INTSOY international variety trial (BSP-30) planted July 27, 1978 and harvested November, 1978 at Jaiba MG, Brazil, primary (Paraná site).

Variety	Grain Yield Kg/ha[1/]
Calland	1920
Cutler 71	1824
Crawford	1780
Columbus	1776
Mitchell	1767
Rillito	1574
Improved Pelican	1541
Forrest	1459
Williams	1453
Bragg	1381
Bossier	1336
Davis	1306
Gasoy 17	1174
Franklin	1116
Ransom	1049
Cobb	975
Grand Mean	1465
Standard error of a variety mean	145
Coefficient of variation	19.8%
5% LSD, variety means	413

1/ Means of four replicates.

DISSEMINATION AND UTILIZATION OF PROJECT CONCEPTS AND RESULTS

I. Strategy Planning Meeting

In an effort to pave the way for an effective utilization of the principles underlying the Benchmark Soils Project and concepts related to it, initial arrangements were made for a panel consultation on the strategy for land evaluation and agrotechnology transfers. The meeting will be sponsored by the Benchmark Soils Project and will be hosted by the Food and Agriculture Organization (FAO) of the United Nations. It is scheduled to be held at the FAO Headquarters in Rome in March 1980.

The intent of the meeting is to develop a strategy for land evaluation research and soil-based transfers of agroproduction technology at an international level in the tropics and subtropics. The specific objectives are:

1. To devise a framework for the effective utilization of agrotechnology transference research that combines national and international efforts and promotes the application of its results in development work,
2. To determine what needs to be done by whom, when, where and how to establish the relationships between soil characteristics and crop requirements in order to obtain a sound basis for soil survey interpretation and land evaluation, and
3. To assist the Benchmark Soils Project in developing a modus operandi for the utilization phase of the Project within the context of more comprehensive international efforts.

In order to ensure an effective interaction, the number of participants will be deliberately small. We expect that high-level officials of AID, the IARCs, FAO, the ISSS, USDA-SCS, the International Soil Museum, EMBRAPA, CNSIGM, Cornell University, and the Benchmark Soils Project of the Universities of Hawaii and Puerto Rico will be represented.

FAO's willingness to host and actively participate in the meeting reflects a strong interest in the BSP and its utilization efforts. It is anticipated that the recommendations of the panel consultation will have far-reaching implications to the future direction of the BSP.

II. Project Impact in Brazil

The BSP has had remarkable impact in Brazil. Indicating an acceptance of project

concepts, the national agricultural research agency, the Empresa Brasileira de Pesquisa Agropequária (EMBRAPA), is now initiating the establishment of a national benchmark soils network in Brazil. EMBRAPA's Servico Nacional de Levantamento e Conservacao de Solos will be executing this program and already has begun to identify Brazilian benchmark soils. The development of an appropriate research policy and design has been deliberately postponed until after the aforementioned FAO/BSP strategy planning meeting in order to ensure compatibility of the Brazilian efforts with similar research conducted elsewhere at the sites of what has been conceived as the International Benchmark Soils Network (IBSN).

In addition to EMBRAPA, UPR's collaborating agency in Minas Gerais, the Empresa de Pesquisa Agropequária de Minas Gerais (EPAMIG) reiterated its firm intent to continue to be centrally involved in BSP and IBSN activities in Minas Gerais.

III. Field Day at Jaiba, Brazil

On the initiative of EPAMIG, a field day was organized and will be held in Janauba and Jaiba in October 1979. The purpose of this activity is to familiarize a larger in-country audience with the philosophy, research and ramifications of the BSP and to disseminate preliminary results.

The field day will be convened by EPAMIG whose president, Dr. H. Mattana Saturnino, extended invitations to all relevant organizations and individuals in Minas Gerais. Some 45 professionals representing universities, private companies, and various research, development and extension agencies of Minas Gerais are expected to attend. UPR's Brazil agronomist M. L. Olson and D. Prudente Santana of EPAMIG have compiled an appealing package of background and reference material on the BSP for distribution among the participants.

IV. Soil Classification Workshop

The Third International Soil Classification Workshop --centrally related to the BSP but funded under a separate grant from AID to UPR-- was in preparation during the report period. The workshop is co-sponsored by the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) and will be held in Syria and Lebanon in April 1980. It will be the third in a series of AID-supported workshops organized by UPR in cooperation with host country agencies with the objective to adapt Soil Taxonomy relative to the soils of the lower latitudes. The Syria/Lebanon workshop will focus on the taxonomy of soils of dry areas and the

redefinition of soil moisture regimes. The Benchmark Soils Project and international transfers of agrotechnology will figure prominently at the meeting as one technical session is dedicated to these topics.

V. Publications

Dr. Nyle C. Brady, editor of Advances in Agronomy, invited Drs. F. H. Beinroth and G. Uehara to prepare an article on the benchmark soils concept for the 1980 issue of this prestigious journal. To ensure a complete and authoritative coverage of the subject and a paper of high professional standards, Drs. R. W. Arnold, F. B. Cady and J. A. Silva were included as co-authors. A 60-page manuscript entitled "Agrotechnology Transfer in the Tropics based on Soil Taxonomy" was prepared. After editing by the UH/BSP publications specialist, Cynthia L. Garver, it will be submitted to Dr. Brady in November 1979. It is anticipated that the paper will create a wide awareness of the rationales underlying the Benchmark Soils Project in the scientific community.

S. P. Nightengale, J. Badillo and G. L. Spain completed the draft of a paper that summarizes the results of the maize variety trials conducted in Puerto Rico. The manuscript will be submitted for publication in UPR's Journal of Agriculture.

The second joint progress report of the Benchmark Soil Project was published by the University of Hawaii in September 1979 and distributed widely. The well-illustrated report focused on the development of the transfer model and soil taxonomic interpretations of crop performance of the three soil families of the BSP network. The report was well accepted and many complimentary comments were received.

"Benchmark Soils News", a newsletter with a feature story, research highlights and related miscellanea combining contributions from personnel of the two projects was again published quarterly by the University of Hawaii for worldwide circulation.

WORKPLAN FOR COMING YEAR

I. General

The first extension of the UPR/BSP, contract AID/ta-C-1158, will end in December 1980. Through this time project activities will be focused mainly on field experimentation and statistical analyses. Field work in Puerto Rico and Brazil

will be phased out during 1980. A second extension without additional funding will be requested for 1981. This extension, if approved, will allow time to conduct final statistical analyses, prepare the summary report and publications, disseminate results, and initiate the utilization phase of the project.

II. Field Experiments

For the six experiment sites in Puerto Rico and Brazil a total of 35 field studies are planned for FY 80. The experiments will generate further data for the statistical test of transferability and fill knowledge gaps relative to the management of Entrustox. The various kind of experiments are summarized below.

Table 43. Field experiments planned for 1979-80

Type of Experiment	Crop			
	Maize	Soybeans	Others	Total
Transfer				
Puerto Rico	12	-	-	12
Brazil	12	-	-	12
Variety				
Brazil	2	2	-	4
Management				
Puerto Rico	4	-	-	4
Brazil	2	-	1	3
	32	2	1	35

A. Transfer Experiments

Two standard transfer experiments with maize will be conducted at each of the six experiment sites in Puerto Rico and Brazil, one during the dry season and one during the wet season. Each transfer experiment conducted in a new area (initial transfer experiment) will be followed by a residual transfer experiment to study the residual effect of previously applied phosphorus.

Grain and stover yields and other yield parameters will be analyzed by the Statistics Section of UPR's Agricultural Experiment Station. Soil, crop and weather data will be entered on IBM sheets for statistical processing.

B. Variety Trials

Since maize hybrid X304C (Pioneer) has been identified as a variety well adapted

for Eutrustox and is now used in all transfer experiments on these soils, there no longer exists the need for extensive variety trials. However, Brazilian national maize variety trials as well as small plantings of maize composites will be carried out in Brazil. In addition, two soybean variety trials will be conducted at Jaiba, one in cooperation with INTSOY and another with IPB.

C. Management Experiments

The management experiments planned for the coming year will focus on irrigation, tillage, liming, multicropping and phosphorus placement.

In Puerto Rico, previously conducted irrigation x nitrogen experiments with maize will be repeated in the dry season in order to obtain more conclusive information about the need for and effect of irrigation. A conventional vs. minimum tillage experiment will also be repeated to reinforce the results from previous experiments. A modification of an earlier P-placement experiment in Puerto Rico will be established in the spring of 1980 to supplement information gained with the first trial and similar P-placement experiment will be conducted in Brazil. Also, the multicropping experiment previously described will be continued in Brazil with the third and subsequent cycles of food crops being planted and intensively managed throughout the year. On the original 1978-79 lime x P field trial plots at Isabela a test for the effect of residual lime and P will be conducted at the Calero site. A similar trial but with initial applications of lime and P is planned for the Bahia site at Jaiba.

III. Statistics

Statistical work will be continued with the general transfer model using all suitable experiments to see if the model can be refined with the currently used site variables or with other site variables that have not been used yet. At the same time grouping of subsets of experiments will be explored in an effort to find out if the treatment x site variation is on the same level of magnitude whether it be experiments within a group x treatment or groups x treatment. Thus, two approaches to the statistical test of transference will be studied.

In addition, routine statistical analyses will be performed for all experiments conducted.

IV. Dissemination

Various dissemination and utilization-oriented activities that have been in preparation during the report period will take place in FY 80. They include a field

day to be held in Jaiba, Brazil in October 1979, a strategy planning meeting to be held in cooperation with FAO in Rome in March 1980, and a soil classification workshop to be held in Syria and Lebanon in April 1980. These activities are described in some detail in a previous section of this report.

At least two technical papers, one on soil taxonomy-based agrotechnology transfer in the tropics and one on the results of maize variety trials, will be submitted for publication in scientific journals. As work on the manuscripts was in progress during FY 79, the papers have been discussed above.

An article on the BSP will be published in Portuguese in EPAMIG's "Informe Agropecuária." Also, BSP Technical Report 5, Laboratory Data and Descriptions of the Soils of the Benchmark Soils Project: Vol. 2 - Puerto Rico Project, will be released in FY 80. Publication of the quarterly newsletter, BSP NEWS, will continue.

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APPENDIX A

I. Experiments conducted at Isabela Agricultural Experiment Station

Exp. No. & Crop	Type of Expt.	Site	Season	Begun	Terminated
1. Soybean	Uniformity	Primary	Wet	7-24-75	10-20-75
2. Soybean	Transfer[1/] (PxK)	Primary	Int.	3-05-76	8-03-76
3. Maize	Transfer (PxK)	Primary	Wet	4-02-76	8-06-76
4. Maize	Variety x P	Primary	Wet	5-14-76	8-30-76
5. Maize	Variety x P	Primary	Wet	7-12-76	11-05-76
6. Soybean	Transfer (PxK)	Secondary #1	Wet	7-30-76	11-29-76
7. Maize	Transfer (PxK)	Secondary #1	Wet	8-02-76	11-16-76
8. Soybean	P x Density x Var.	Primary	Wet	9-05-76	1-03-77
9. Soybean	Transfer (PxK)	Secondary #1	Dry	12-09-76	3-28-77
10. Maize	Transfer (PxK)	Secondary #1	Dry	12-12-76	4-18-77
11. Soybean	Seedbed Preparation	Substation	Dry	12-13-76	5-31-77
12. Soybean	Transfer (PxK)	Primary	Dry	12-21-76	4-14-77
13. Maize	Transfer (PxK)	Primary	Dry	12-22-76	4-26-77
14. Maize	P-placement x levels	Primary	Wet	4-04-77	8-02-77
15. Maize	Water (irrig) x N	Primary	Wet	5-05-77	8-25-77
16. Maize	Transfer (PxK)	Primary	Wet	5-20-77	9-20-77
17. Maize	Transfer (PxK)	Secondary #1	Wet	6-02-77	9-27-77
18. Maize	Variety x P	Primary	Wet	6-17-77	10-04-77
19. Maize	Transfer (P x N)[2/]	Primary	Wet	6-23-77	10-17-77
20. Maize	Transfer	Secondary #1	Dry	11-15-77	3-27-78
21. Maize	Transfer	Primary	Dry	12-12-77	4-20-78
22. Maize	Variety	Primary	Dry	12-13-77	4-18-78

1/ Unless designated as residual, all transfer experiments listed were initial transfer experiments.

2/ Experiment PR-19 and all maize transfer experiments thereafter were with P and N as variables.

Experiments conducted at Isabela Agricultural Experiment Station (cont'd)

23.	Maize	Residual transfer	Primary	Dry	1-12-78	5-22-78
24.	Maize	Water (irrig) x N	Primary	Dry	1-18-78	5-31-78
25.	Soybean	Residual transfer (PxK)	Secondary #1	Dry	2-17-78	7-24-78
26.	Maize	Residual transfer	Secondary #1	Wet	4-10-78	8-02-78
27.	Maize	Transfer	Primary	Wet	4-25-78	8-08-78
28.	Maize	Variety x P x N	Primary	Wet	4-25-78	8-10-78
29.	Maize	Water (irrig) x N	Primary	Wet	4-26-78	rain damaged abandoned
30.	Maize	Transfer	Secondary #1	Wet	5-08-78	8-30-78
31.	Maize	Residual transfer	Primary	Wet	5-10-78	8-28-78
32.	Maize	Tillage (Min. vs. Plow) x Density	Primary	Wet	5-18-78	9-11-78
33.	Maize	Transfer	Secondary #2	Wet	6-08-78	9-26-78
34.	Maize	Residual transfer	Primary	Dry	11-17-78	3-21-79
35.	Maize	Residual transfer	Secondary #1	Dry	11-17-78	3-19-78
36.	Maize	Residual transfer	Secondary #2	Dry	11-21-78	3-27-79
37.	Maize	Transfer	Primary	Dry	12-06-78	4-19-79
38.	Maize	Transfer	Secondary #1	Dry	12-06-78	4-17-79
39.	Maize	Transfer	Secondary #2	Dry	12-12-78	4-24-79
40.	Maize	Water (irrig) x N	Secondary #1	Dry	12-14-78	4-30-79
41	Maize	Residual transfer	Secondary #1	Wet	5-02-79	8-27-79
42.	Maize	Residual transfer (2nd residual)	Secondary #1	Wet	5-02-79	8-27-79
43.	Maize	Residual transfer	Primary	Wet	5-3-79	8-29-79
44.	Maize	Transfer	Secondary #1	Wet	5-17-79	9-06-79
45.	Maize	Transfer	Primary	Wet	5-18-79	9-07-79
46.	Maize	Residual transfer	Secondary #2	Wet	5-25-79	9-11-79
47.	Maize	Lime x P	Secondary #2	Wet	5-25-79	9-12-79
48.	Maize	Transfer	Secondary #2	Wet	5-30 79	9-10-79
49.	Maize	Tillage x [illegible]	Primary	Wet	6-04-79	9-13-79

APPENDIX A

II. Experiments conducted or assisted by BSP at Jaiba, MG, Brazil

Expt. No. & Crop	Type of Expt.	Site	Season	Begun	Terminated
1. Maize	Transfer[1/] (PxK)	Primary	Wet	10-21-76	3-11-77
2. Maize	Variety x P	Primary	Wet	10-26-76	3-15-77
3. Maize	Variety x Density	Primary	Wet	10-28-76	3-16-77
4. Maize	Variety, Nat'l.	Primary	Wet	10-30-76	3-22-77
5. Maize	Variety Annex	Primary	Wet	10-30-76	3-22-77
6. Soybean	Transfer (PxK)	Primary	Wet	11-24-76	4-29-77
7. Soybean	Variety, INTSOY	Primary	Wet	11-25-76	2-03-77
8. Maize	Transfer (PxK)	Primary	Dry	6-07-77	12-15-77
9. Maize	Transfer (PxN)[2/]	Primary	Dry	6 08-77	12-16-77
10. Maize	Irrigation, EMBRAPA	Primary	Dry	6-11-77	11-23-77
11. Sorghum	Irrigation, EMBRAPA	Primary	Dry	6-12-77	10-05-77
12. Soybean	Variety, INTSOY	Primary	Dry	6-23-77	10-07-77
13. Soybean	Variety x P	Primary	Dry	7-11-77	11-10-77
14. Maize	Variety x P	Primary	Dry	7-25-77	1-26-78
15. Maize	Density	Primary	Wet	11-06-77	4-17-78
16. Soybean	Density	Primary	Wet	11-08-77	3-15-78
17. Maize	Variety, Nat'l.	Primary	Wet	11-09-77	4-10-78
18. Maize	Variety	Primary	Wet	11-10-77	3-31-78
19. Maize	Transfer	Primary	Wet	11-10-77	3-31-78
20. Maize	Transfer	Secondary #1	Wet	11-20-77	4-26-78
21. Maize	Transfer	Secondary #2	Wet	11-21-77	5-05-78
22. Maize	Transfer	Primary	Dry	6-20-78	12-15-78
23. Maize	Residual Transfer	Primary	Dry	6-16-78	12-14-78

1/ Unless designated as residual, all transfer experiments listed were initial transfer experiments.

2/ Experiment B-9 and all transfer experiments thereafter were with P and N as variables.

Experiments conducted or assisted by BSP at Jaiba, MG, Brazil (cont'd)

24.	Maize	Transfer	Secondary #1	Dry	6-20-78	11-29-78
25.	Maize	Residual Transfer	Secondary #1	Dry	6-17-78	11-22-78
26.	Maize	Transfer	Secondary #2	Dry	6-19-78	12-05-78
27.	Maize	Residual Transfer	Secondary #2	Dry	6-19-78	12-02-78
28.	Maize	Irrigation, EMBRAPA	Primary	Dry	7-20-78	11-28-78
29.	Sorghum	Irrigation, EMBRAPA	Primary	Dry	7-20-78	11-28-78
30.	Soybean	Variety INTSOY	Primary	Dry	7-27-78	11-(6-30)-78
31.	Multicrop	Intensive Mgmt.	Primary	Dry/Wet	9- -78	Continuing
32.	Maize/Sorghum	Planting Schedule EPAMIG	Primary	Wet	11-05-78	5- -79
33.	Maize	Varieties, normal EPAMIG	Secondary #2	Wet	11-13-78	5- -79
34.	Maize	Varieties, precocious EPAMIG	Secondary #2	Wet	11-13-78	5- -79
35.	Soybean	Varieties, IPB	Primary	Wet	1-15-79	6- -79
36.	Maize	Transfer	Primary	Wet	1-09-79	6-16-79
37.	Maize	Residual Transfer	Primary	Wet	1-16-79	7-10-79
38.	Maize	Transfer	Secondary #1	Wet	1-12-79	6-12-79
39.	Maize	Residual Transfer	Secondary #1	Wet	1-15-79	7-06-79
40.	Maize	Transfer	Secondary #2	Wet	1-10-79	6-12-79
41.	Maize	Residual Transfer	Secondary #2	Wet	1-12-79	7-06-79
42.	Maize	Composite	Primary	Dry	4-11-79	9-20-79
43.	Maize	Transfer	Primary	Dry	6-06-79	
44.	Maize	Transfer	Secondary	Dry	6-07-79	
45.	Maize	Transfer	Secondary	Dry	6-08-79	
46.	Maize	Residual Transfer	Primary	Dry	7-03-79	
47.	Maize	Residual Transfer	Secondary	Dry	7-04-79	
48.	Maize	Residual Transfer	Secondary	Dry	7-05-79	
49	Maize/Sorgum	Irrig., line-source (EMBRAPA)	Primary	Dry	6-05-79	
50.	Maize	Density X P X Irrig.	Primary	Dry	7-25-79	

APPENDIX B

PROJECT PERSONNEL

Puerto Rico

Principal Investigator:	Friedrich H. Beinroth
Senior Agronomist:	Gene L. Spain
Agronomists:	Jose Badillo Feliciano
	Stevan P. Nightengale
Soil Chemists:	Lillian Costa Mayoral
	Milagros Miró
	Luis Carlos Sarmiento
Administrative Aide:	Elsie González de Sánchez
Secretaries:	Ingrid A. Velez Ramos
	Lucy Velez
Research Aides:	Ruben García
	Jose A. Robles
Consultants:	Jack Keller
	Larry A. Nelson

Brazil

EPAMIG Liaison:	Derli Prudente Santana
Agronomists:	Marvyn L. Olson
	Antonio Marcos Coelho
Research Aides:	Narbal de Sá
	Marcos A. C. Torres
Field Foreman:	Delcino C. Jorge
Driver/Mechanic:	Ivandir Pereira Miranda
Typist:	Ademar Fernandes dos Anjos