XN-AAZ-817-B

Interim Progress Report # 3

Nov.1, 1986-June 1, 1987

Project AID-SCI 936-5442

Development of Appropriate Technologies for Overcoming Different Mechanisms of Phosphorus Retention in Central American Soils

I. RESEARCH PROGRESS

Most of the research activities proceded smoothly in this period. The plan of activities for 1987 was approved by ROCAP. Preliminary field experiments were successfully carried out at the CATIE station in Turrialba; an M.S. thesis on alternative methods of applying Phosphorus to beans was completed; soil samples were sent to the SCS laboratory in Lincoln, Nebraska for mineralogical analysis; P retention isotherms of the thirty soils specified in the project have been completed and these results correlated with other soil properties; and a second M.S. student began his research activities; and most of the sites for the field experiments to be carried out beginning in September, 1987, have been selected.

A.Field Experiments at CATIE

As a preliminary to the field experiments to be carried out on soils of different mineralogical characteristics in the final phase of the project, a prototype of these field experiments was planted at CATIE in January, 1987. As was pointed out in the previous interim report, the unavailability of the project vehicle, which finally did arrive in April, 1987, precluded field experiments at other sites in this period as originally proposed. Retention characteristics of the CATIE soil had been studied in

the M.S. thesis of Ing. Wilbert Campos; and the soil appeared to have the characteristics of P retention by both precipitation and adsorption mechanisms identified in the project as a characteristic of several Central American soils. Several of the treatments tested by Ing. Campos in the greenhouse were included in the field trial. One experiment was a 3X 2^4 factorial with the factors bean variety, liming, fertilizer P, foliar P, and P applied by seed imbibition. A single replicate was used and the third and fourth order interactions used to estimate error. The analysis of variance and significant effects and interactions are given in Table 1. Varieties, liming, and P application (300 kg ha^{-1} P)gave significant positive effects on bean yield. P imbibition had a significant negative effect. The interactions, imbibition X varieties, imbibition X liming, and imbibition X P were all significant. These interactions, summarized in Tables 1a, 1b, and 1c show that in the absence of liming and P fertilization, seed imbibition of Phosphorus (3 hours in a solution of K_2HPO_4, containing 8000 ppm of P) did increase bean yields, showing that the practice may have some validity where neither liming nor P fertilization is feasible. Despite the use of only one replicate, precision was acceptable (C.V. =19.87%). Foliar samples of the beans are presently being analyzed and will be used for a more complete evaluation.

The second experiment combined a complete factorial (2^3 (liming, foliar P, and seed imbibition) with five levels of fertilizer P (0, 150, 300, 450, and 600 kg ha^{-1} of P) in a split plot experiment with two replicates. Thus, considerable precision was available for the P response curve which could be combined with the P adsorption isotherms to determine external P

Table 1. Analysis of Variance and Principal Significant Effects of the 3 X 2^4 Experiment

Source of Variation	DF	SS	MS	F
Varieties	2	2115430	1057915	17.97**
Liming	1	308481	308481	5.24*
Soil P application	1	5923480	5923480	100.6**
Foliar P	1	138675	138675	2.35(n.s.)
Seed imbibition of P (IMB)	1	639870	639870	10.87**
Vars X Liming	2	25647	12823	0.21 (n.s.)
Vars X Soil P	2	466362	233181	3.96*
Vars X Fol. P	2	827	414	0.007 (n.s.)
Vars. X Seed P	2	633244	316622	5.37*
Liming X P	1	29601	2960	0.50
Liming X Foliar P	1	850	850	0.014
Liming X Seed P	1	389520	389520	6.61*
Soil P X Foliar P	1	2523	2523	0.04
Soil P X Seed P	1	420751	420751	7.14*
Foliar P X Seed P	1	54675	54675	0.92
Residual	27	1589072	58854	

1a. Varietal Effects (kg/ha beans at 14% moisture)

VARIETY	Mean Yield	Effect of Soil P		Effect of Seed Imbibition	
		-P	+P	-Imb	+Imb
ICA Pijao	1519	1036	2001	1746	1291
IGUACU	1046	719	1373	1207	885
PUEBLA 152	1108	863	1352	1065	1149

1b. Main Effects (kg/ha beans at 14% moisture)

-IMB	1339	-P	873	-Liming	1144	-Foliar P	1278
+IMB	1109	+P	1576	+Liming	1304	+Foliar P	1170

1c. Liming Effects (kg/ha beans at 14% moisture)

	-IMB -Soil P	+IMB -Soil P	-IMB, + Soil P	+IMB, + Soil P
No Lime	671	874	1668	1373
With Lime	1118	838	1902	1360

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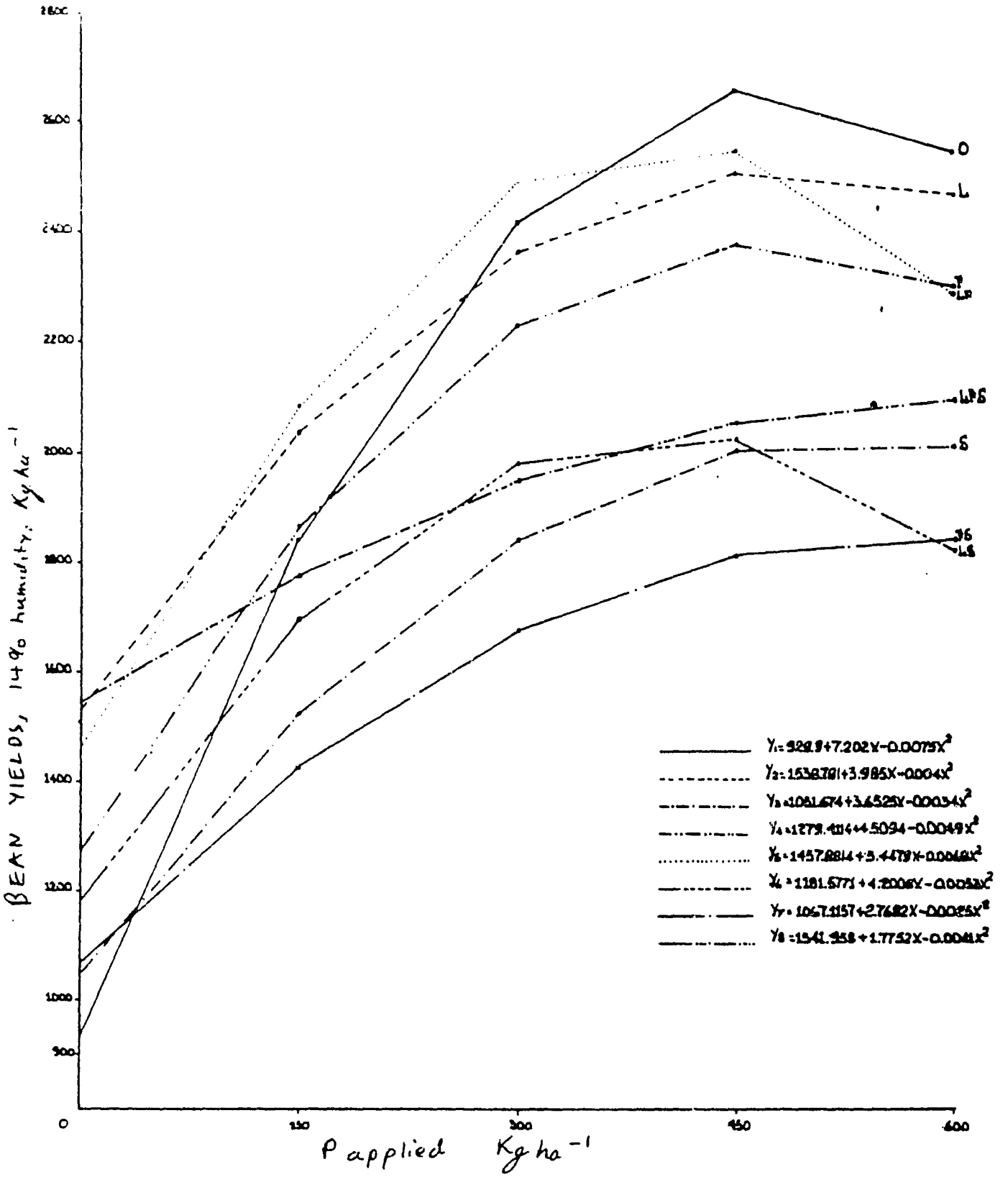
requirements using the method of Fox (1981). External P requirement for the ICA-Pijao variety without soil amendments or seed treatment was found to be 0.084 ppm P in the soil solution which compares well with the value of 0.08 reported for the ICA-Huasano variety by CIAT (1977) in Colombia on a soil of volcanic origin, like the one used in the present study. Interpretation of the effect of liming is complicated by the fact that liming shifted the P adsorption isotherm upward as was found by Friesen, Juo, and Miller (1980) on a Nigerian Ultisol with similar levels of exhangeable aluminum as the soil used in the present study. However, the level of fertilizer P required for 95% of maximum yield is lower with liming as is generally reported in the tropics (Lathwell, 1979) so that when the response curve is combined with the isotherm in order to determine the external P requirement, (Figure 2) , the latter is found to be 0.089 ppm , higher than in the absence of liming. Though this result may not at first seem reasonable, it should be remembered that liming increases the amount of P in the soil solution. Hence, there will be a higher level of soil solution P at all levels of applied P in the limed plots. It should be noted that Friesen et al. observed this effect only at higher levels of lime application as were used in the present study (5 t ha^{-1})

As can be seen in Figure 1, the effect of foliar P application and seed- imbibition increased the intercept value of the response curve but decreased the slope. A combination of liming with foliar P or seed imbibition reduced considerably the amount of P required to obtain maximum yield and consequently reduced the external P requirement somewhat.



RESPONSE OF BEANS ICA-PIJAO TO PHOSPHORUS WITH DIFERENT COMBINATION OF LIME, FOLIAR APPIED P. AND SEED-IMBIBED P. TURRIALBA, 1987

In Figure 2, percent maximum yields are plotted against P levels in the soil solution as calculated from the isotherms for limed and unlimed soil for four treatments (Control, liming, seed imbibition, and foliar P application). The curves for the remaining four treatments are presented in Figure 3.

All of the values for the external P requirement only vary from 0.082 to 0.093 ppm, which appear to be quite reasonable. Lower values might be found if the soil is allowed to react with the fertilizer P for a longer period as was found by CIAT in the second year of the experiment referred to above(CIAT, 1978).

B. M.S. Thesis of Wilbert Campos.

A M.S. thesis based on the greenhouse screening component of the project was submitted to the CATIE-University of Costa Rica graduate program by Ing. Wilbert Campos, who received a scholarship from the project. The thesis was entitled "Manipulacion del cultivo del Frijol (Phaseolus vulgaris L.) para superar diversos mecanismos de retencion de fosforo en suelos de Centroamerica". Ing. Campos worked with four bean varieties (Rio Tibaji and Iguacu, selected by CIAT as being tolerant of low soil Phosphorus levels and ICA Pijao and Puebla 152, considered intolerant) with three soils: an Ultisol with high levels of exchangeable aluminum, an Andept with high levels of amorphous aluminum, and a Humitropept with high levels of both exchangeable and amorphous aluminum.

There were three phases to the study. In the first, the effect of drying and liming on different physical and chemical characteristics of the three soils was studied. the amounts of nutrients necessary to achieve desirable levels in each of the soils was studied. P retention isotherms were determined for each

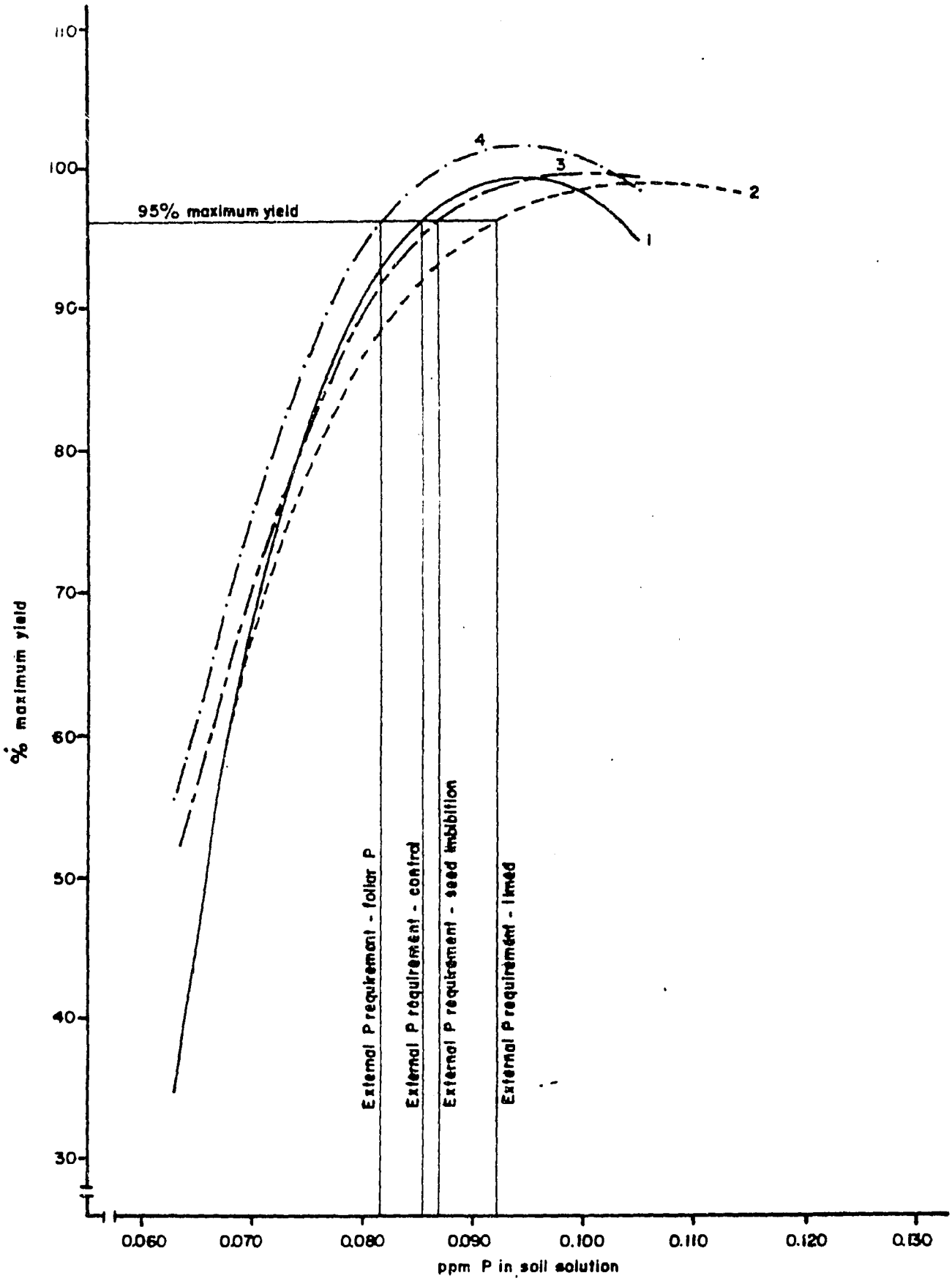


Figure 2 Determination of external phosphorus requirement of beans under four management systems

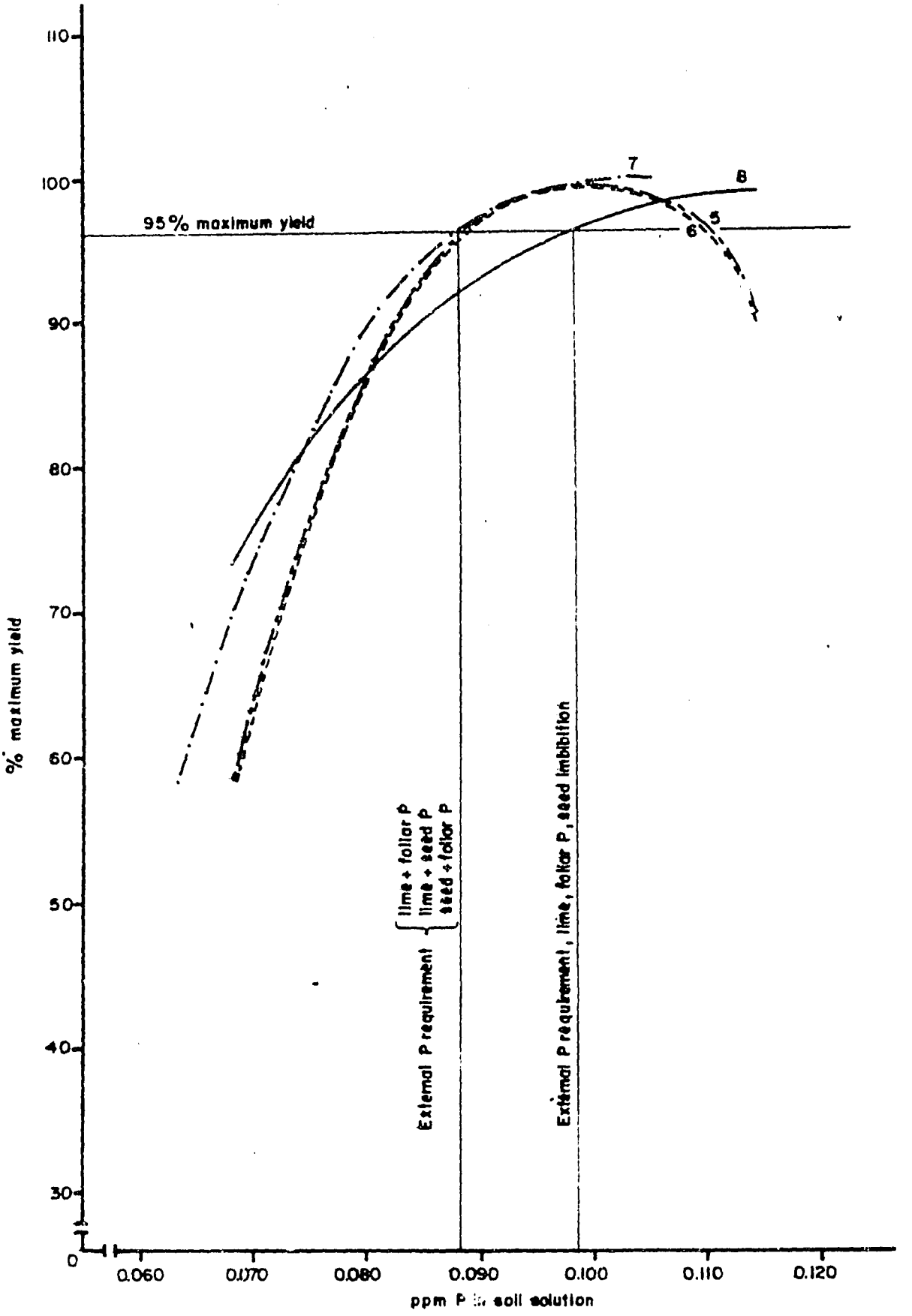


Fig. 3 Determination of external phosphorus requirements of beans with combinations of liming, seed imbibition, and foliar P

soil in the wet and dry and limed and unlimed states.

In the second phase different formulations and concentrations of phosphorus containing solutions as well as times of imbibition were evaluated to determine the P-source, concentration, and imbibition time which most increased P content without decreasing viability.

The third phase was a greenhouse experiment in which liming, four bean genotypes, and foliar and seed imbibed P application were evaluated in each of the three soils.

Principal results of the study were as follows:

1) Drying affected soil physical properties, such as texture, more than chemical properties, such as P retention

2) P retention of all three soils was quite high, about 90% as determined by the isotherms.

3)Highest increase of P content of the seed and germination was achieved by imbibition for three hours of a solution of potassium phosphate (K_2HPO_4), containing 8000 ug/ml P.

4) Liming was especially effective in increasing P uptake in beans in soils with high levels of exchangeable aluminum. It has less effect in soils with more andic properties, containing low levels of exchangeable aluminum.

5) There were differences among genotypes in P uptake from soils receiving the same treatment.

6) Seed imbibition increased P utilization by the plants while foliar application tended to reduce it.

. Mineralogical Analyses of Soil Samples by SCS Laboratory in Lincoln, Nebraska

During the months of November and December, 1986, the agronomist paid by the project worked at the destruction of organic matter and separation of clays on 90 samples, representing 90 horizons of the thirty soils identified by the project for which mineralogical characterization did not exist. Following contacts made with Dr. J. Kimble of the SCS laboratory in Lincoln, Nebraska, the prepared samples as well as unaltered samples of the same soils were sent to the SCS laboratory through the kind services of Dr. Madison Wright of Cornell University who hand carried the samples to the U.S. Dr. Kimble acknowledged receipt of the samples in February, 1987, and said there would be no difficulty in completing the required characterizations byAugust, 1987. We have not yet had any further word from Dr. Kimble although, following instructions of Dr. Hari Eswaran, of SMSS, he sent us characterizations of some 25 other soils, from Panama and Nicaragua, which will be of great use in determining the occurrence of mineralogical characterics identified as important in the project. There is a very good possibility that Dr. Ray Bryant of Cornell University will be available as a consultant to the project from January to June, 1987. He will work on correlating the mineralogical information with other soil characteristics. This information will be of great use not only to the project but also to SMSS.

b. Correlation of P retention with other soil characteristics.

Working with some 37 soils which are being characterized by the project, the chemist from the University of Costa Rica, who is one of the participants in the project, carried out ten different determinations of properties which were then correlated with P retention as determined by isotherms and the New Zealand P retention determination. These results are presented in Tables 3 and 4 for all thirty seven soils and for the twenty soils classified as Andepts respectively. Soil pH determined in NaF correlated best with P retention by both methods for both groups of soils although use of this measurement in non -Andepts has been criticized (Kimble,Holzhey, and Holmgren, 1984). Aluminum extracted by acid oxalate, which has been considered a better measure of amorphous aluminum correlated better with New Zealand P retention than with isotherm-determined P retention. Strangely, the correlation with P retention by isotherms improved somewhat while that with New Zealand P retention decreased somewhat when only Andepts were considered. A reverse trend was shown for citrate-dithionate Aluminum which gave higher correlation in andepts with New Zealand P and lower correlations in andepts with isotherm P. A similar trend was shown for aluminum extracted in 4 N KOH, which is supposed to characterize andic properties better than NaF (Kimble et al.,1984) although it did not correlate well with P retention by the isotherms for the soils described as Andepts. Further analyses of this data will be carried out using multiple regression techniques. It would seem that the pH in NaF and Al determined in acid oxalate are the best predictive measures of P retention. The two determinations were more highly

TABLE 3. CORRELATIONS FOR ALL SOILS

	% M.O	pH NaF	Al Oxalato	Al citrato-dithionito	Al Pyrofosfato	Al KOH	Fe Oxalato	Fe citrato-dithionito	Fe Pyrofosfato	Reider Intercambio
% New Zealand P-retention	0.6165**	0.8563**	0.8492**	0.6851**	0.3427	0.6306**	0.5902**	−0.811**	−0.3286	−0.6859**
% M.O	—	0.7233**	0.5488**	0.6660**	0.4279*	0.5364**	0.5329**	−0.7533**	−0.1041	−0.6303**
pH NaF	—	—	0.8825**	0.8030**	0.5109**	0.7630**	0.6455**	0.8520**	−0.1906	−0.6743**
Al Oxalato	—	—	—	0.6856**	0.3317	0.7519**	0.6916**	−0.8016**	−0.3217	−0.6319**
Al Citrato-dithionito	—	—	—	—	0.7110**	0.8882**	0.4839**	−0.6772**	0.1421	−0.6461**
Al Pyrofosfato	—	—	—	—	—	0.6406**	−0.3055	0.2578	0.3258**	−0.4722**
Al KOH	—	—	—	—	—	—	0.4970**	0.5620**	0.0541	−0.7041**
Fe Oxalato	—	—	—	—	—	—	—	0.5337**	−0.1939	−0.5660**
Fe Citrato-dithionito	—	—	—	—	—	—	—	—	0.2578	0.6747**
Fe Pyrofosfato	—	—	—	—	—	—	—	—	—	0.0453
% P retention isotherms	0.4383*	0.7462**	0.5370**	0.5890**	0.4098*	0.5574**	0.5793**	0.4471*	0.094	−0.3587*

TABLE 4 CORRELATIONS FOR SOILS CLASSIFIED AS ANDEPTS

	% M.O	pH NaF	Aluminio Oxalato	Aluminio citrato-dithionito	Aluminio Pyrofosfato	Aluminio KOH	Fe Oxalato	Fe citrato-dithionito	Fe Pyrofosfato	Acidez Intercambiable
% P-retenido Nueva Zelanda	0,4471*	0,8901**	0,8155**	0,7829**	ns	0,7062**	0,5396*	−0,7933**	0,071	−0,7439**
% M.O	—	0,6003**	0,2853	0,5974**	0,3247	0,3053	0,2727	−0,6429**	0,1121	−0,4815*
pH NaF	—	—	0.8024**	0.9134**	0.5755**	0.7419**	0.4220	0.8410**	0.0564	0.6114**
Al Oxalato	—	—	—	0.7180**	0.3246	0.8051**	0.5823**	−0.6450**	−0.1612	−0.5737**
Al citrato-dithionito	—	—	—	—	0.6659**	0.8140**	0.2408	−0.7251**	0.2133	0.5549*
Al Pyrofosfato	—	—	—	—	—	0.5226**	0.0675	−0.3895	0.6299**	0.4361
Al KOH	—	—	—	—	—	—	0.2372	−0.5100*	0.0899	−0.6256**
Fe Oxalato	—	—	—	—	—	—	—	−0.2797	0.2692	ns
Fe citrato-dithionito	—	—	—	—	—	—	—	—	0.8635	0.6577**
Fe Pyrofosfato	—	—	—	—	—	—	—	—	—	0.0467
% P-retenido from isotherms	0.[illegible]	0.[illegible]57**	0.[illegible]24**	0.4876*	0.2379	0.3343	0.5737**	−0.5118*	−0.1618	−0.3555

correlated (r = 0.86) in all 37 soils than in just the Andepts (r = 0.80).

E. M.S. Thesis of Alexis Samudio

The other student who receives a scholarship from this project has begun his thesis work using a soil from the Caizan region of Panama, which is the major bean-growing area of that country. The soil has andic properties, relatively, low-levels of exchangeable aluminum and moderate levels of P retention. Ing. Samudio , who is of Panamanian nationality, will determine external P requirements of four of the most important Panamanian bean varieties. He will precede this work with greenhouse studies to determine response of these varieties to different lime and phosphorus levels as well as foliar and seed imbibed P. Soil was brought from Panama in April, 1987. Greenhouse work will begin in July. Field experiments will begin in October, 1987, which corresponds to the planting date in that region of Panama. Preliminary test have shown the soil to be low in zinc. Effect of zinc and incorporation of lime on P response of beans will be determined under field conditions.

F. Other field experiments.

Field experiments similar to the ones carried out in Turrialba and planned for Panama are scheduled to be planted beginning in September, 1987,in the following sites: San Isidro, San Vito, Fraijanes, Rio Frio, Puriscal, San Carlos. Experimental areas belonging to the University of Costa Rica and the Costa Rican Ministry of Agriculture are available at most of these sites.. Planting dates for beans vary somewhat, from September

to December, over these sites.

II. Changes in Research Plans.

As noted above, progress was very much as expected during this period so that no changes in research plans should be necessary. Field experimentation should begin on schedule in September. While there might be some delay in the receipt of the mineralogical analyses from the laboratory in Lincoln, this should not result in any change in programmed activities.

The very good possibility that Dr. Ray Bryant of Cornell University will be able spend his sabatical at CATIE, partially financed by the project should help in the final write-up of the research results. Hopefully, he will be able to integrate the existing information on soils in the region with the findings of the project. The receipt of more soil analyses from SMSS will somewhat enhace the scope of the project because there is apparently more information available than was originally thought.

The arrival of the project vehicle has been a great help in carrying out diverse activities. However, there have been some unanticipated expenses associated with insuring the vehicle and obtaining another set of keys when the originals disappeared from the vehicle while it was parked in the CATIE garage.

The laboratory equipment ordered by the project has arrived in Costa Rica and should be released from customs by the end of August, 1987, one year after it was ordered.

A more serious problem, mentioned in the previous report, is the increase in the cost of maintaining a student at

CATIE. The money budgeted for student scholarships will not be sufficient to support Ing. Samudio until the termination of his thesis research. More funds are being sought from PSTC for this purpose but efforts so far have not met with any response.

III. BENCHMARK DATES

July, 1987	Wilbert Campos takes final thesis exam
	Alexis Samudio begins greenhouse experiment
August, 1987	Mineralogical results received from SCS
	Alexis Samudio submits thesis proposal
September, 1987	Greenhouse study terminated
	Alexis Samudio takes admission to candidacy examination
	Field experiments planted in Pursical and San Isidro
October, 1987	Field Experiments planted in Panama and San Vito.
November, 1987	Field experiments planted in Rio Frio and Fraijanes
	Fourth Interim report and workplan for 1988 submitted to ROCAP
December, 1987	Field Experiments planted in Turrialba and San Carlos
	Experiments in Puriscal and San Isidro harvested
January, 1988	Experiments in Panama and San Vito harvested.

Arrival of Dr, Ray Bryant

March, 1988 All field experiments harvested

April, 1988 Analysis of results for final report begins.

IV. Literature Cited

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