PN-ABB-094

AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C. 20523

DATE: 9/30/88

MEMORANDUM

TO: AID/PPC/CDIE/DI, room 209 SA-18

FROM: AID/SCI, Victoria Ose VO

SUBJECT: Transmittal of AID/SCI Progress Report(s)

Attached for permanent retention/proper disposition is the following:

AID/SCI Progress Report No. 5.249
4th interim. PR

Attachment

PPC/CDIE

Program in Production and
Sustained Agricultural
Development
CATIE
Turrialba,
Costa Rica
June 15, 1988

Dr. John Malcolm
S & T Agr
406 B; SA-18
Washington, DC 20523

Dear John:

I am enclosing a copy of the fourth interim project report for Project AID-SCI 936-5442. We have been getting rather good results both in finding soil characteristics that relate to P retention and in relating P retention to the soil taxonomy. We are finding more retention in the great groups with higher organic matter such as the Humitropepts and Humults than in the corresponding groups with less organic matter. This would imply, as we have suspected, an important role for the organic matter in P retention although it is not yet clear how much of this is due to the aluminum bound in the organic matter. Dr. Bornemisza of the University of Costa Rica has been extracting aluminum with Pyrophosphate which is supposed to extract the organically bound aluminum. It is quite high in some soils of the area.

As you are probably aware, we have received an additional $13,000 for the student thesis and the extra field work which I asked you about last year. Thank you for whatever you did to help this go through. Although by our calculations, the $13,000 should have brought the project total to $147,000, AID calculates that $159,000 is authorized for the project. According to the CATIE accountants, we have received $157,000 from AID. I wrote to Dr. Asher, asking to extend the project for another year at a cost of $30,000. Otherwise, we will have to stop all work on P retention here. With the $30,000 , we can measure residual effects in the experiments done in Costa Rica and Panama last year and see how well our correlations hold up when applied to soils of another country, perhaps Guatemala or Honduras, which has a similar mix of volcanic and non-volcanic soils. If we really have $12,000 more than I thought , we would only need an additional $18,000 to carry out these activities in 1989.

As you might have heard, I had accepted a position with an AID supported IITA project in the Cameroun. I was there in February and March. When I was there, I realized how

much more expensive it was to live there than in Costa Rica so I asked IITA for an additional $5000 per year salary. (I was supposed to take up the position in August when my contract with CATIE terminated). In response to my request, they withdrew their offer of employment-- so it looks like I will be in Central America a little longer. Although most of the Cameroun has considerably older soils than Costa Rica, with lower levels of organic matter, there are some volcanic soils and P retention is considered a major problem. so, I was hoping to use some of the techniques we developed to work on P retention there. As this project has considerable funding, they could probably subcontract for doing the P retention work.

I guess Ray Bryant of Cornell will present the paper at the ASA meetings in Anaheim. He seems to have enjoyed spending his sabbatical here. He helped us with the classification work related to the project and also helped organize the soil classification and soil geography courses in the graduate program. We would hope to be able to continue this type of collaboration in the future.

Thank you again for your assistance. Any suggestions you might have about getting funding to continue the P retention work would be sincerely appreciated. I have teaching obligations here in December and family obligations require that I be in the states in January so I doubt I will come to Anaheim unless I can find funding. I generally make it a practice to come to the ASA meetings every third year, which means I should be there in 1989 wherever they are.

Very truly yours,

Donald L. Kass
Specialist in Soil
Management and Physics
Higher Education Project

INTERIM PROGRESS REPORT No 4.

July 1, 1987- April 1, 1988

Project AID-SCI 936-5442

5.249

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

I. RESEARCH PROGRESS

Progress was satisfactory in this period. All of the field experiments were completed, including the experiment in Panama which will form the basis of the thesis research of the student receiving a scholarship from this project. Dr. Ray Bryant of Cornell University, who has been hired as a consultant to the project, arrived in Costa Rica to spend a six month sabbatical at CATIE. He began organizing all of the extant chemical and mineralogical information on soils available in the SMSS database and those obtained by this project. He will also revise the classification of these soils. Further analyses were also made of the chemical data obtained by the University of Costa Rica on some 30 Costa Rican and Panamanian soils. There was further evidence that aluminum bound in the organic fraction of the soils as well as free iron oxides, possibly occurring as coatings on the clay surfaces, rather than allophane , was responsible for much of the P retention in these soils. A manuscript is being prepared from these findings.

A. Field Experiments

The agronomist and soil classification specialist of the University of Costa Rica harvested three experiments in February

and March of 1988. Principal results are shown in Table 1. The Talamanca variety performed best in all locations and produced maximum yields with relatively low additions of P. Generally, higher levels of phosphorus were required to produce maximum yields at the Rio Frio site than at the other two sites although the other two soils showed equivalent or higher indices of P retention. Lime was applied at rates calculated to bring the aluminum saturation to 35% and 0 respectively. Thus rates were much lower at the Rio Frio site than at Guarumal while no lime was applied at Coto Brus where there was no exchangeable aluminum. At the Guarumal site, liming affected the amount but not the form of the P response.

Maximum yield was obtained between 100 and 200 kg P ha^{-1} with or without liming. However, in Rio Frio, liming increased both the amount and form of the P response. Without lime, maximum yield was 319 kg ha-1 obtained by applying 200 kg ha^{-1} of P while when 0.8 T ha^{-1} of lime was applied, maximum yield of 527 kg ha^{-1} was obtained with 300 kg ha^{-1} of P. These results are best explained by the fact that in the Guarumal soil, all of the potentially reactive aluminum is exchangeable (and hence readily extracted with KCl) while in the Rio Frio soil, there are forms of aluminum bound in the organic matter and in the amorphous material . Thus, the KCl extracted aluminum is a poor measure of the active aluminum. These differences are better explained by considering some of the chemical characteristics of these soils shown in Table 2.

Table 1. Analyses of Variance for experiments carried out in three sites in Costa Rica

Source of Variation	SITE: GUARUMAL DF	GUARUMAL MS	GUARUMAL Signif. F	COTO BRUS DF	COTO BRUS MS	COTO BRUS Signif F	RIO FRIO DF	RIO FRIO MS	RIO FRIO Signif F
Blocks	2	241582	0.32	2	56291	0.01	2	23963	0.39
Bean Var.	1	491360	0.18	2	525125	0.06			
Resid	2	115530		4	83666				
Lime	2	652334	0.00				2	80459	0.11
Lime X Var	2	104112	0.13						
Resid	8	39691							
Levels P	4	1872848	0.00	4	177861	0.14	4	88106	0.004
P X Var.	4	80960	0.40	8	217954	0.05			
P X Lime	8	57447	1.00				8	27678	0.171
Var X PXLime	8	62071	1.00						
Resid	48	77835		24	92579		24	17062	

Main effects(kg/ha):

BEAN VARIETIES:

Talamanca	924	917	353
Huasteco	776	637	
Huetar	562		

LIMING:

0-	680	0	- 276
3 T/ha	943	0.8 T/ha	- 423
6 T/ha	927	1.3 T/ha	- 359

P levels

0	600	600	186
100	986	1300	337
200	947	675	407
300	940	1175	407
400	776	833	425

TABLE 1, cont.

Significant Interactions:

P X Variety:

	Guarumal	Coto Brus	Rio Frío
Talamanca:			
0	611	600	
100	1144	1375	
200	947	675	
300	1033	1175	
400	883	833	
Huasteco:			
0	589	808	
100	828	1000	
200	947	[illegible]75	
300	847	500	
400	669	600	
Huetar:			
0		341	
100		433	
200		741	
300		558	
400		733	

P X Liming:

0 Lime X:

0 P	404
100P	816
200 P	712
300 P	845
400 P	621

3T ha^{-1} lime X:

0 P	675
100 P	1191
200 P	1095
300 P	1017
400 P	738

6T ha^{-1} lime X:

0 P	720
100 P	950
200 P	1033
300 P	958
400 P	971

0 Lime X :

0 P	271
100 P	221
200 P	319
300 P	213
400 P	360

0.8 T ha^{-1} lime X:

0 P	145
100 P	486
200 P	495
300 P	527
400 P	458

1.3 T ha^{-1} lime X:

0 P	143
100 P	302
200 P	409
300 P	481
400 P	459

Table 2: Some chemical characteristics of soils used for field experiments

Soil	Horizon	Aluminum extracted by				Iron extracted by			P retention:	
		1. KCl	2. Acid Oxalate	3. Pyrophosphate	4 Citrate dithionite	4-3	5. Citrate dithionite	6. Pyrophosphate	5-6	NZ	Isotherm (a)
		(cmol kg^{-1})	%								
Guarumal (Paleustult)											
	Ah	5.0	0.34	0.22	0.80	0.58	6.12	0.38	5.74	55.6	850
	Bt_1	9.1	0.16	0.20	0.84	0.64	6.42	0.08	6.34	52.7	1150
Rio Frio (Typic Tropudult)											
	Ah	1.0	0.84	1.12	1.88	0.76	5.90	0.55	5.35	57.8	1060
Coto Brus (Typic Hydrandept)											
	Ah		3.00	1.88	2.02	0.14	2.14	1.40	0.74	93.6	2900
	AB		3.44	1.20	1.53	0.33	4.45	0.47	3.98	96.6	2400

a) P addition (ug/g) required to obtain 0.2 ppm P in soil solution

It can be seen from Table 2 that the Guarumal soil had low levels of oxalate and citrate-dithionite extractable aluminum but high levels of dithionite citrate extractable iron. The Rio Frio soil had somewhat higher levels of oxalate extractable aluminum and quite high levels of pyrophosphate extractable aluminum. the Coto Brus soil represents a more "classic" volcanic soil with high levels of oxalate extractable aluminum, low levels of KCl extractable aluminum and dithionite citrate extractable iron. According to the Japanese literature (Wada and Gujigake, 1979), the aluminum and iron extracted by pyrophosphate represesent the fractions bound to humus while the aluminum and iron extracted by oxalate represent the aluminum and iron incorporated into allophane and imogolite. The difference between the aluminum extracted by dithionite and pyrophosphate (4-3 en Table 2) is aluminum in allophane-like constituents while the difference between the iron extracted by dithionite and that extracted pyrophosphate repesents iron in iron oxides (Wada, 1977).

Applying these criteria to the soils in question, it would seem that most of the P retention of the Guarumal soil is due to exchangeable iron and aluminum. The Rio Frio soil has lower levels of exchangeable aluminum and free iron but higher levels of oxalate extractable and pyrophosphate extractable aluminum , indicating the presence of some amorphous material and a considerable amount of aluminum bound in the organic fraction. The P retention levels of the two soils as measured by the New Zealand P retention test and the amount of P adddition required to have 0.2 ppm P in the soil solution (Fox and Kamprath, 1970), are similar , being only slightly higher in the Rio Frio soil although there are probably several more mechanisms of P retention operating in that soil than in the Guarumal soil. The Coto Brus soil has a much higher level of P retention, most of which is

probably due to the presence of allophane although the organically bound aluminum probably plays a role. This is to some degree illustrated by the difference in P retention of the two horizons. The A_h horizon has a higher level of P retention by the isotherm method and a lower level by the New Zealand P retention test than the AB horizon. The A_h horizon has a higher level of pyrophosphate bound aluminum but a lower level of oxalate extractable aluminum than the AB horizon. One could explain these differences by saying that the New Zealand P retention test favors has some bias toward the aluminum bound in the allophane since it too includes an extraction with oxalate. The higher P retention measured by the isotherm probably includes more of the organically bound aluminum measured by the pyrophosphate extraction.

The difference in mechanisms of P retention can perhaps be used to explain the difference in the effect of liming in the Guarumal and Rio Frio soil. In the Guarumal soil, liming increased yields but did not affect the nature of the P response. Maximum yield was achieved with 100 kg ha^{-1} P both in the presence or absence of liming. This would be explained by the high levels of KCl extractable aluminum and the low levels of oxalate and pyrophosphate extractable aluminum. Liming in this soil should merely reduce the levels of exchangeable aluminum. In the Rio Frio soil, liming might actually increase the capacity for P retention because aluminum held in the organic complex (as indicated by the high level of Pyrophosphate extractable aluminum) and aluminum in the form of allophane (as indicated by the higher level of oxalate extractable aluminum) might actually be released by liming. Thus, 300 kg ha^{-1} P was required to give maximum yields when the soil was limed and only 200 kg ha^{-1} when the soil was not limed although, of course, yields were higher when lime was applied.

A significant P X variety interaction was observed at the Coto Brus site. The Huetar variety required higher levels of P to produce maximum yields than the Talamanca or Huasteco varieties. However, the overall response to P was not significant at this site although it was at the Guarumal and Rio Frio sites. Further analyses of these experiments will be made when more data, such as foliar P content and P levels in the soil following treatment are available.

B. Thesis experiment in San Andres, Panama.

This experiment was planted in November, 1987, and harvested in March, 1988. The design was similar to the Costa Rican experiments but treatments involving no-tillage and zinc were also included because farmers in the region do not normally plow previous to bean planting and soil analyses showed unusually low levels of zinc by the Olsen extraction. The experiment was a split-split plot with three bean varieties in the main plots, five tillage and fertilizer treatments (control, zinc, tillage, tillage plus lime, tillage plus lime and zinc)in the subplots, and five phosphorus levels in the subsubplots. The P levels were 0, 100, 200, 400, and 600 kg ha^{-1} in the tillage treatments and 0. 50, 100, 150, and 200 kg ha^{-1} in the no-tillage treatments where the P was banded. There were two replications. Only the subsubplots with the same levels of P (0, 100, and 200 kg ha^{-1}) were used for the analysis of variance shown in Table 3.

It can be seen that there was only a significant response to P and for the interaction treatments X varieties. The Rosado variety was the only cultivar to respond to liming.

Table 3: Analysis of variance of experiment in San Andres, Panama

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	F value
Blocks	1	3601200	3601200	9.23
Cultivars	2	154285	771542	0.19
Error(a)	2	780195	390097	
Treatments	4	554352	138588	1.26
Cultivars X Treatments	8	2797989	349748	3.20
Tillage X Rosado vs 105 R & Renacimiento	1	699875	699875	6.40
Zn without tillage X Rosado vs 105 R and Renacimiento	1	18528	18528	0.17
Liming with tillage X Rosado vs 105 R and Renaciemiento	1	1539591	1539591	14.09
Zinc with liming X Rosado vs 105 R and Renaciemiento	1	129168	129168	1.18
Tillage X 105 R vs Renaciemiento	1	4319	4319	0.04
Zn without tillage X 105 R vs Renacimiento	1	163185	163185	1.49
Liming with tillage X 105 R vs Renacimiento	1	286020	286020	2.61
Zinc with liming X 105 R vs Renacimiento	1	384	384	0.003
Error (b)	12	1311520	109283	
P	2	6970809	3485404	66.73
P X Cultivars	4	1955518	488879	9.36
P X Treatments	8	489209	61151	1.17
P x Cults. X Treatments	16	1494186	93386	1.78
Error (c)	30	1566840	52228	

C.V.: Error(a) = 28.16% ; Error(b) = 14.90 %; Error (c) = 10.3 %

Cultivar X P interaction:

P level (kg/ha)	Cultivar: Renacimiento	105-R	Rosado
	----------kg/ ha----------		
0	1834	1829	1833
100	2292	2364	2392
200	2455	2366	2607

It would appear from the above table that the Rosado and Renacimiento cultivars responded to higher applications of P thatn did the 105-R cultivar although all cultivars responded to 100 kg ha^{-1} of P . Further analyses of the response curves in those treatments where higher levels of P were applied will be necessary to determine the exact nature of the cultivar X p interaction. The student is presently terminating foliar analyses and determining P adsorption isotherms on the soil following treatment with lime and P. It is expected that he finish his thesis by August , 1988.

C. Soil Data Base

Since his arrival in January, 1988, Dr. Ray Bryant of Cornell University has been working on a database which will incorporate the information obtained by the project with the existing soils information available through previous SMSS activities in the area. Data have been obtained by SMSS on some 83 soils from Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama. R base system V is being used as the data

management system for entering, searching, and outputting data. For about half of these soils, some data related to P retention (New Zealand P retention, oxalate extractable aluminum, citrate-dithionite extractable iron and aluminum) was available from SMSS.

At the end of the project, the database should contain a total of some 110 soils with information relating to P retention on some 70 soils. The planned approach for statistical analyses is to correlate P retention data with Fe/Al characteristics of these soils, then use the correlations to classify soils represented in the Central American database with respect to Phosphorus retention characteristics and observe the relationships to soil taxonomic classification. This activity should be terminated prior to Dr. Bryant's departure in July, 1988.

D. Further analysis of data reported in previous progress report

Foliar analyses were run on the beans in the experiments carried out in Turrialba in 1987 and reported in the previous progress report. Foliar P levels were found to be unusually high in all treatments, being above 0.5% in all treatments even without P applications. Foliar P levels did increase with increasing soil P applications reaching a maximum of about 0.64 % when between 300 and 450 kg ha^{-1} of P was applied. As maximum bean yields were generally obtained with this level of P application, determination of external and internal P requirements of the beans would result in the same level of P application being recommended.

II. Changes in Research Plans

No real changes in research plans were necessary during this period though some adjustments to changing situations was required. Fortunately, the political crisis in Panama did not affect the harvest of the field experiment in that country. Had the harvest been a few weeks later, there might have been more effect. The student was also able to terminate most of the foliar and soil analyses at the Faculty of Agricultural Sciences in Chiriqui before returning to Costa Rica in April, 1988, where he is presently terminating data analyses. Unfortunately, some $2500 of his scholarship funds remain on deposit in a Panamanian bank and cannot be withdrawn at present. At present, these funds represent CATIE rather than AID funds since CATIE advanced the scholarship funds to the student in expectation of the $13,000 supplement promised for May, 1988.

In February, 1988, the principal scientist was offered a position with the AID sponsored IITA-NCRE project in Cameroun. Partially due to the fact that further funding for research activities related to P retention would no longer be possible at CATIE due to the rejection of a proposal sent to AID-SCI in August, 1987, the principal scientist accepted the offer. He felt that there would be more opportunity to continue research related to P retention in Cameroun where P retention has been identified as a major production restraint. The contract of the principal investigator with CATIE terminates in August, 1988. He hopes to be able to submit the final report prior to leaving for Cameroun.

It has been pointed out by the chemist of the University of Costa Rica that much more information could be obtained by the

project if the field experiments harvested in 1988 could be maintained for another year so that residual effects could be measured. Long-term effects of liming and P fertilization on P retention characteristics of several soils could also be determined. The Panamanian research and extension agency, IDIAP, which collaborated most positively with the experiment in San Andres, Panama, has also expressed interest in continuing the research activities. Unfortunately, there are no project funds available for such continuation. If the proposal on the role of organic matter in P retention and avialability in Central American soils had been accepted by AID-SCI, there would have been such funding. Continuation of these experiments would only require a small amount of funding, perhaps $10,000 per year. Thus considerably more information could be obtained for a cost considerably less than funding a new project.

Although AID-SCI approved our request for an additional $13,000 to defray increased scholarship costs and the maintenance of the laboratory assistant for another five months, the funding has not yet been received by ROCAP. Fortunately, CATIE was able to advance the scholarship money in the expectation of AID-SCI's eventual payment, promised for May or June. It was also necessary, however, to use the funds originally earmarked for the writing of the final report to pay the laboratory assistant. It is hoped that the funds will arrive from AID-SCI soon enough to not cause any further problems.

III. BENCHMARK DATES

April ,1988	Termination of entry of existing data in database
April-June, 1988	Termination of laboratory work
May, 1988	Analysis of data in database
May, 1988	Final profile descriptions terminated
July, 1988	Termination of consultancy by Dr. Ray Bryant
August, 1988	Alexis Samudio, Panamanian M.S. student financed by project, completes M.S. thesis
September, 1988	Final project report submitted

IV. Literature cited

Fox, R.L. and E.J. Kamprath. 1970 . Phosphate sorption isotherms for evaluating the P requirements of soils. Soil Sci Soc. of Amer. Proc. 34: 902-907.

Wada, K. 1977. Allophane and Imogolite. p. 603-638 in J.B. Dixon and S.B. Weed, eds. Minerals in soil environments. ASA. Madison.

Wada, K. and N. Gunjigake. 1979. Active aluminum and iron and phosphate adsorption in ando soils. Soil Sci. 128: 331-336.