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IFDC/CIAT PHOSPHORUS PROJECT

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With basic funding from International Development Research Centre (IDRC), Canada, The International Fertilizer Development Center (IFDC) and the Centro Internacional de Agricultura Tropical (CIAT), since 1977 have carried out a cooperative project to identify more effective sources of phosphate fertilizer to use on acid, infertile soils of tropical Latin America using, where possible, phosphate sources indigenous to the region.

In general, IFDC is dedicated to the development of appropriate fertilizer technology and related know-how needed to sustain and increase food production in the developing countries. IFDC's phosphate research program is aimed at helping developing countries to look for ways in which they may (a) develop their own phosphate deposits and (b) reduce the costs of producing phosphate fertilizers by looking at less energy-and capital-intensive technology.

The IFDC/CIAT project deals with one of the activities of the IFDC phosphate program: the development of ways to utilize the finely ground phosphate rock (PR) directly as a fertilizer or through some chemical modification to enhance its suitability as a phosphate source for crops. The resultant products from laboratory, pilot plants and greenhouse tests have been evaluated at various agricultural research centers in Colombia, Ecuador, Peru, Costa Rica and Venezuela. By so doing, the phosphorus project was able to identify the chemical and physical properties that will lead to the effective use of the end products in developing countries.

During 1982 IFDC prepared experimental products from ore types from Huila and Pesca in Colombia, Fosbayovar in Perú, and Lobatera and Riecito in Venezuela, with emphasis on reducing the energy and raw material costs for production. Intermediates and products such as finely ground PR, granulated rock, partially acidulated and granulated rock were studied.

According to results obtained by the project, materials and/ or practices presently showing promise include (a) direct application of the more reactive types of finely ground rock, (b) partially acidulated PR (the quantity of acid used is less than that required for superphosphate), (c) extended superphosphate (a mixture of superphosphate and finely ground PR), and (d) a minigranulated form of the more reactive PR.

To implement promising research station results at the farm level, both social and economic factors were also considered during 1982. In this year activities continued toward interdisciplinary planning of on-farm research to identify the fertilizer technology components and management strategies appropriate to the circumstances of small farms in Colombia.

With the overall objective of identifying phosphorus fertilizer alternatives, based on low cost indigenous raw materials, with a high probability for availability, competitiveness and farmer acceptance, a new phase (IV) of the project was initiated in July, 1982.

This new phase titled "On-Farm Suitability of Indigenous Phosphate Products", consists of multidisciplinary research to be conducted in Colombia over a 2-year period.

The purpose of phase IV of the project is to utilize the information obtained from that research which was conducted under experimental station conditions to carry out a systematic evaluation of fertilizer materials and management which are (a) competitive with high cost conventional fertilizers on both an agronomic and economic basis, (b) possess characteristics which are both adoptable and culturally acceptable at the farm level, and (c) calibrated sufficiently with appropriate soil test methodology.

This type of transition from basic experimental station research prior to extention and demonstration activities is of critical importance for the following reasons:

1. While the relative agronomic effectiveness of several low-level technology products appear promising under controlled conditions, their performance under farm-level management constraints (i.e. support fertilization, weed and insect control, lack of irrigation, etc.) has not been validated.

2. The low-level technology products differ from conventional phosphorus fertilizers in terms of both initial and residual nutrient availability, cost, and nutrient content. The economic consequences of these differences has yet to be determined.

3. It has been identified that changes in handling and method of fertilizer placement are required for the low solubility indigenous

products as compared to conventional fertilizers due to differences in both chemical and physical properties. It is essential to determine if these changes are both adaptable to the physical and social constraints imposed by infrastructure and culturally acceptable to farmers.

4. To provide a reasonable assurance of success in future extension and demonstration activities related to changes in fertilizer source, callibration with soil test methodology under farm level conditions is still necessary to provide an initial guideline for rates of fertilizer application for a variety of crops.

To provide the information identified above, research is necessary with input from soil scientists, an economist, and a sociologist. While this type of integrated transition from basic research prior to a national level extension program is often bypassed and the composition of the research team is unique, it is felt that the contribution will be invaluable in assuring success in the subsequent transfer of technology appropriate itself will serve as a model to determine the potential benefit prior to future technology transfer efforts.

Colombia has been chosen as the target area within Latin America for the following reasons:

1. Presence of 4 indigenous deposits of phosphate ore
2. Abundance of basic experimental data on use of alternative P sources under Colombian conditions
3. Abundance of soils likely to be suitable for use of

alternative sources

4. Well developed research infrastructure to promote project efficiency.

The proposed research focuses on determination of the suitability of the use of finely ground and partially acidulated phosphate rock from Colombia as opposed to processed P fertilizer. Initial activities involved delineation of 4 pilot areas in which both the socio-economic and agronomic conditions are potentially suitable for the use of phosphate rock. While 4 deposits of phosphate ore are present in Colombia, a single source of phosphate rock will be selected for evaluation within each pilot area. A standard commercial P fertilizer is used for comparison in each pilot area. The expected pay-off from this phase of the project includes more efficient utilization of local phosphate resources and increased food production at the small-farm level and in the less developed frontier regions of Colombia. Results are expected to define conditions which permit the use of low cost phosphate fertilizers with low production technology requirements. At the same time conditions would be identified where utilization of these products is not appropriate in order to limit indiscriminate use and disappointing results. Definition of management requirements of alternative phosphorus fertilizers will also provide the basis for subsequent outreach and extension programs.

Research Activities

Phosphorus Project, Phase III. During the first 8 months of the year agronomic research activities concentrated in final testing for residual effects of triple superphosphate (TSP), finely ground PR, partially acidulated PR and TSP extended with PR, methods of application and varietal response of common beans to P sources and mixtures in a *Typic dystrandept* from Popayán, very high in P fixation, and in an *Orthoxic palehumult* from CIAT-Quilichao, using beans and cowpea as test crops.

Residual effects and methods of application. A very important factor which must be considered in the determination of the suitability of the P sources is the residual value. Unlike the mobile nutrients, P remains in the vicinity of application for long periods of time and remains available to provide a portion of the crop's requirements for a number of cropping periods. Previous experiments established in Las Guacas, Popayán, showed that the highly reactive PRs were equal or better than TSP in providing residually available P in each of the three subsequent semesters following the initial cropping period. The medium and low reactivity PRs tended to increase in effectiveness until they became equal or very close (82%) to residual TSP in the third crop. In order to determine (a) the relative effectiveness of Huila PR on an Andept with a higher P retention capacity than that of Las Guacas, (b) if mixtures of PR with varying proportions of TSP or partially acidulated PR would serve to supply the initial plant requirements for water-soluble P, and (c) to evaluate methods of application, experiments were established with beans in CIAT-Popayán station for the first time during 1981A. Results of the first harvest were discussed in the 1981 Annual Report. The second and third harvests with reapplications of the initial P rates (Figures 1, 2 and 3) still are showing that the relative agronomic effectiveness (RAE) of Huila PR, when broadcast and incorporated is less than 50% as effective as soluble P, except when low P rates are used. For the third crop of beans, Figure 2, an application of 44 kg P/ha as TSP produces almost equal yields as 176 kg P/ha applied as finely ground Huila PR. This agrees with the results discussed in the 1981 Annual Report, that a reduction in effectiveness of PRs is observed on Andepts which exhibit higher P retention and higher reactive Al than Ultisols and Oxisols.

For the first crop of beans (Annual Report 1981), the method of application greatly influences the effectiveness of the Huila PR (Figure 1). Band application resulted in yields with an RAE of 40% as effective as broadcast and incorporated. In the case of the first crop this reduction in yield potential from PRs may be very important for small farmers that apply fertilizers with a localized placement technique, but it could become unimportant if residual effect is considered (Figure 2), because the yield differences between broadcast and band PR applications practically

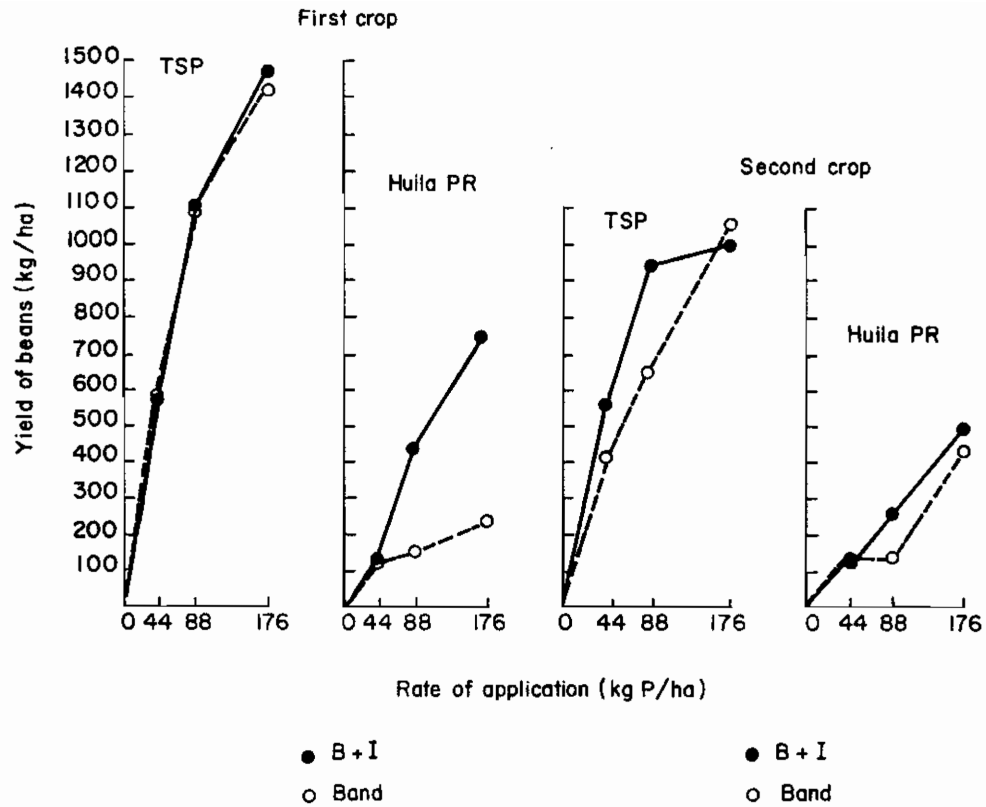

Figure 1. Residual effect of TSP and Huila PR on the production of beans on an Andosol from CIAT-Popayán. The P sources were broadcast and incorporated (B + I) or banded.

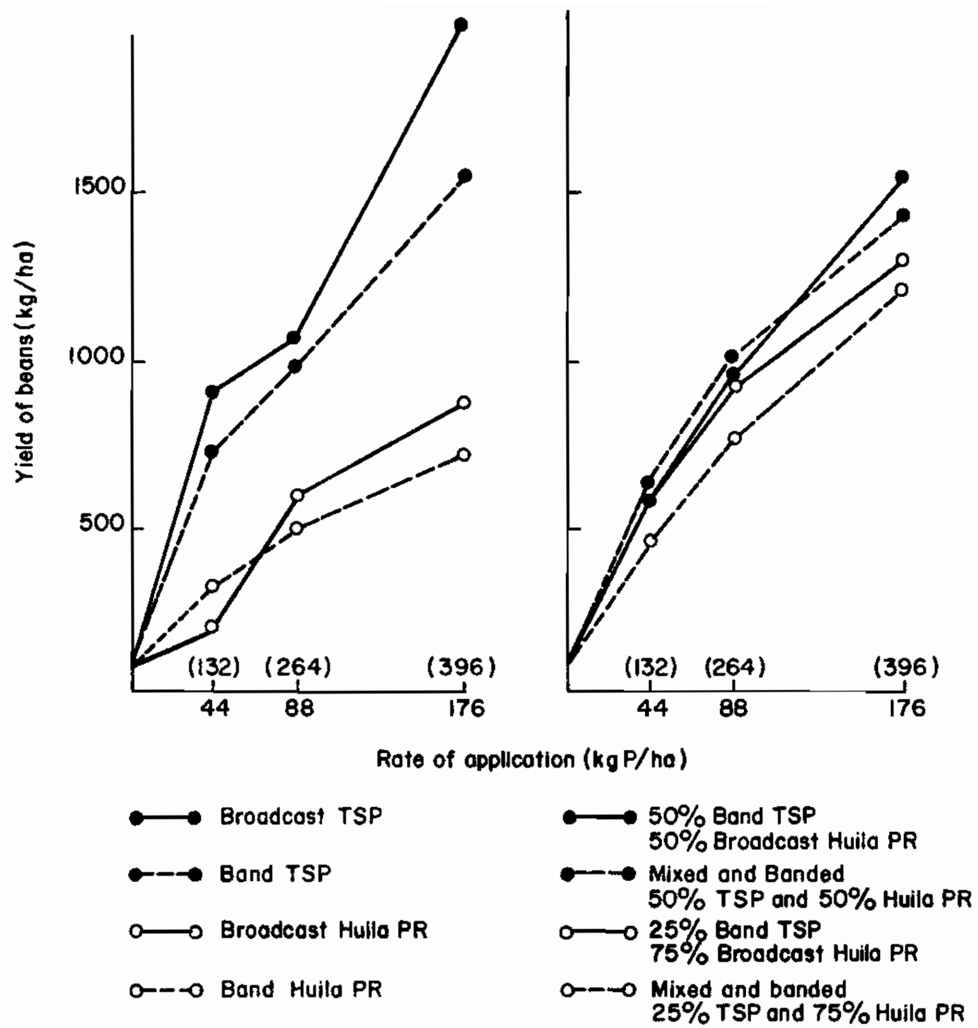

Figure 2. Response of beans (G 4000) as affected by source, rate, method of application and residual effect (CIAT-Popayan 1982 A). Numbers in parenthesis represent total P applied to the soil for 3 crops.

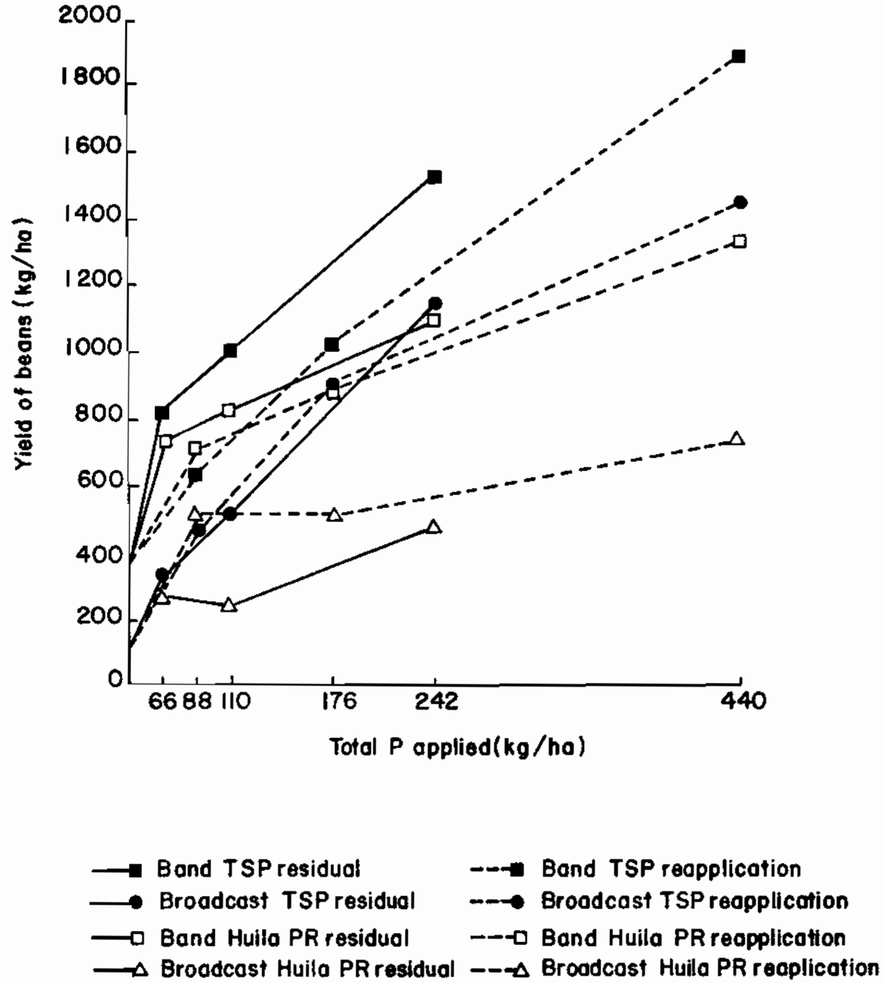

Figure 3. Response of beans (G 4000) as affected by source, rate, method of application and reapplication of 44 kg P/ha as banded TSP or broadcast Huila PR. Third crop 1982 A. All band applications + 44 kg P/ha as banded TSP; all broadcast applications + 44 kg P/ha as broadcast Huila PR.

disappear for the second and third crops. Possibly, the first and second application of banded PR was uniformly incorporated to the soil during soil preparation, and the residual effect of this later incorporated PR compensated for the yield reduction due to band application of PR for the third crop.

In the case of TSP, for the first crop, nearly identical response curves were observed regardless of the method of application (Annual Report 1981). For the second and third crops (Figures 1 and 2), yields were generally higher when TSP was broadcast and incorporated than when the water soluble fertilizer was band applied. This confirms that the potential advantage of reduced contact with the soil by using localized placement is not of great importance in these soils probably due to the fact that broadcast TSP increased the volume of soil from which P could be extracted. Once several P applications have been made, and the available P in the soil has increased, then band applications of TSP can be a better practice than broadcast applications (Figure 3).

Residual effect of management of mixtures of TSP and PRs. An experiment to evaluate the effectiveness of mixtures of TSP and Huila PR and the management of these mixtures was initiated during the first semester of 1981, using G 4000 beans as a test crop. Two more crops were planted in the same plots during 1981B and 1982A semesters. Reapplications of the initial P sources, rates and mixtures were performed for these two new crops. Results of the first experiment indicate that the response of the beans to added P was systematically reduced as the proportion of TSP in the mixture was reduced. In the case of the second and third harvests (Figure 2), TSP alone was generally better than the mixtures, but mixtures of 50% TSP banded and 50% Huila PR broadcast and incorporated produced almost equal yields to the 25% TSP - 75% Huila PR mixture. This was not the case when the TSP and the PR were mixed and band applied. These results confirm that after 3 crops the major portion of the applied P utilized by the plant was still provided by the water soluble P carrier. In general, yields of the third crop were higher than those of the first and second crops, indicating that the P fertility level of the soil is showing significant improvement due to the presence of both the TSP and the lower cost indigenous material.

Residual effect of crops and P sources. In order to study the influence of a crop and lime application on the effectiveness of two P sources, TSP and Huila PR, experiments were established during the first semester of 1980 using maize and cowpea on a Quilichao Ultisol. Only 1/2 t/ha of dolomitic lime was applied to the cowpea and 5 t/ha to the maize, 30 days before planting the first crop. After four continuous crops of cowpea and maize, a fifth crop of cowpea was planted in both experiments in order to see residual effects of crops and P sources. According to results of the previous four crops, cowpea responded strongly to P supplied as TSP or Huila PR, but for maize TSP was a better P source than Huila PR for the first crop. Results of the fifth crop of cowpea in both experiments are shown on Figure 4. Even for the check plot, cowpea yielded more when previous crops were cowpea. Apparently four consecutive crops of maize have depleted the available P in the soil probably helped by the liming effect of 5 t lime/ha. In general there is a good residual effect of both TSP and Huila PR but this is slightly better when cowpea was the previous crop. There is a good residual effect in both crop sequences to high P rates (88 kg P/ha). Apparently, cowpea can effectively use a nonsoluble P source like Huila PR.

Modified indigenous PRs and its residual effect. Partial acidulation of PR in varying proportions with either H_2SO_4 or H_3PO_4 increases initial plant-available P. For this reason, partially acidulated Pesca PR, 20 and 40%, with H_2SO_4, and cogranulated mixtures of Pesca PR with 18% and 9% TSP, have been tested. Table 1 shows the water and citrate soluble P of the different products. In an experiment conducted in CIAT-Popayán during the second semester of 1981 and the first semester of 1982, the effectiveness of partially acidulated Pesca PR and mixtures of TSP and Pesca PR and the residual effect was evaluated with G 4000 beans. It can be observed in Figure 5a that the partial acidulation of the PR to 40% produces similar yields to TSP at rates of 44, 88 and 176 kg P/ha. Cogranulation (18% of TSP) produces yields almost

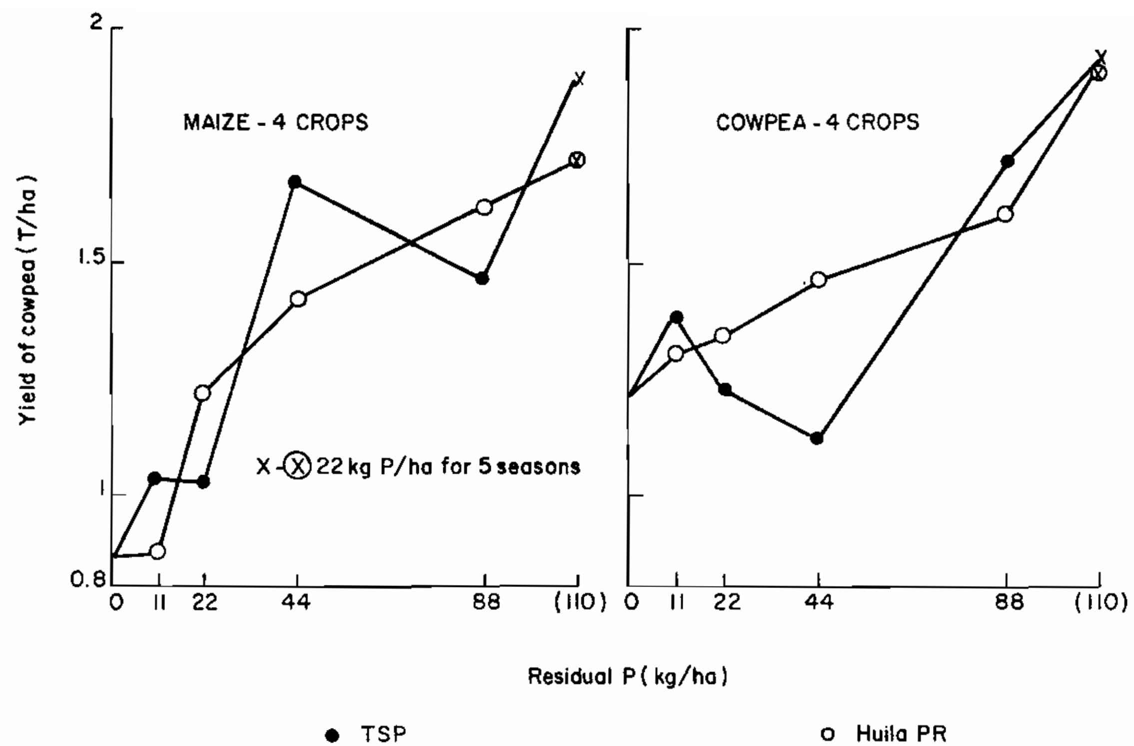

Figure 4. Residual effect of two P sources and four P rates on yield of cowpea grown on a Quilichao Ultisol planted after 4 consecutive crops of maize or cowpea. Number in parenthesis is the total P applied for 5 crops.

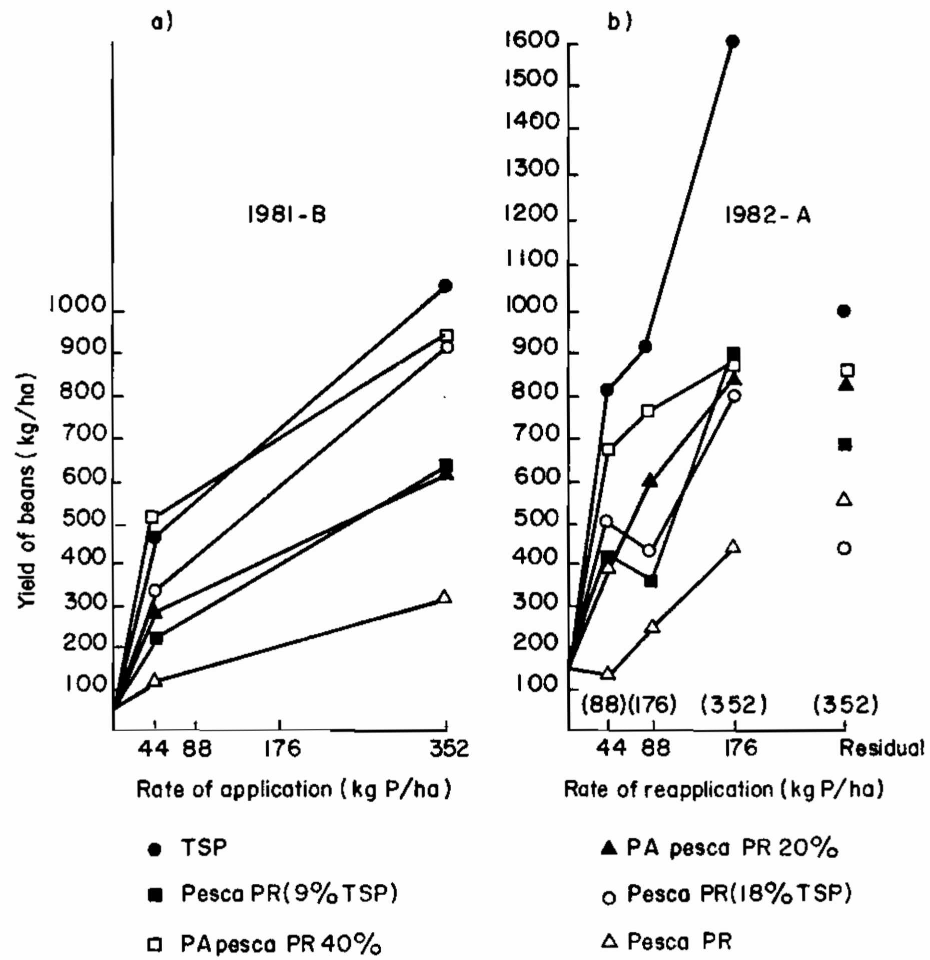

Figure 5. Effect of partial acidulation and cogranulation of TSP with Pesca PR on the production of beans on an Andept from CIAT-Popayan. Numbers in parenthesis represent total P applied for the two crops.

Table 1. Solubility of modified Pesca phosphate rock

Source	Modification	H_2O Sol. P, %	Citrate Sol. P %	H_2O + Citrate Sol. P, %
Pesca PR	Finely ground	0.0	2.9	2.9
	20% PA (H_2SO_4)	18.2	21.8	40.0
	40% PP (H_2SO_4)	57.1	19.4	76.5
	Cogran. 9% TSP	11.2	21.5	32.7
	Cogran.18% TSP	22.6	22.7	45.3

equal to partially acidulated Pesca PR (40%) at 352 kg P/ha rate. At all P rates, yields decreased as the water and citrate solubility of the P decreased, and similar yields were obtained with partially acidulated Pesca PR (20%) and cogranules of Pesca PR with 9% TSP. During the first semester of 1982, this experiment was repeated in the same plots with reapplication of the same P sources at rates of 44, 88 and 176 kg P/ha. Plots that had received 352 kg P/ha during the first crop were planted but no additional P was added in order to see the residual effect of the different P sources. Figure 5b shows the results of the second harvest. In this case, reapplication of soluble P sources resulted in better yields than those of low P solubility. When high P rates were reapplied (176 kg P/ha) there were no yield differences among the Pesca PR modified products. Apparently the yield increase was due to the soluble P present in each of the products tested, because the response of beans to residual P showed yield differences among the P sources producing higher yields for those with high soluble P like TSP and partially acidulated Pesca PR, 40 and 20%.

Figure 5b also shows a good residual effect of finely ground Pesca PR. Yield increase of residual 352 kg P/ha, applied as Pesca PR, was 120 kg of beans/ha, if 115 kg of beans/ha representing the increase of the check plot are subtracted from the yield obtained for this treatment. It is also interesting to observe that when Pesca PR or partially acidulated Pesca PR was used, one single application to the first crop or two applications of half of the same P rate to each crop produces equal yields for the second crop. A yield decrease was observed for the residual P treatment of 352 kg P/ha when TSP was used, showing the effect of the high P fixation capacity of the soil.

Residual effect of P sources influenced by new applications of P rates and sources. During the first semester of 1978 an experiment was established in CIAT-Quilichao to observe the response of a rice-peanut rotation to P rates and sources. The P sources used were TSP, Pesca, Huila, Sardinata PRs and mixtures, 50-50%, of TSP with these three PRs. Three crops of rice and two of peanuts were obtained from this experiment during 2 1/2 years. The last crop of rice in general was very poor, due mainly to very low available P in the soil. For this reason, in April 1982, new rates of P were added to the plots using TSP, Huila PR and two new PRs from recently discovered deposits in Colombia: Azufrada, Departamento of Santander and Tolima, Departamentos of Cundinamarca and Tolima. Figure 6 shows some of the results obtained when cowpea was used as the indicator crop. Results of this experiment indicate that (a) the residual effect was the same for all the P sources, independent of their solubility or initial agronomic effectiveness; (b) the residual effect increased with increasing initial P rates, independent of the P source; (c) in general the residual effect of the finely ground PRs was better than that of the mixtures of PR with TSP. This was more evident at low P rates;

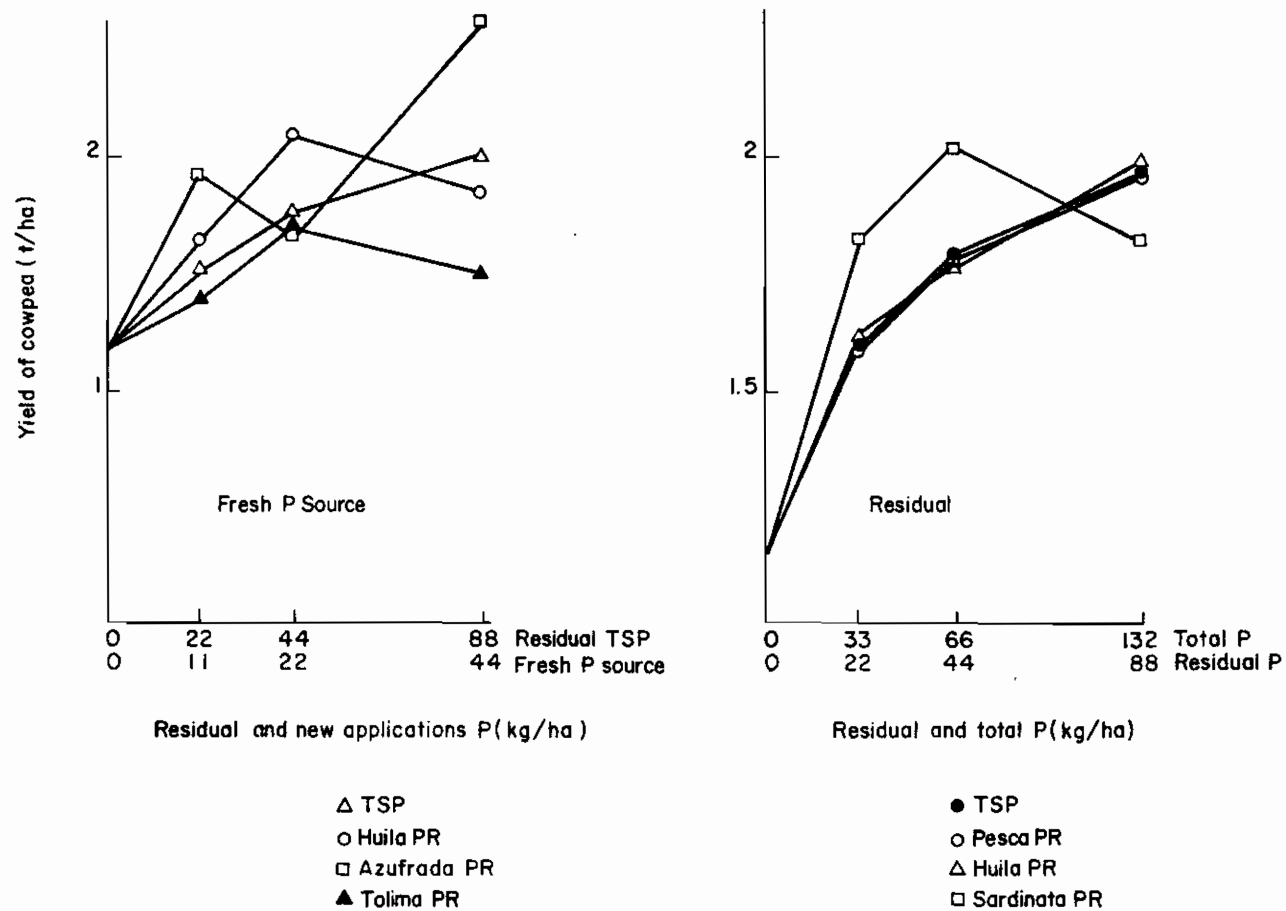

Figure 6. Residual effect of P sources influenced by new applications of TSP and Huila, Azufrada and Tolima PRs.

(d) if the initial application was from a soluble P source like TSP the response of cowpea to P reapplication was independent of the P source added; (e) if the initial application was from Pesca or Huila PRs the response was better with reapplication of TSP, Huila or Azugrada PRs. If a low P rate was applied initially, the best response to reapplication was with TSP; (f) in general, the response to residual Sardinata PR (low initial agronomic effectiveness) was better than the response to residual Pesca or Huila PRs.

Differential response of bean varieties to P sources and lime. In order to investigate (a) if differences exist among varieties in their relative efficiency in use of P from sources of low P solubility; (b) to determine the need for soluble P in a soil with high P fixation capacity, and (c) to investigate the soluble P/lime interaction, an experiment was established on a CIAT-Popayán Andept during the first semester of 1982. Although variation in the yield of beans among replications was relatively high it is interesting to analyze some of the results obtained. Figure 7 shows the response of the five bean varieties tested to P rates applied as TSP, Huila PR and a mixture of 50% P as TSP and 50% as Huila PR. The results obtained indicate that in general there was a differential response among the varieties to applied P. The best responses were obtained with Carioca, followed by A 248, G 4000 and A 358. The variety G 05059 presented the lowest response to P fertilization

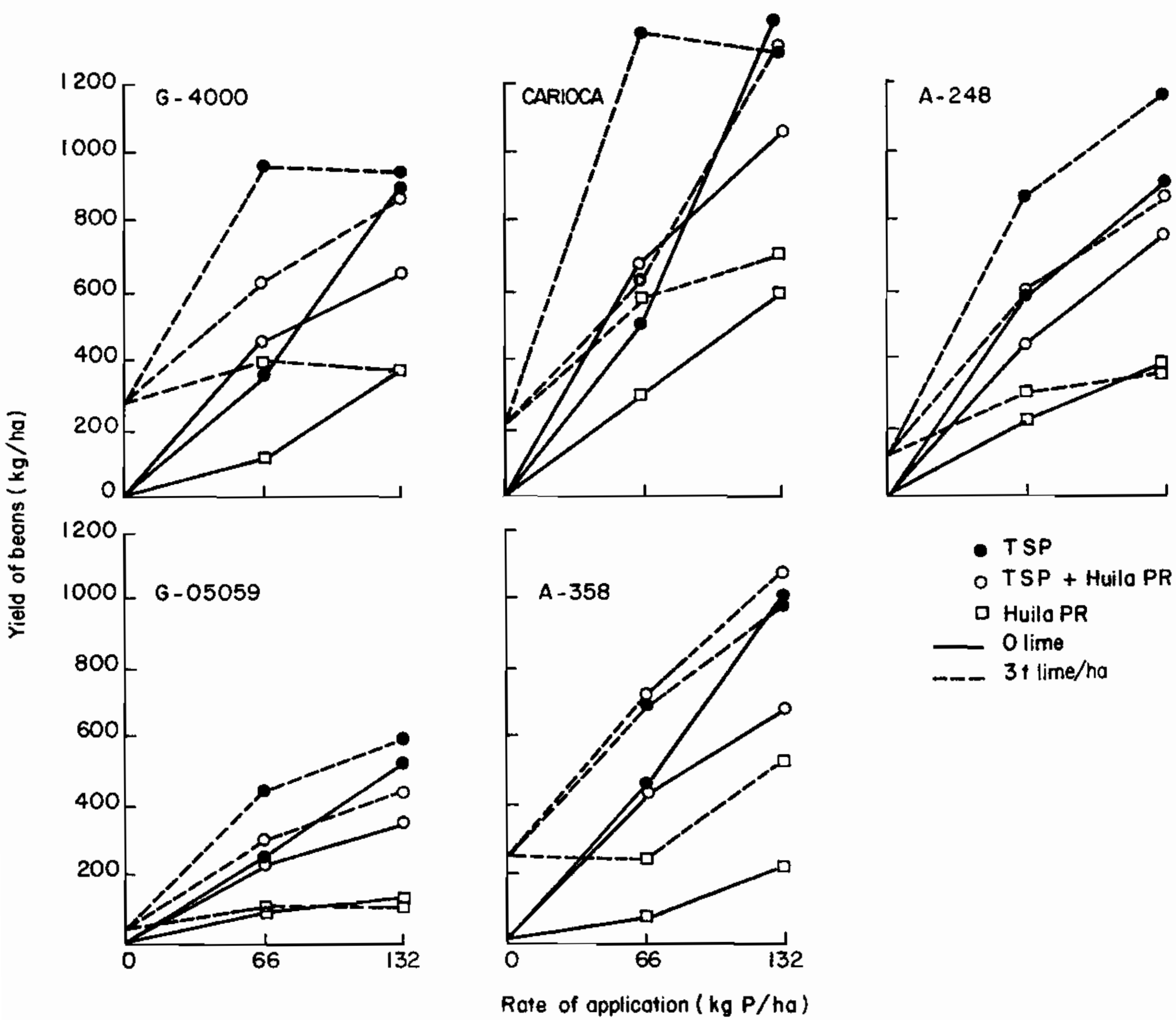

Figure 7. Effect of P rates, sources and liming on yield of five bean varieties grown on a CIAT-Popayán Andept.

and also yields in the check plots were very low. As in other experiments on this soil, relative agronomic effectiveness of the P sources followed the order: TSP > TSP + Huila PR > Huila PR, but when the rate of P applied was only 66 kg/ha, the mixture of TSP and PR produced yields equal to TSP alone. Figure 8 shows that a differential response was obtained of the varieties to Huila PR applications. In this case, varieties Carioca, A 248 and G 4000 presented a good response to Huila PR when compared with varieties A 358 and G 05059.

In general, the application of 3 t of lime/ha produced a yield increase when no P was added, but this increase was higher for the varieties G 4000, A 358 and Carioca. Lime also increased the response to P except when a soluble P source was used at a high rate. Varieties that responded to liming did not show yield increase when lime and Huila PR are used together, if these treatments are compared with the yield obtained with the Huila PR alone. Probably the application of 132 kg P/ha as Huila PR (1,500 kg Huila PR/ha), that is very high in free $CaCO_3$, is sufficient to provide the Ca demand of four of the varieties tested, and to neutralize some of the exchange acidity of the soil. It is possible also that the Ca concentration due to liming was high enough to restrict the dissolution of the PR due to common ion effect. With varieties like G 4000 and A 358 yields were better using 3 t lime/ha than 750 kg Huila PR/ha. In the case of varieties that only present slight responses to lime, apparently it is better to use Huila PR alone instead of lime without P, or the combination of lime and Huila PR.

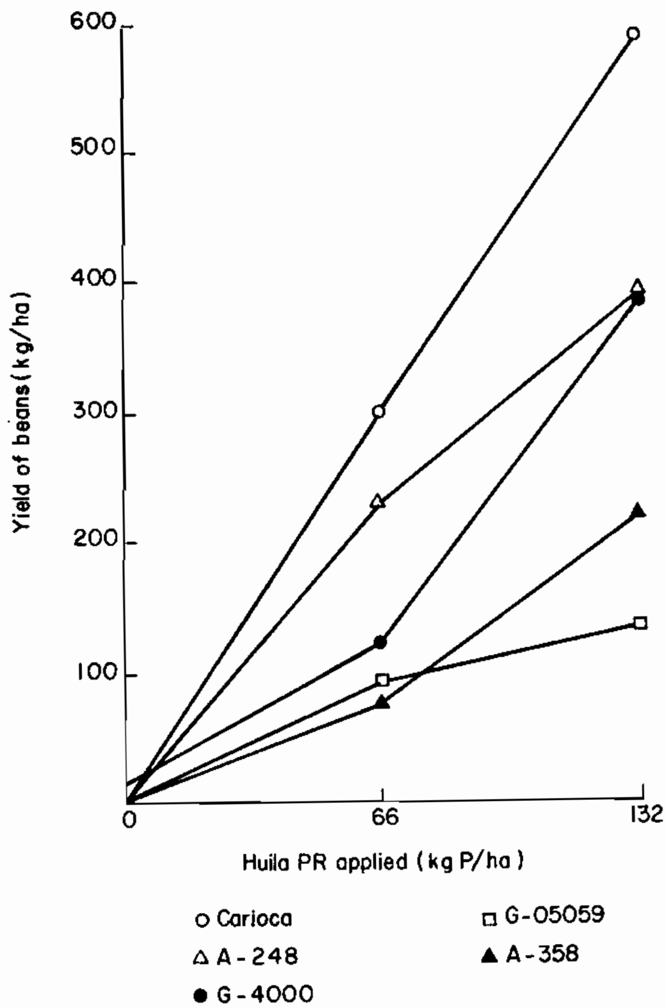

Figure 8. Response of five bean varieties to applications of Huila PR. CIAT-Popayan Andept.

Social Science On-Farm Research

Overview. On-farm research in phase IV of the Phosphorus Project is multidisciplinary, involving studies of farmers' socio-economic circumstances, current fertilizer practices, and potential constraints to adoption of new strategies for use of phosphate fertilizer, in combination with experimental evaluation of new fertilizer materials with trials in farmers' fields.

The primary objective of the social science on-farm research in 1982 was to provide diagnostic information for the phase IV pilot areas on the socio-economic environment in which farmers' manage soil fertility. This information is used as a guide in design of on-farm trials, in specification of research objectives associated with identification of potential adopter groups or farm types, and ultimately in evaluation of results of farm trials. An important component of this diagnostic information is the study of farmers' empirical knowledge systems for managing their soils, crops and available fertilizers. Social institutions, social roles, farmers' cultural beliefs and values associated with land resources and soil fertility are analyzed towards characterizing the environment in which new phosphate fertilizers require to be tested in order for farmers to adopt them rapidly and successfully.

Research in 1982 was concerned with application of the results of in-depth diagnostic study to the evaluation of on-farm trials planted to cassava in Cauca department, Colombia in 1981 and to the design of further cassava trials in this pilot area for phase IV of the project.

An in-depth study of the Piedmonte region of Meta department, Colombia was initiated towards design and evaluation of on-farm trials in this region to be planted in 1983.

An alternative methodological approach to the in-depth study was developed and implemented for design of farm trials in phase IV pilot areas in Cauca and Nariño departments, Colombia. Rapid diagnostic studies with key informant interviews were conducted by the project sociologist and assistant agronomist to characterize farmer management of bush beans in Cauca, maize-bean associations and potatoes in Nariño for design of farm trials which were planted in each of these crops in Semester B, 1982. A short bulletin on this methodology was prepared for use by national program research and extension personnel participating in the project.

A study of socio-economic factors in soil erosion was conducted in Cauca department, one of several case studies contributing to a world-wide project on socio-economic constraints to soil conservation supported by the Internation Federation of Institutes for Advanced Study (IFIAS). Project staff also collaborated in research for similar case studies conducted in Cundinamarca, Colombia with the Instituto Geográfico Agustín Codazzi. Final results of the case studies were presented at a workshop in September, 1982 at the International Soils Museum, Wageningen, Holland.

On-farm trials, Pescador, Cauca Department. The on-farm research site in Pescador is one of the phase IV pilot areas, located in the mid-altitude tropics at 1,500 - 2,000 masl, and is a region of cassava production on Oxisols and Oxic Inceptisols. The region represents an agricultural system with a concentration of small farms producing primarily cash crops on marginal soils which are acid and very low in phosphorus. The research area lies within good access of product markets and fertilizer supplies including Huila PR, which began to enter the local market in 1980-1.

Findings of the diagnostic study of farmers' soil fertility management practices and patterns of fertilizer adoption were reported in 1981. Based on survey data for a sample of 102 farms collected in the cassava production region including Pescador and the nearby community of Mondomo, a farm typology was developed. Factor analysis identified four types of farm in the sample which accounted for 73.4% of variance in nine variables characterising allocation of land to different uses, and use of labor on-farm and off-farm, both family and hired labor. Factor scores were generated to classify individual farms into types characterized by the factor loadings, as follows: (a) The agricultural laboring type of farm is characterized by a high man-land ratio; scores high on an index of agricultural employment off-farm; and is associated with low use of hired labor for on-farm operations; (b) the land-extensive type of farm is characterized primarily by a high proportion of area in pastures and a livestock component, a low man-land ratio, and a relatively low proportion of area to cassava.

(c) family cassava farms are associated with a specialization in cassava production, with a low proportion of area in coffee, and a high factor loading on the index of family labor use in on-farm operations; (d) intensive cassava farms are so termed for a high proportion of land in cassava, coupled with a high negative factor loading on the proportion of land in fallow.

Table 2 shows patterns of land use which characterize each type of farm. These patterns were found to differ in important ways with respect to the availability of fallow land for rotation with the cassava crop, a central consideration in farmers' decision-making about whether or not to use fertilizer for cassava, as discussed in the 1981 Annual Report.

Information on the land use patterns for cassava of different types of farm was utilized in combination with information from farmers in the region on their classification of soils, fallow periods and vegetation to define a framework for evaluation of results of cassava trials harvested in October-November 1982. Four experimental sites in Pescador were characterized with participating farmers and ranked by them as to expected fertility (or cassava yields) according to the criteria shown in Table 3 along with the corresponding soil analysis for each site. For economic evaluation of trial results three questions were posed which are associated with soil fertility management strategies of different types of farm: (a) At what rates (and with which of two sources of P tested) is fertilizer an economic alternative to rotation of

Table 2. Characteristics of farm types, Pescador-Mondomo region, Cauca, Colombia

Farm Type	Farm size (ha)	Man-land ratio	Percent of Area			
			Coffee	Cassava	Pasture	Fallow
Land extensive farms	14.8	0.48	12	7	46	29
Family cassava farms	11.4	0.56	12	23	8	52
Intensive cassava farms	6.6	0.85	31	40	9	14
Agricultural laboring farms	2.8	2.20	33	13	0.7	47

Table 3. Characterization of on-farm trial sites, Pescador-Colombia.

Farmers'[a] ranking	Farmer Classification			Soil Analysis					Total Mycorrhizal spores (no/10 g dry soil)
	Color - Texture	Vegetation	Fallow period	Bray II P (ppm)	O.M. %	pH	K	Al % Sat.	
1	"*negra parda y dura*" (black volcanic ash, A horizon)	"*rastrojo de pasto amargo*" or "*bitter pasture*"	6 years fallow	2.61	13.98	4.95	0.17	55.17	7
2	"*colorada pegajosa*" (red balsatic clay, eroded B horizon)	0	"*soca*" 2 cassava crops after 4 years fallow	1.52	6.37	4.50	0.06	64.27	0
3	"*mezcla*" (partially eroded black volcanic ash, A horizon)	"*rastrojo*" bracken, secondary-brush, pasture	1 cassava crop followed by 3 years fallow	1.49	8.78	4.80	0.21	58.54	12
4	"*colorada flojo y mezcla*"	"*pasto puntero y yaragua*" pasture	about 40 years fallow	0.73	8.33	4.90	0.08	68.73	20

[a] 1 = worst, 4 = best.

1 or 2 successive cassava crops with well-rested, fallow land (cf. plot 4, Table 3)?. This question is relevant primarily for land-extensive farms which, as Table 2 shows, have ample resources for maintaining a viable land rotation with cassava. It also relates to renting-in of well-rested fallow land by small intensive cassava farms, often on a share-crop basis; (b) at what rates are different sources of phosphate fertilizer an economic alternative to rotation of cassava with poorly-rested fallow land (cf. plots 1 and 3, Table 2)? This question is relevant primarily to the family cassava farm which sustains land rotation, albeit with a degraded fallow; (c) at what fertilizer rates can sequential cropping of cassava (in excess of 2 succesive crops) be intensified as an alternative to rotation with a degraded fallow (cf. plot 2, Table 2)? How do low-cost phosphorus sources, such as direct application of finely ground rock phosphate, perform in sequential cropping and are these an economically attractive alternative to higher-cost water soluble phosphates for farmers facing capital constraints, such as the small, agricultural laboring farms?

Figure 9 shows net benefit curves for each of the 4 sites in Pescador, for two replications per site where two sources of P, Huila PR and TSP were applied at three rates (25, 50 and 100 kg/ha P), with and without support nutrients (50 kg/ha N and 50 kg/ha K_2O). Variable costs include the additional costs of land preparation for fallow land where appropriate, costs of fertilizer application, fertilizer materials and transportation, and additional labor for weeding after fertilizer applications as found from analysis of

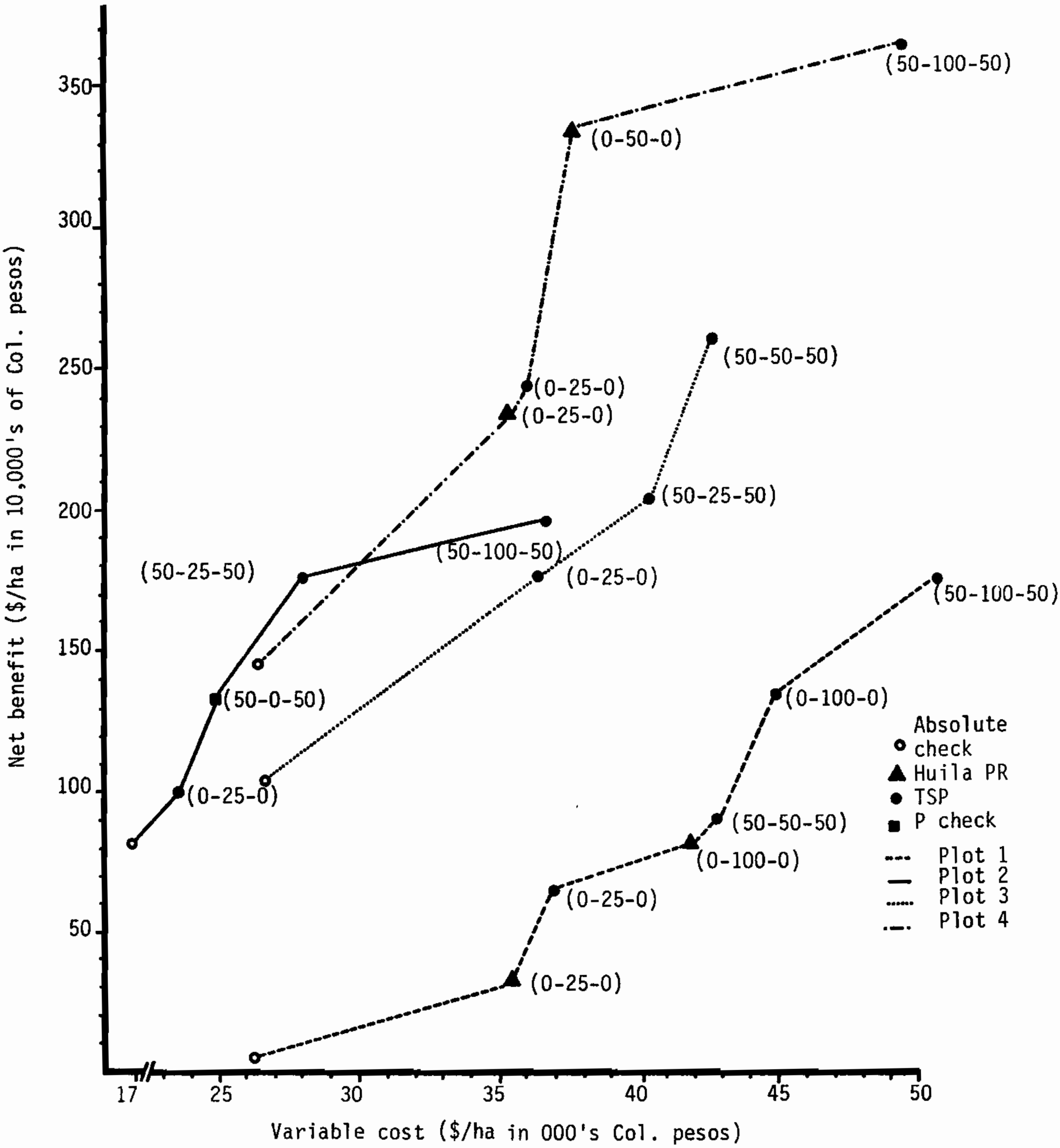

Figure 9. Net benefit curves for four on-farm trial sites, Pescador, Colombia

production costs on farmers' own plots. More detailed statistical analysis of the agronomic results will be required before final conclusions about their economic implications are drawn. However, the data in Figure 9 indicate some basic trends.

First, economic returns from the absolute check (no fertilizer applied) for each site bear out farmers' expectations in their ranking of the expected fertility of the plots, shown earlier in Table 3. For example plot 1, although fallow for 6 years, was ranked least "fertile" due to its vegetation of "pasto amargo" used by farmers as an indicator of very poor soil, and in general yields were lowest on this plot.

Second, the net benefit curves show that in general treatments with direct application of finely ground rock phosphate were dominated in terms of marginal rates of return by TSP on plots with degraded fallow or several successive cassava crops. However, on less degraded soils with a long fallow, direct application of 50 kg/ha of P from rock phosphate appears economically more advantageous than more costly applications of TSP, except when support nutrients were applied with TSP at a higher rate of P/ha. Overall the marginal rate of return to incremental expenditures for the fertilizer applications shown in Figure 9 is likely to be attractive to farmers. Small farmers, such as intensive cassava farms, or small agricultural laboring farms who want to intensify successive cultivations on a plot can do so utilizing TSP, as illustrated by plot 2, as a substitute for planting without fertilizer on new plots with degraded fallow. Moreover such farmers could potentially obtain a high rate of return on a small incremental expenditure for TSP (50 kg/ha P) and support nutrients for cultivation of a third successive crop, instead of cultivating a new plot with a long fallow rest period (eg. plot 4) without fertilizer, as has been traditional practice.

Although the economic incentives from the net benefit curves appear convincing for small farmers to adopt a phosphorus management strategy based on use of TSP on degraded soils and rock phosphate for less degraded soils, results from the diagnostic study indicate some qualifications to this conclusion which will require further investigation. The study found that farmers with a tradition of land-extensive shifting cultivation, without education in concepts of nutrient content of different fertilizers, prefer a fertilizer which "goes further" (rinde más). That is one which is relatively bulky, such as organic fertilizer or rock phosphate, and enables them to apply fertilizer at a lower cost to a large area, or to several plots, rather than investing the same amount of capital in more costly fertilizer applied to a smaller area. This strategy enables farmers to diversify planting dates and locations, susceptibility to drought, hail or pest and disease attacks which would otherwise increase their exposure to risk if resources were concentrated in a small area of land, utilizing a relatively costly fertilizer such as TSP. Therefore, it is expected that small farmers will utilize direct application of rock phosphate, even though sub-optimal in economic terms in comparison with TSP, and that phase IV of the project will test and develop strategies for efficient use of rock phosphate which are compatible with small farmers' objectives and needs for minimizing both exposure to risk and absolute levels of capital expenditure.

Socio-economic factors in soil-erosion. This study examined the socio-economic incentives for over-exploitation of soil resources in a Colombian cassava farming system. Several features of the local agrarian structure can be understood as characteristic of those confronting small farmers in low-income countries.

Market forces shaped by the economy at large structure a pattern of land use which gives increasing importance to cultivation on marginal soils of a crop with very low returns to labor, or more generally, to variable capital. In this instance, the crop, cassava, is cultivated with traditional slash and burn practices which exacerbate soil fertility decline, deforestation and erosion as the availability of fallow land for rotation with cassava in the farming system decreases.

Influential interest groups which are external to the local economy, shape soil conservation policy objectives which amount to restricting use of traditional practices in cassava cultivation in the study area. Implementation of soil conservation with small-scale engineering works is limited in scale, and has a crisis-management approach which appears unrelated to soil management practices that farmers find desirable.

Several factors lent support to the hypothesis that these small farms face powerful economic and institutional incentives to discount potential long-run gains to soil conservation practices in favor of short run improvement in their income from cassava production. First, the profitability of local coffee production has declined, and other alternative crops to cassava such as sugar cane or beans and maize face uncertain markets compared with rising demand for cassava starch locally. Second, with traditional technology it is more profitable to plant newly cleared plots than to cultivate successive cassava crops on a plot, despite efforts to restrict clearing new land. Farmers' current methods of applying fertilizer in cassava, which are in part an adaption to their perception that fertilizer is lost by erosion on steep slopes, do not provide a profitable alternative to the traditional slash and burn. The profitability of rotating cassava plots for a short period of time with current technology discourages farmers from making a long-run investment in soil conservation on a plot such as establishing the recommended live contour barriers.

Third, land tenure arrangements and the social norms for sharing land among family members which occur especially among small farms, are short term and contribute to a decision-making environment in which the small farmer discounts soil losses. Fourth, the credit administration program of the local extension service can only serve the majority of its clientele by effectively reaching a high proportion of small farms growing cassava. The agency is constrained from enforcing soil conservation practices in theory tied to credit, by the lack of a profitable alternative to slash and burn methods which would enable farmers to make repayments on loans.

In conclusion, the socio-economic constraints to improved soil management and erosion control identified in the study area indicate that efforts to restrict slash and burn methods of cassava cultivation is a means of implementing soil conservation have little prospect of success. Effective implementation of soil conservation practices depends vitally on providing farmers with improved cassava production technology that compensates farmers for the short-run costs of abandoning slash and burn practices.

As a follow-up to findings of this study, the IFDC Phosphorus Project's on-farm testing program in the study area is conducting research on potential for improved cassava yields and profitability, by evaluating costs and returns to cassava production combining improved fertilizer practices with establishment of live contour barriers to control soil erosion on steep slopes. Only by providing economically viable practices which increase farmers' income in the short run, can farmers be expected to invest in the long-run goal of soil conservation.

<u>Social Relations of Land Utilization and Fertilizer Adoption at Agricultural Frontier: Phosphorus fertilization of upland rice in the Llanos Orientales, Colombia</u>.

In the department of Meta, interviews with 31 upland rice farmers revealed significant differences in fertilizer practices, especially with regard to quantities and sources of P applied.

Farmers were selected haphazardly, within three sub-regions, and after the interviews, grouped into four categories.

"Capitalized Farmers" (22.5% of the sample) plant over 100 ha rice and usually owned over 200 ha land. "Professionals/Investors" (12.9% of the sample) plant between 26 and 85 ha rice to supplement their incomes from their professions or as a retirement activity. "Colonos" (22.5% of the sample) are the men or the sons of men who colonized the land in the 1950's or before. They plant between 12 and 100 ha rice. They owned farms of between 100 and 150 ha, except for one who planted rice on his father's 500 ha farm. "Small farmers" (41.9% of the sample) owned between 8 and 37 ha on one or two farms (except for one who planted on rented land only), and planted between 8 and 20 ha rice. Two in this category planted 60 and 90 has respectively.

The Rice Grower's Federation (FEDEARROZ) estimates that 75% of the land planted in rice (wet and upland) is rented. In this sample, 12.9% of the farmers planted only on rented land; 80.6% (N=25) planted on owned land--48.4% (N=15) planted only on owned land and 32.2% (N=10) on both owned and rented land or in <u>compañía</u>

(partnerships in which the costs and profits are shared. The land may be rented or owned by one of the partners). Rentals are usually for a single harvest, but there are also contracts for three years which carry a lower price.

None of the farmers planned fallow periods for the land in rice that they owned, except for that which was too moist for a sorghum rotation. In the past, four had planted pastures on crop lands when agriculture became unprofitable. The strategy of grazing cattle on crop lands as an alternative to the risks and high costs of agriculture is commoner in Meta than this sample suggests.

Fertilization strategies for upland rice were based on soil analyses by only 6 of the 31 farmers (19.3%). While only 6 (19.3%) limed the soil they planted annually or biannually, 15 of the farmers (48.4%) had used lime in the last 5 years. Rental land is not limed, except when the contract is for three years. Upland rice was fertilized with Urea and KCl and different sources of phosphorus at 20, 50 and 70 days after germination. In this sample, half of the farmers fertilized twice, one quarter once, and one quarter three or more times. The fertilizers used by the farmers are shown in Table 4; the amounts and sources of P in Tables 5 and 6; and the amounts of N in Table 7.

Most striking are the low quantities of P provided in the generally acid and infertile soils of the Llanos. Upland rice is planted in class II, vega soils, which are considerably more fertile

Table 4. Fertilizer use per ha, in bags of 50 kg, among Meta Piedmont farmers, 1982 A

Farmer Category	Nutrient and Source			
	Nitrogen Urea	Potassium KCl	Phosphorus variable	
			Quantity	Source
"Capitalized farmers"	4	1	a	"chelating"
	2-3	1	1	DAP + 300 kg PR
	3	0	a	14-14-14
	1	0.5	1	DAP
	3-3.5	1	2	DAP
	2 (1981)	1	1	TSP
	2-3	1	2	DAP or 116 kg PR
"Colonos"	3.5	0	1	15-15-15
	3	1	1	DAP
	3	1	1.5	DAP
	2 + ammonium sulphate	0	0	
	a	1	0	
	1.7	1.7	2	15-15-15
	2	2	1	DAP + 300 kg PR
	5	2	1	DAP
"Professionals/ investors"	2	2	10	basic slag
	2	0	0	
	1.5	0	1	DAP
	3	1	0	
"Small farmers"	0.9	0.7	0	
	2	0	0	
	2.5	1	1	10-20-20
	4	1	0	
	6	2	0	
	2	0	2	15-15-15
	3.5	0	1	15-15-15
	4	1	1	15-15-15
	0.7	0	3.3	compound
	1.5	0	3	15-15-15
	2	0	2	15-15-15
	2	0	0	
	1	1	1	10-30-10

[a] No data available.

able 5. Phosphorus used by Meta Piedmont farmers, kg P/ha, 1982 A[a]

Farmer Category	44+		33.2 - 44		33 - 22.3		11.4 - 22		4.8 - 11		4.4-		None		Dont know		Totals	
	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)
Capitalized	1	14.3	0	0	0	0	2	28.6	2	28.6	0	0	0	0	2	28.6	7	100.0
Colonos	0	0	1	14.3	0	0	1	14.3	3	42.8	1	14.3	1	14.3	0	0	7	100.0
Prof/Invest.	0	0	0	0	1	25.0	0	0	1	25.0	0	0	2	50.0	0	0	4	100.0
Small	0	0	0	0	0	0	1	7.7	4	30.8	3	23.1	5	38.5	0	0	13	100.0
Totals	1	3.2	1	3.2	1	3.2	4	12.9	10	32.3	4	12.9	8	25.8	2	6.4	31	99.9

[a] ICA's recommendations, based on soil analyses are the following:

P ppm	kg P/ha
0 - 10	44
10 - 15	22 - 33
15 - 30	11 - 22
30+	0 - 11

Table 6. Sources of phosphorus and timing of application among Meta Piedmont farmers, 1982 A

Farmer Category	Source		Timing of application		Source		Timing of application		Source		Timing of application		Other		None	
	DAP N	(%)	Pre-planting	Post-planting	Compound N	(%)	Pre-planting	Post-planting	Calfos PR N	(%)	Pre-planting	Post-planting	N	(%)	N	(%)
Capitalized	4	57.1	1	3	1	14.3	1	0	0	0	0	0	2	28.5	0	0
Colonos	4	57.1	3	1	1	28.5	1	0	0	0	0	0	0	0	1	14.3
Prof/Invest.	1	25.0	0	1	0	0	0	0	1	25.0	1	0	0	0	2	50.0
Small	0	0	0	0	8	61.5	1	7	0	0	0	0	0	0	5	38.5
Totals	0	29.0	4	5	11	35.5	3	8	1	3.2	1	0	2	6.4	8	25.8

Table 7. Nitrogen used by Meta Piedmont farmers, kg/ha, 1982 A[a]

Farmer Category	Above 65 kg N	(%)	Within 30-65 kg N	(%)	Below 30 kg N	(%)	Totals N	(%)
Capitalized	5	71.4	2	28.5	0	0	7	99.9
Colonos	4	57.1	3	42.9	0	0	7	100.0
Prof/Invest.	1	25.0	3	75.0	0	0	4	100.0
Small	4	30.7	6	46.2	3	23.1	13	100.0
Totals	14	45.2	14	45.2	3	9.6	31	100.0

[a] ICA recommends 30 kg N/ha with no piricularia control
60 kg N/ha with piricularia control

than the class III and IV soils used for irrigated rice. Nonetheless, 1982 soil analyses on half of these farms showed that the amounts of phosphorus in the soil ranged from 3.30 ppm to 18.44 ppm (Bray II).

11 kg P is considered minimum P for upland rice. 70.9% of the farmers (N=22) provided less than 11 kg P. Among small farmers, 92.3% (N=12) used less than 11 kg P (see Table 5).

The differences in sources of phosphorus are explained by the farmers' and their agronomists' access to the sources of new technology, in this case, FEDEARROZ. In 1981 FEDEARROZ announced a rice fertilization plan based on replacing compound (N-P-K) fertilizers with simple ones, and recommend the use of imported diammonium phosphate (DAP)(18-46-0) as a source of phosphorus. Since only the large farmers and the agronomists who serve them are aware of these changes, small farmers continue buying the fertilizers produced in Colombia.

Farmers are clearly making decisions about phosphorus fertilization and these rebound on the total amount of N used. It is notable that the farmers who used DAP--"new technology" did not necessarily use it correctly. The Instituto Colombiano Agropecuario, ICA, recommends that DAP be applied before planting or at planting, but several DAP users ignore this advice and mix it with the first or second of their regular 20-50-70 day applications or Urea and KCl (Table 6). Nor is it clear that DAP is the most appropriate source of P for upland rice. A CIAT agronomist and a "Capitalized Farmer" who is also a plant pathologist believe that the N in DAP, when it is applied correctly, at or before planting, increases the crop's vulnerability to piricularia. This is presumably also the case with compounds like 10-20-20 or 15-15-15.

The use of DAP and compound fertilizers as a source of P, thus contributed to the generally high proportion of farmers who used more N on their rice than the quantities recommended by ICA (Table 7). The tendency was strongest among "Capitalized Farmers", where 71.4% (N=5) used over 65 kg N/ha in contrast with the "Professionals/Investors" among whom 25% (N=1) used over 65 kg N/ha, and the "Small Farmers", among whom 30.7% (N=4) used over 65 kg N/ha. This may have contributed to increased costs in controlling piricularia during the year the most planted variety lost its resistance to the disease.

If the relationships between sources of phosphorus, excess N and vulnerability to piricularia is correct, phosphate rock may be an especially appropriate source of P for upland rice in the Llanos.

In order to assess the generaliziability of these data for experiment design, a larger survey of farmer practices is planned for 1983.

Training and Conferences

During 1981 the Phosphorus Project was involved in the training courses that CIAT offers to Latin American agronomists that are working in the fields of pasture, beans and rice production giving lectures and greenhouse and field training as follows:

1. Tropical Pastures. (a) Fertilization of tropical pastures. Responses of tropical pastures to N, P, K, Ca, Mg, S and micronutrients fertilization.

2. Beans. (a) Effect of soil salinity and alkalinity on the production of beans in Latin America.

3. Rice. (a) Chemistry of flooded soils; (b) Phosphorus fertilization for rice production; (c) Nitrogen fertilization for rice production; (d) Soil acidity and liming; (e) Practical recommendations for fertilization of soils used for upland and low-land rice production.

In addition, seven lectures were given during trips to Turrialba, Costa Rica, Feb. 17-18, Lavras, Vicosa and Brasilia, Brazil, May 26-28 June 1, and La Habana, Cuba, June 26-29. The Topics of the lectures were "Efficient Utilization of PR's for agriculture", "Chemistry of P in soils of the tropics".

In the cities of Pereira and Jamundí, during field days and in Bogotá, Cúcuta and Bucaramanga five conferences were given to agronomists, farmers and general public on the "Agronomic effectiveness of Colombian PR's".

Audiotutorials

With the collaboration of CIAT Training and Conferences Unit, the Rice and Tropical Pasture Programs, four audiotutorials were prepared during 1982.

1. Nitrogen fertilization for rice
2. Phosphorus fertilization for tropical pastures
3. Nitrogen fertilization for tropical pastures
4. Agronomic effectiveness of phosphate rocks

International Collaboration

During 1982, project staff collaborated with IFDC, Outreach Division to organize a course on "Fertilizer Efficiency Research in the Tropics" (FERITT), in the Escuela Agrícola Panamericana "El Zamorano" - Honduras, and with the Agro-Economic Division to prepare a chapter on Micronutrient Problems in Tropical Latin America for the book "Micronutrients and the Agricultural Ecology of Tropical Food Crop Production", edited by P.L.G. Vlek and J. J. Street. Dr. Vlek visited the Project, April 1 - June 26, to collect information on micronutrients in the Latin American Tropics. During this time he visited national and international research institutes in Mexico, Colombia, Ecuador, Peru and Brazil. Dr. Street visited Colombia, Venezuela and Central America also to collect information on micronutrients.

The Project continued collaboration in the agronomic and socio-economic studies with research national institutes and universities in Colombia, Bolivia, Peru, Ecuador, Venezuela, Costa Rica and England (Reading).

Publications

Ashby, J.A. 1982. "Strengths of Anthropology and Related Social Sciences". In The Role of Anthropologists and other Social Scientists in Interdisciplinary Teams Developing Improved Food Production Technology. IRRI, Los Baños, Philippines.

Ashby, J.A. 1982. "Farmer Field Preparation and Tillage Practices: Implications for Fertilizer Testing and Evaluation". Soil and Tillage Research. Vol 2.

Ashby J.A. and Pachico D.H., 1982. "Co-ordinating Planning and Implementation for Growth and Equity Objectives in Rural Development Agencies. A case study from Colombia". In International Association of Agricultural Economists Occasional Papers. No. 3.

Ashby, J.A. (forthcoming). "Socio-Economic Factors in Soil Erosion: A case study of Pescador and Mondomo, Cauca Department, Colombia". In Socio-Economic Factors and Constraints in Soil Conservation, E.G. Hallsworth (editor). Westview Press.

Hammond, L.L., and Leon, L.A. Effectiveness of 7 Phosphorus Sources During the 5 years Following Application to an Acid Colombian Oxisol. Paper to be presented at the ASA annual meetings. Anahein, California. November 1982.

Leon, L.A., Fenster W.E. and Hammond L.L. Alternatives for Phosphorus Fertilizer Management in Establishing Improved Forage Grasses on Acid Colombian Soils. Paper to be presented at the ASA annual meetings. Anahein, California. November 1982.