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It was also approved that the network should include Regional Trials C and D in which selected germplasm from RTB (5 to 10 entries) should be evaluated in grass/legume mixtures under grazing. The methodologies for these two levels will be discussed in a future workshop planned for 1981.

Reports of the first Regional Trials already established were presented. Figure 81 shows the location of the existing trials in the target area.

Eventually the Regional Trials Network will provide information to the national institutions and to CIAT about the range of adaptability of pasture germplasm to specific ecological conditons. This information should be a solid basis for extrapolating tropical pastures research findings throughout the target area of the Program.

Printed Media

New titles in the area of tropical pastures published by CIAT in 1979 are shown in Table 95. At CIAT's Documentation Center a newsletter on tropical pastures (in Spanish) was initiated to provide relevant network information to researchers, basically in Latin America.

CIAT/IFDC PHOSPHORUS PROJECT

The objective of the CIAT based IFDC Phosphorus Project is to develop a phosphorus management strategy for the various crops and cropping systems now employed on the acid infertile soils of subtropical and tropical Latin America. Since the soils under consideration are low in both available and total P and generally have a high P fixation capacity, the P needs of the soil as well as the plant must be considered. It is not likely that these P needs will be accommodated through the use of triple- or simple-superphosphate (TSP and SSP, respectively) because of their high cost per unit of phosphate. Also, since these forms of P are quite soluble, a large percentage of the P is fixed by the soil and thus, in part, is not available to the plant.

It seems reasonable, therefore, that less available forms of P such as phosphate rock (PR), partially acidulated PR, cogranulated mixtures of S with PR, and cogranulated mixtures of TSP or SSP with PR may be reasonable alternatives to either TSP or SSP. Not only are these forms of P less likely to be fixed by the soil but their residual value should prove to be superior to that of the more available forms of P. It is also logical to take advantage of the soil acidity by using PR or other similar P carriers that will respond favorably under an acid environment.

In addition, the cost per unit of P as PR is about one-third that for TSP or SSP. In this regard, South America is fortunate in that there are some 17 known major PR deposits (CIAT Annual Report, 1978).

A series of greenhouse and field experiments have been established in Colombia, Ecuador, and Peru in which many of these South American PRs and their altered products are being tested for agronomic effectiveness using several different test crops. To date, many of these PR carriers appear to be promising and in some instances have shown to be superior to TSP.

Phosphate Rocks

A greenhouse experiment was conducted on an Oxisol from Las Gaviotas in the Colombian Llanos Orientales, to compare the agronomic effectiveness of 18 different phosphate rocks (PR) with TSP, and *Panicum maximum* as the test crop. Yield results are given in Table 96.

The PRs which are known to be highly reactive such as North Carolina, Fosbayovar, and Gafsa performed nearly as well as TSP. Other PRs such as South Africa, Florida, Huila, Maranhao, Arad, and Pesca also appear promising for direct application. In general, the effectiveness of all the rocks increased with higher rates when compared to simiar rates of TSP.

In a field experiment conducted on a Carimagua Oxisol with *Brachiaria decumbens,* six PRs were compared to TSP. This long-term experiment which was established in 1976 included application rates ranging from 0 to 400 kg P_2O_5/ha, all broadcast and incorporated into the topsoil. To date, the grass has

Table 96. Agronomic effectiveness of phosphate rocks determined by yield of Panicum maximum grown on an Oxisol under greenhouse conditions.

P source	Relative yield (%) P applied (mg/pot) 50	100	200	400
TSP[1]	100 (13.3)[2]	100 (19.0)	100 (20.2)	100 (22.2)
Brazil				
Abaeté	11	33	52	55
Araxá	30	33	56	58
Catalao	5	6	22	38
Jacupiranga	12	13	19	51
Maranhao	60	69	86	91
Patos de Minas	27	42	66	72
Tapira	4	7	10	23
Colombia				
Huila	58	59	84	84
Pesca	56	61	80	83
Sardinata	29	44	68	74
Israel				
Arad	62	62	95	92
Peru				
Fosbayovar	99	79	104	91
Tunisia				
Gafsa	63	72	114	105
South Africa	71	68	93	92
United States				
Florida	59	71	86	91
North Carolina	70	78	107	108
Tennessee	42	51	78	95
Venezuela				
Lobatera	56	56	65	76
Control (0.6)				

1 TSP considered 100% within each level of applied P.
2 Figures in parenthesis are yields in g/pot as the sum of three cuttings.

been cut 11 times and the comparative yield results are given in Table 97. In all cases, the yields obtained with the PRs compared favorably with those for TSP at all levels of applied P. Althought the initial yields were higher for TSP, the residual value of the PRs appears superior to that of the more soluble form. Based on this experiment it would appear that an initial application of 50 kg P_2O_5/ha is sufficient for grass forage production.

In a similar field experiment conducted in collaboration with the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA), in Peru, on a Pucallpa Ultisol, *B. decumbens* yielded slightly better with Fosbayovar PR than with SSP (Table 98). These data are consistent with those from Carimagua (Table 99).

Agronomic Effectiveness of P Placement

A field experiment was set up in CIAT-Quilichao to determine which would be the best method of P application as TSP, in conjunction with different levels of broadcast and incorporated Pesca PR, for a forage production scheme. *B. decumbens* was used as the test crop and to date five cuts have been taken. The results are quite surprising as the application of Pesca PR is comparing very favorably with TSP and combinations of TSP with PR (Table 99). It should also be noted that the topdressed PR also performed similarly to all other treatments. This would indicate that at least some PRs could be used as P sources on established pastures.

Table 97. Relative agronomic effectiveness of phosphate rocks from several sources as determined by yield of Brachiaria decumbens grown in the field at Carimagua (sum of 11 cuts taken over a 40-month period), 1976-1979.

P source	Relative yield (%) P_2O_5 applied (kg/ha) 25	50	100	400
Annual TSP	(28.6)[2]	(31.6)	(32.3)	(39.2)
Residual TSP[1]	100 (19.4)[2]	100 (27.0)	100 (28.0)	100 (33.7)
Florida (USA)	124	92	101	105
Fosbayovar (Peru)	121	79	105	106
Gafsa (Tunisia)	106	107	107	101
Huila (Colombia)	93	112	100	109
Pesca (Colombia)	109	81	112	113
Tennessee (USA)	104	76	96	107
Control (12.4)				

1 Assumed at 100% for each level of application.
2 Dry matter yields in t/ha.

When this experiment was established, the control plots were so P-deficient that it was difficult to obtain a good stand of grass. However, with time it is apparent that considerable mineralization of P occurs. As a result, after five cuts of the grass, the control plots were yielding about 50% of the high P treatments. This has also been noted in other experiments at CIAT-Quilichao and is quite atypical for a soil classified as an Ultisol.

Agronomic Effectiveness of Granule Size of PR

A greenhouse experiment with maize was set up on a Carimagua Oxisol to determine the effect of granule size on P availability of several P carriers. The results of two harvests are given in Table 100. In the case of the more reactive PRs, the yields were approximately the same for the ground and minigranulated materials which compared very favorably with those for TSP and SSP. With the lesser reactive PRs, P availability decreased with increasing granule size and yields did not compare favorably with the soluble P carriers at any given mesh size.

The relative yields decreased markedly for all PRs when the -6 + 14 mesh granules were employed.

Table 98. Effect of two rates and sources of phosphorus on yield of Brachiaria decumbens grown in the field on a Pucallpa Ultisol (sum of 3 cuts), 1978-1979.

P source	Yield (t/ha) P applied (kg/ha) 40	160
SSP	9.7	11.2
Fosbayovar (Sechura)	10.9	11.9
Control (4.7)		

Agronomic Effectiveness of PR:TSP Ratios

A field experiment was set up to study the agronomic effectiveness of three Colombian PRs, alone and in combination with TSP, on yield of rice and peanuts grown in rotation at CIAT-Quilichao. Results for two harvests of rice and one of peanuts are given in Table 101.

In general, with the first rice harvest, yields increased with each additional increment of P as PR, except in the case of Huila PR where near maximum yields were obtained with 50 kg P_2O_5/ha. With the lesser reactive Pesca and Sardinata PRs, the 1:1 ratios of PR:TSP generally gave higher yields at the lower P application rates. This illustrates the initial need for a soluble form of P when low rates are used.

Table 99. Management of phosphorus in establishing and maintaining Brachiaria decumbens grown in the field at CIAT-Quilichao (sum of 5 cuts), 1978-1979.

P source (kg P_2O_5/ha)	Method of application	Relative yield (%) Pesca phosphate rock (kg P_2O_5/ha) 0	100	200	400
TSP					
0		53	87	98	100
50	Topdress	103	96	95	103
100	Topdress	88	98	106	-
50	Banded	58	85	95	100[1] (17.1)[2]
100	Banded	84	75	102	-
50	Broadcast & incorporated	82	98	102	98
100	Broadcast & incorporated	104	103	102	-
50	Strips	-	-	-	84
Pesca[3]	Topdress	-	75	103	89

1 Treatment regarded as 100%.
2 Dry matter yield in t/ha.
3 Included as topdress treatment of PR only.

Peanut yields did not reflect the levels and combination of applied P with the exception of Huila PR which yielded comparably to TSP at the high rate of application. Many of the PR treatments at the lower levels of applied P were only slightly better than the P-free control.

The second rice harvest showed large yield increases at all levels and combinations of applied P. It appears that significant amounts of P are being released from all of the PRs and the yields of rice were comparable to similar P applications of TSP.

In a similar experiment with *B. decumbens,* the yields after six cuts were comparable to those just described for rice (Table 102). Although the initial two cuts of grass were considerably higher for those treatments with higher ratios of TSP, the total yields are about the same within a given rate of P due to the residual value of the PRs. At the lower rate of applied P, the yields obtained with Sardinata PR, however, are somewhat lower due to its apparent low reactivity.

Agronomic Effectiveness of Cogranulated Mixtures of PRs with TSP and SSP

When monocalcium phosphate is applied to the soil it forms dicalcium phosphate and phosphoric acid. In order to take advantage of this acid, it seems logical that if SSP or TSP were cogranulated with PR, the acid might react with the PR rather than being dissipated in the soil.

A greenhouse experiment was conducted to study the effect of the ratio of PR to SSP and TSP on yield of maize grown on a Carimagua Oxisol. Table 103 shows quite clearly that as the ratio of soluble P is increased, yields increase correspondingly. When the ratios of PR:TSP or SSP in powder are compared to

Table 100. Effect of granule size of five phosphate rocks applied to maize (200 kg P_2O_5/ha) grown in the greenhouse on a Carimagua Oxisol (sum of two harvests).

P source	Relative yield (%) Powder (200 mesh)	Minigranule (-48 + 150 mesh)	Regular granule (-6 + 14 mesh)
TSP	91	95	100[1] (17.7)[2]
SSP	114	98	97
Arad (Israel)	116	84	18
Araxa (Brazil)	63	44	15
Florida (USA)	84	95	26
North Carolina (USA)	95	97	55
Pesca (Colombia)	45	32	20
Control (2.4)			

1 TSP is regular granule size assumed to be 100%.
2 Figure in parenthesis is tissue yield in g/pot.

Table 101. Agronomic effectiveness of three Colombian phosphate rocks, alone and in combination with TSP, as measured by relative yields of upland rice and peanuts grown in rotation at CIAT-Quilichao, 1978-1979.

P source	PR:TSP[1]	Relative yield (%) Rice 1978B 50 (kg P_2O_5/ha)	100	200		Peanuts 1979A 50	100	200		Rice 1979B 50	100	200	
TSP banded	1:0	91	101	100[2]	(5.5)[3]	79	94	100[2]	(3.8)[3]	85	93	100[2]	(7.2)[3]
Huila PR	1:0	103	99	109		82	77	95		97	83	104	
Huila PR + TSP	1:0	99	108	111		72	80	86		76	84	104	
Pesca PR	1:0	73	95	93		72	68	77		83	91	97	
Pesca PR + TSP	1:1	79	94	103		69	73	74		86	91	96	
Sardinata PR	1:0	71	73	94		68	73	76		83	79	04	
Sardinata PR + TSP	1:0	85	96	94		75	74	84		83	86	97	
Check			(2.9)[3]				(2.5)[3]				(4.9)[3]		

1 Based on total P_2O_5 content of P source.
2 200 kg P_2O_5/ha as TSP assumed to be 100%.
3 Yield in t/ha.

Table 102. Effect of varying ratio of TSP and each of three Colombian phosphate rocks on the relative yield of Brachiaria decumbens grown in the field at CIAT-Quilichao (sum of 6 cuts), 1978-1979.

P source	PR:TSP[1]	Relative yield (%) (kg P_2O_5/ha) 100	200
TSP	0:1	94	100[2] (21.2)[3]
Huila PR	1:0	88	99
Huila PR + TSP	3:1	84	103
Huila PR + TSP	1:1	87	97
Huila PR + TSP	1:3	84	94
Pesca	1:0	81	95
Pesca PR + TSP	3:1	95	93
Pesca PR + TSP	1:1	90	95
Pesca PR + TSP	1:3	102	118
Sardinata	1:0	71	84
Sardinata + TSP	3:1	80	93
Sardinata + TSP	1:1	72	91
Sardinata + TSP	1:3	82	90
Check 63%			

1 Based on total P_2O_5 content of P sources.
2 200 kg P_2O_5/ha as TSP assumed to be 100%.
3 Dry matter yield in t/ha.

Table 103. Effect of ratio of phosphate rock to SSP and TSP on yield of maize grown in the greenhouse on a Carimagua Oxisol (sum of 2 harvests).

P source	Relative yield (%)[1] PR:SSP or TSP 1:0	3:1	1:1	1:3	0:1
SSP	-	-	-	-	100[2] (18.9)[3]
TSP	-	-	-	-	91
Florida RP + SSP	71	70	91	99	-
Florida RP + TSP	71	72	92	98	-
Pesca RP + SSP	27	53	75	99	-
Pesca RP + TSP	27	64	70	89	-
Check (16%)					

1 All P rates were averaged. Granule size used: Minigranule (-48 + 150).
2 SSP assumed to be 100%.
3 Tissue yield in g/pot.

minigranules (Table 104), it appears that the latter are more effective sources of P when a more reactive PR such as Florida is used. In the case of the lesser reactive PR from Pesca, the results vary depending on whether the PR was mixed with SSP or TSP. In general, when Pesca is mixed with SSP, the ground PR appears superior to the minigranulated material. The reverse is true when the Pesca PR is mixed with TSP. The reason for this is being studied.

Agronomic Effectiveness of Partially Acidulated PR

A field experiment is being conducted to determine the agronomic effectiveness of partially acidulated PR (20% with H_2SO_4) on yield of upland rice at Carimagua. To date only one harvest has been taken (Table 105).

At the lower rate of application (100 kg P_2O_5/ha) there was an increase in yield with the partially acidulated Florida PR over the nonacidulated one. Minigranulation further enhances this effect. In the case of North Carolina PR, there appears to be a slight yield decrease with acidulation. At the higher rate of applied P, all treatments compared favorably with TSP.

In another field experiment at Carimagua with partially acidulated Florida PR (20% with H_3PO_4) and *Panicum maximum* as the test crop, similar results to those just described for Florida PR were obtained (Table 106). The partially acidulated minigranule was better than powdered PR. It is also interesting to note how well the partially acidulated regular size granule (-6 + 14 mesh) performed at the higher rates of application. The residual value of these larger particles could be quite significant agronomically.

It is apparent that if partially acidulated PR is to have an agronomic impact, lesser reactive rocks should be used. Since many of the PRs in South America have

Table 104. Effect of ratio of phosphate rock to SSP and TSP, and granulation on yield of maize grown in the greenhouse on a Carimagua Oxisol (sum of 2 harvests).

P source	Ratio PR:SSP or TSP	Relative yield (%)[1] Powder	Minigranule (-48 + 150 mesh)
SSP	0:1	105	100[2] (18.9)[3]
TSP	0:1	88	91
Florida PR	1:0	65	71
Florida RP + SSP	3:1	59	70
Florida PR + SSP	1:1	51	91
Florida PR + SSP	1:3	89	99
Florida PR + TSP	3:1	66	72
Florida PR + TSP	1:1	56	92
Florida PR + TSP	1:3	73	98
Pesca PR	1:0	40	27
Pesca PR + SSP	3:1	61	53
Pesca PR + SSP	1:1	83	75
Pesca PR + SSP	1:3	101	99
Pesca PR + TSP	3:1	55	64
Pesca PR + TSP	1:1	57	70
Pesca PR + TSP	1:3	79	89
Control (16%)			

1 All P rates were averaged.
2 SSP minigranulated treatment assumed to be 100%.
3 Tissue yield in g/pot.

relatively low reactivities, perhaps partial acidulation will be beneficial. Greenhouse screening trials are currently underway to evalute this.

Phosphorus Fixation Mechanisms

In an attempt to gain a better understanding of the P fixation mechanisms in the tropical soils of Latin America, several different analyses were carried out to determine if certain parameters could be correlated. These analyses were run on 23 different Colombian soils; a summary is given in Table 107.

In general it was found that active Al (extracted with NH_4OAc buffered at pH 4.8), reactive Al (extracted with $MgCl_2$ at pH 8.2 to 8.5), and organic matter content appeared to be directly correlated with P fixation. There appears to be no consistent relationship between P fixation and other soil parameters such as soil pH, exchangeable Al, and free Fe oxides.

Table 105. Effect of partial acidulation, P rates, and granulation of two phosphate rocks on yield of upland rice grown in the field at Carimagua, 1978.

P source[1]	Granule size	Acidulation with H_2SO_4 (%)	Relative yield (%) (kg P_2O_5/ha) 100	200
TSP	Regular	100	81	100[2] (4.3)[3]
North Carolina PR	Powder	0	79	93
North Carolina PR	Powder	20	74	98
North Carolina PR	Minigranule	0	93	112
North Carolina PR	Minigranule	20	84	109
Florida PR	Powder	0	70	107
Florida PR	Powder	20	81	109
Florida PR	Minigranule	0	74	107
Florida PR	Minigranule	20	95	100
Control (42%)				

1 TSP was band applied and all phosphate rocks broadcasted.
2 TSP 200 kg P_2O_5/ha as TSP assumed to be 100%.
3 Yield in t/ha.

Table 106. Effect of partial acidulation, P rates, and granulation of Florida phosphate rock on yield of Panicum maximum grown in the field at Carimagua (1 cut), 1979.

P source	Granule size	Acidulation with H_3PO_4 (%)	Relative yield (%) (kg P_2O_5/ha) 50	100	200
TSP	Regular	100	50	73	100[1] (6.0)[2]
Florida PR	Powder	0	28	53	73
Florida PR	Minigranule	20	53	63	82
Florida PR	Regular	20	37	68	102
Control (1.7%)					

1 200 kg P_2O_5/ha as TSP assumed to be 100%.
2 Dry matter yield in t/ha.

Table 107. Summary of average soil chemical parameters grouped into relative P fixation categories (soils from 23 Colombian sites).

Category	Soil classification	Relative P fixation	% P fixed (10 ppm P added)	pH	Organic matter (%)	Exchangeable Al (meq/100 g)	% Al saturation	Active Al (meq/100 g)	Reactive Al (meq/100 g)
1	Andept	Very high	80%	5.3	20.4	1.3	39.2	12.3	29.8
2	Andept-Oxisol-Ultisol	High	60-80%	5.0	7.8	2.3	40.9	3.8	8.9
3	Oxisol-Inceptisol	Medium	40-60%	4.8	4.2	2.5	56.7	3.1	7.3
4	Mollisol	Low	40%	6.3	4.3	0.2	0.8	0.7	3.4

Category	Free Fe oxide (% Fe_2O_3)	P-Al ppm	% P-Al of total P	P-Fe ppm	% P-Fe of total P	Organic P (ppm)	% organic P of total P	Number of sites
1	2.9	16.2	2.1	6.3	1.1	603.0	72.0	4
2	4.6	4.1	0.8	46.4	6.7	267.1	54.8	6
3	4.7	1.2	0.6	8.7	5.7	126.8	40.2	8
4	2.9	4.5	0.9	6.5	1.4	106.9	21.2	5

LAND RESOURCE EVALUATION OF TROPICAL AMERICA

In order to create a foundation for the effective development and transfer of germplasm based technology, and to facilitate the development and revision of research priorities compatible with geographic realities and economic trends, CIAT, in conjunction with national agencies including the Centro de Pesquisa Agropecuaria dos Cerrados, Empresa Brasileira de Pesquisa Agropecuaria (CPAC-EMBRAPA) in Brazil and the Ministries of Agriculture of other countries, is currently evaluating land resource information in tropical America. The work started in mid-1977 as a specific study of the Oxisol and Ultisol regions to help establish technical priorities for forage improvement. Land information is reduced to a common base in terms of climate, landscape, vegetation, and soils. The study now covers over 850 million ha (Figure 82). The 1977 and 1978 CIAT Annual Reports contain progress reports and some preliminary findings.

With the virtual completion of the study as originally envisaged by mid-1979, its scope was extended to cover regions of interest for CIAT's other commodity programs including cassava, beans, rice and maize (Andean region only), and to provide useful information for crop, forage, and agro-forestry production throughout tropical Latin America in general.

In order to accelerate the analysis of the land resources information, a computerized data storage, retrieval and analytical system, map and data printout facility has been set up. This is readily expandable and permits the analysis of the land resource data in the light of additional information from other sources, particularly economic studies. The information recorded in the data bank has already been made available to agricultural institutions as a series of computer tapes.