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Soil Phosphorus Availability and Eucalypt Phosphorus Uptake from Soluble and Insoluble Sources of Phosphorus

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Abstract
P recovery efficiency from natural rock phosphates and a concentrated phosphate by *Eucalyptus grandis* plantation in relation to triple superphosphate was evaluated in field trials conducted in the cerrado area of Brazil. Two experiments were carried out in two sites of the Savanna area of Minas Gerais State, Brazil. The rates of the natural phosphates (RP) Araxa and Patos de Minas(P_2O_5 24% and Ca 25%), were 500, 1000, 2000, and 4000 kg/ha and Arafertil (33% -P_2O_5 and 33% Ca)concentrated rock was tested using 1000kg/ha rate only. The triple superphosphate (TP = 45% -P_2O_5 and 13% Ca) was applied at 250, 500, 1000, and 2000 kg/ha. Mehlich -1 and Bray -1 extractants were used to extract P from the soil. The concentration of P extracted varied with the reagent used. Mehlich-1 extracted about 38.8% more P over the Bray -1 extractant at both sites, although, in one of the sites the extraction was 18% higher than the other. On both experimental sites, application of phosphate from both natural and concentrated forms increased tree height, stem volume and above ground dry matter production, but there was no difference between them at the rate of 1000 kg/ha. P-fixing capacity by trees increased with increasing soil P utilization efficiency. P recovery by the trees varied from 3 to 11% depending on rates and source. But P fixing capacity was higher for TP than for RP.
Keywords: Araxa rock, concentrated arafertil; recovery efficiency, P-fixing capacity and eucalypt.

1. Introduction.

Soils in the tropical and subtropical regions are highly weathered due to high rainfall and temperatures. Also, most soils have low natural nutrient status (Johnston, 2000 ; Awodun,2007; Awodun *et al.,* 2012) These soils have low cation exchange capacity, high capacity to fix P and are susceptible to high rates of nutrient leaching when in the cation form (Mokwunye and Vlek, 1986.; Mokwunye *et al.,* 1986; Gonçalves *et al.,* 2004 and Grierson *et al.,*2004). Such soils include Latosols, Ultisols, Entisols, and Inceptisos which occupies the cerrado (savanna type of vegetation) area of Minas Gerais State of Brazil (Barros *et al.,* 1982: Gonçalves *et al.,* 1997,2004) . These soils are characterized by having low P in available forms. Lack of available P is due either to P being chemically bound as Fe or Al phosphate as in more sandy acid Ferrasols, or to the high fixation capacity of Fe or Al oxides and clay minerals as in loamy Latosols. Many of such soils may contain considerable reserves of P in unavailable forms, both organic and inorganic (Johnston, 2000). The requirement of large amounts of phosphate to correct the fertility of these soils justifies studies to optimize fertilization efficiency. The performances of some rock phosphate (especially the reactive ones) may be comparable to more soluble fertilizers (Resende *et al.,* 2007), because of P conversion from soluble into less labile forms, while the rock phosphate release the nutrient gradually through time (Novais and Smith, 1999).

Eucalypts is the most important tree in the commercial plantation of Brazil. Currently, over 4 million hectares have been planted with eucalypts, which is the main source of wood for pulp and charcoal production (Barros and Novais, 1996; Fonseca *et al.,* 2007). Eucalypt responds to fertilization positively, and correct diagnosis and efficient use of fertilizer is essential to allow for corrective measures, including prescriptions of fertilizers or lime, to maximize plant productivity (Dell, 1996). Application of phosphate fertilizers is obligatory for all afforestation programs in Brazil (Barros et al., 2005).The present work compared the recovery efficiency of three natural phosphates with triple superphosphate in planting *Eucalyptus grandis* in the Cerrado area of Brazil.

2. Materials and Methods.

2.1.1 Description of Location and Experimental Site

Two field experiments were conducted at Carbonita (Longitude 17^0 44^1 W and Latitude 43^0 14^1S) and Bom Despacho (Longitude 19^0 35^1 W and Latitude 45^0 17^1E) in the state of Minas Gerais, Brazil . The mean annual rainfall at Carbonita was 1260 mm, the mean temperature 20^0C and the altitude of 726 m while in Bom Despacho the rainfall was 1476 mm, the temperature was23.3^0C and the altitude 703 m. The soil in both sites was classified as an Oxisol(Table 1), the vegetation is Cerrado a savannah type of vegetation.

The treatment consisted of sources and rates of P fertilizers application of the natural phosphate rocks, Araxa (AR, 24% P_2O_5 and 25% Ca) and Patos of Minas (FP, 24% P_2O_5 and25%Ca) were at the rates of 500, 1000, 2000 and 4000kg/ha . Concentrated phosphate rock - Arafertil (AF, 33% P_2O_5 and 35% Ca) was tested at 1000kg/ha. Triple superphosphate (TP) was applied at 250, 500, 1000 and 2000 kg/ha. *Eucalyptus grandis* seedlings were planted, spaced at 2.0 by 1.0m. Each experimental plot contained 600 seedlings. The treatments were laid out in random block with three replicates. The fertilizer s were broadcast applied and incorporated into the soil surface layer (0 to 20cm depth) by discing. Nitrogen and potassium were added as a 20-0-20 mixture at the rate of 150 kg/ha.

In a side trial, AR was broadcast applied at 1000kg/ha as indicated previously combined with triple superphosphate (TP) at 100,200 and 400 g/planting hole. Therefore, it was expected that AR would provide P for growth maintenance and TP would function as starter P fertilization.

2.2.1 Soil Analysis

At both sites (Carbonita and Bom Despacho) , soil samples were collected randomly at depths of 0 – 20cm, at five different points in each plot. The soil samples were placed into polythene bags and bulked for routine analysis. Physical characteristics were evaluated based on the equivalent particle size and moisture, in agreement with the methodology of Embrapa (1979) and field capacity was analyzed using transparent column method (Fernandes, 1967). The pH was determined in a ratio of 1:2.5 soil-water, with contact time of 60 minutes (Embrapa, 1979), potassium and phosphorus by Mehlish-1 (Vettori, 1969), extractable phosphorus by the method Bray-1 (Braga, 1980), and anions by exchange resin IRA-400 (Quaggio and Raij, 1983), exchangeable cation (Al^{3+}, Ca^{2+} and Mg^{2+}), as presented in the methodology of Vettori (1969). Organic matter was determined using Walkley - Black potassium dichromate oxidation method (Embrapa, 1979).Remaining phosphorus in the solution was evaluated using the method describe by Neves,(1983). The composition of the clay mineralogy was determined by the method of allocation (Resende *et al.,* 1987)

2.2.2 Plant data collection

The volume of the stem per hectare was estimated using height measurement, DBH, and counting the number of trees. For biomass determination, a tree of mean diameter (DBH) and height was felled per plot and its components (leaves, branches, stemwood, and stembark) weighed and sampled for dry matter determination (at 70^o C) and chemical analyses. Samples from the forest floor were also collected, weighed and chemically analysed. The weight per treatment was then used to extrapolate the weight per hectare basis. Using this information and the nutrient content, the amount of P and Ca in tree biomass was calculated.

The efficiency of phosphorous recovering (R) by the tree was estimated using the formula below (Prasad *et al.,* 1984)

$R = (E_m - E_t) \times 100/E$

R = recovering percentage.

E_m = Amount of P in the fertilized trees.

E_t = Amount of P in the unfertilized trees.

E = Total amount of P applied as fertilizer.

The equivalence between the natural phosphate rocks and the triple superphosphate (EqTS) was estimated using the formula below (Goedert *et al*., 1986)

$EqTS = (x_1 / x_2) * 100$

X1= Dose of total P in the form of triple superphosphate necessary to obtain the maximum production;

X2= Dose of the total of the appraised match source, necessary to obtain the same production.

EqTS represents the percentile relationship among the dose of the match in the forms of triple superphosphate and the match in the natural source tested.

The production level ''Y'', corresponding to 90% of the maximum production was selected to calculate EqST. The Y level and the corresponding rate of the natural phosphate were established from regression equation for the production of dry matter of tree above -ground parts of the plants as dependent variable of the rates of P_2O_5 of each tested natural source; it was then calculated using, the EqTS rate.

3. Results and Discussions.

Soils at both sites were acidic with low native nutrient content (Table1). The soil at Carbonita was more acidic with low pH than Bom Despacho. However, both values were sufficiently low to promote the solubilization of the phosphate rocks (Novais and Smyth, 1999) and release P to the plants. The use of four fertilizer sources at Carbonita and Bom Despacho gave varied results according to the rates applied but similar in effects when locations are considered (Tables 2 and 3). Soils at both sites maintained their characteristic acidic with pH ranging from 3.60 to 4.40. Compared with the control, all the fertilizer sources promoted slight increase in the pH of the soil.

Table 1: Initial physical and chemical analysis of soil samples collected at 0 – 20cm layer.

Characteritics	Carbonita	Bom despacho
pH	3.9	4.3
Al (cmol/kg)	1.00	1.40
Ca (cmol/kg)	0.00	0.07
Mg (cmol/kg)	0.01	0.01
K (mg/dm^3)	13	52
P(mg/dm^3)	1.0	1.1
Organic matter (%)	4.35	2.68
Fe_2O_3 (%)	11.7	9.3
AlO_3 (%)	29.26	23.78
SiO_2 (%)	14.05	20.49
TiO_2 (%)	1.06	0.89
P_2O_5 (%)	0.02	0.03
Coarse sand (%)	5	7
Fine sand (%)	14	10
Silt (%)	68	71
Clay (%)	13	12
Field capacity (%)	37.9	34.9
Kaolinite (%)	30.2	44
Goetite (%)	15.0	12.0
Gibsite (%)	23.0	7.0
P (remaining) mg/L*	16.1	22.4

* P content in the supernatant solution after shaking a solution containing 60mg/L P with 10g soil for 10 minutes and rest for overnight.

On acid soil, aluminum (Al) and iron (Fe) are the major soil elements responsible for retaining plant available P, while on calcareous soils, which generally have higher pHs, plant available P is mostly associated with Ca (Fixen and Grove,1990; Barberis *et al.,*1996; Sims *et al.,* 1998a, Maguire *et al.,* 2001a). It is expected that soils at Bom Despacho will be more productive than the soils at Carbonita, this is because it will contain more of P reserve (Tables 2 and 3), and low sorption capacity as inferred from Fe and Al oxide contents(Table 1). The content of P in soils amended with FP was 8.38% more than AR and 2% more than TP when combined rates of 1000 and 2000 kg/ha of fertilizer types were compared at 0-10 cm depth at Carbonita. At Bom Despacho,P content of soil which received FP was 30% more than AR and 26% more than TP.

3.1.1 **Effect of different sources and rates of phosphate fertilizer on the recovered phosphorus**

Table 4 presents the data on the effect of different sources and rates of phosphate fertilizers on the recovered phosphorous by Mehlich –I and Bray -1 extraction, taken at different soil depth at Carbonita and Bom Despacho. The result indicates that, incorporated fertilizers were restricted to the topsoil layer, particularly the layer 0-5cm. It was also observed that, the homogenization of the fertilizers was better in Carbonita than Bom Despacho. The maximum extracted values of P demonstrate a great deficiency of those soils; at different soil depth, in their natural condition (Table 3). This is consistent with the work of Lopes (1983). Mehlich and Bray-1 are acid extractants and solubulize natural phosphate. Soil test is not straight forward, despite various development in changing from old to new soil test methods(Gartley and Sims, 1994). In both sites, there were great similarities in the recovered values, independent of the extractant used and the soil layer considered (Table 4). More P was extracted by Mehlich-1 and Bray-1 were from soils that received application of Araxa phosphate. This may be attributed to the acidic characteristic of the extractant. Mehlich-1 extracted about 38.8% more P over the Bray -1 extractant at both Carbonita and Bom Despacho, with 18.4% higher content in the last site. This might be because of high pH values (4.3) recorded for Bom Despacho as against 3.9 for Carbonita. The result is consistent with the findings of Fabres (1986), Fullin (1986) and Fonseca(1987). Acidic conditions, active surfaces of Fe and Al oxides promotes high phosphorous fixation (Johnston, 2000 and Mendonça *et*

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*al.,*2006).The basis of all agronomic soil P tests is to extract a proportion of plant available P, but in most cases the amount of P extracted varies greatly between soil tests, as some are much stronger chemical extractants than others (Pote *et al.,*1999b).

Table 2: Chemical characteristic of soil at Carbonita 2 years after fertilizer application.

		pH-3/		P-2/		K-2/		Ca-3/		Mg-3/		Al-3/	
		Depth (cm)											
Source	Rates	0 - 10	10 - 40	0 - 10	10- 40	0 - 10	10 - 40	0 - 10	10 - 40	0 - 10	10 – 40	0 - 10	10 - 40
	Kg/ha			mg/dm³						cmol/dm³			
TP	250	3.85	4.10	7	1	21	11.5	0.00	0.00	0.00	0.00	1.28	0.69
	500	4.10	4.15	16	1.5	21.5	9.5	0.00	0.00	0.00	0.00	1.13	0.67
	1000	3.90	4.10	11	1	47	21.5	0.03	0.01	0.02	0.00	1.14	0.59
	2000	3.90	4.05	20	1.5	22.5	12.6	0.04	0.00	0.00	0.00	1.28	0.87
AR	500	3.85	4.20	3	1	21	13	0.00	0.00	0.00	0.00	1.25	0.71
	1000	3.90	4.15	6	1	25	14.5	0.00	0.00	0.03	0.02	1.32	0.71
	2000	3.60	4.05	19.5	2	25	12.5	0.19	0.00	0.00	0.00	1.27	0.66
	4000	4.20	4.25	35.5	1	25.5	14	0.27	0.000.00	0.03	0.00	1.07	0.65
FP	500	4.00	4.20	1.5	1	20	12	0.00	0.00	0.00	0.00	1.24	0.68
	1000	3.95	4.20	6.5	1	20.5	11.5	0.03	0.00	0.00	0.02	1.19	0.80
	2000	3.95	4.00	26.5	1.5	24.5	13.5	0.19	0.03	0.02	0.02	1.24	0.78
	4000	3.95	4.10	110	1	27	14.5	0.26	0.03	0.02	0.02	1.04	0.67
AF	1000	3.95	4.10	12	1	16	13	0.11	0.03	0.00	0.00	1.30	0.77
E	0	3.80	4.05	1	1	16	9.5	0.00	0.00	0.02	0.00	1.19	0.73

1_/ =Soil: water ratio 1;2.5 2_/ Mehlich extraction. 3_/ KCl mol/extraction.

Table 3; Chemical properties of soil at Bom Despacho after fertilizer application.

		pH1/		P-2/		K-2/		Ca-3/		Mg-3/		Al-3/	
Source	Rates	Depth(cm)											
		0 - 10	10 – 40	0 - 10	10 - 40	0 - 10	10 -40	0 - 10	10- 40	0 - 10	10 - 40	0 - 10	10 - 40
	Kg / ha					mg /dm³					cmol /dm³		
TP	250	4.00	4.45	3	1	41	31	0.00	0.00	0.00	0.00	1.6	1.25
	500	4.10	4.55	7.5	1	51	35	0.03	0.03	0.02	0.00	1.7	1.26
	1000	4.00	4.50	15	1	34	28	0.02	0.00	0.00	0.00	1.73	1.27
	2000	4.05	4.50	31	2	44	36	0.03	0.00	0.02	0.00	1.72	1.24
AR	500	4.00	4.30	7	1	44	32	0.08	0.03	0.00	0.00	1.59	1.32
	1000	4.20	4.50	6	2	36	30	0.06	0.03	0.02	0.02	1.59	1.23
	2000	4.15	4.40	33	2	42	27	0.13	0.03	0.00	0.00	1.51	1.31
	4000	4.10	4.50	93	2	45	39	0.24	0.04	0.00	0.00	1.38	1.25
FP	500	4.40	4.60	2	1	44	33	0.04	0.02	0.00	0.00	1.45	1.25
	1000	4.10	4.50	10.5	1	39	32	0.04	0.03	0.00	0.00	1.63	1.02
	2000	4.20	4.50	82	1	45	31	0.13	0.00	0.03	0.00	1.42	1.21
	4000	4.10	4.40	101	2	40	33	0.18	0.04	0.02	0.02	1.53	1.29
AF	1000	4.10	4.30	18	1	42	34	0.08	0.00	0.00	0.00	1.65	1.25
E	0	4.20	4.50	1	1	44	35	0.08	0.06	0.02	0.02	1.53	1.29

Where TP : Triple superphosphate. AR : Araxa phosphate. FP : Phosphate from Patos of Minas.
Also, AF : Concentrated Arafertil Phosphate and E : Control

Table 4; Phosphorus recovered by Mehlich-1 and Bray-1 extractants as affected by different sources and rates of phosphate fertilizer applied to eucalypt plantation in Carbonita and Bom Despacho, Brazil.

		Carbonita				Bom Despacho			
Source	Rates	Depth(cm)							
		0 -5	5-10	10 -20	20 -40	0 -5	5 - 10	10 - 20	20 -40
	Kg / ha	Mehlich -1 mg dm^{-3}							
TP	250	12.2	2.2	1.2	1.0	3.8	1.5	1.0	1.0
	500	5.8	26.6	1.5	1.0	12.5	2.2	1.2	1.0
	1000	17.2	4.5	1.0	1.0	27.8	2.9	1.5	1.0
	2000	30.0	11.2	2.6	1.0	56.8	4.9	1.2	1.0
AR	500	4.0	1.5	1.0	1.0	12.2	2.2	1.0	1.0
	1000	7.9	4.2	1.2	1.0	10	1.3	1.0	1.5
	2000	20.5	17.6	2.2	2.0	71.2	4.6	1.5	1.2
	4000	53.4	18	1.0	1.0	184	3.2	1.2	1.5
FP	500	2.2	1.2	1.0	1.0	3.0	1.5	1.0	1.0
	1000	9.5	2.8	1.0	1.0	9.8	10.8	1.2	1.0
	2000	33.2	20	1.0	1.0	98.8	45.2	1.5	1.0
	4000	161.5	57	1.0	1.0	155.5	44.6	1.8	1.2
AF	1000	19.2	5.2	1.0	1.0	32.9	2.6	1.2	1.0
E	0	1.0	1.0	1.0	1.0	1.0	1.2	1.0	1.0
	Kg / ha	Bray -1 mgdm^{3}							
TP	250	6.2	2.6	1.7	0.8	2.2	0.7	0.5	0.5
	500	4.0	12.2	1.7	0.8	18.9	2.7	2.6	1.0
	1000	21.5	8.6	0.9	0.8	26.1	2.6	0.8	0.6
	2000	40.2	22.8	1.9	1.4	91.6	5.3	1.8	0.6
AR	500	3.3	1.5	1.0	0.9	6.7	1.9	0.9	0.8
	1000	6.4	2.9	1.4	1.1	5.2	0.8	0.5	0.8
	2000	9.9	5.6	1.5	0.7	34.1	1.3	0.8	0.8
	4000	21	7.8	0.9	0.5	27.6	2.0	0.7	1.0
FP	500	2.2	1.4	1.2	0.8	3.0	1.3	0.9	0.7
	1000	7.5	2.3	1.7	1.2	3.6	4.7	0.8	0.7
	2000	13.9	4.7	1.3	1.2	16.4	4.7	0.8	0.7
	4000	36.9	10.3	1.2	0.9	35.4	4.0	0.6	0.6
AF	1000	5.7	2.1	2.0	1.4	4.0	1.6	0.9	0.8
E	0	1.5	1.4	1.0	1.2	1.0	0.9	0.7	0.9

TP= Triple superphosphate; AR= Araxa phosphate; FP = Patos of Minas; AF = concentrated Arafertil and E = control.

The relationship between the P recovered by the extratants, Mehlich-1 and Bray-1 from the 0-20cm layer and the rates of applied fertilizers was determined for each P source soil adjusting regression models (Table 5) . Phosphorus content by the two extractants increased lineally with the fertilizer rates . The only exception was observed with the application of TP when the Mehlich-1 was used on Carbonita soil. The steepness of the adjusted equations corroborates the highest recovery capacity of Mehlich-1 extractant, in the treatments with natural phosphate rock due to its acidic effect. Starting from the relationship between nutrient recovery, nutrient applied (Table 5), as well as of the quantity of nutrient necessary to obtain of 90% maximum production of dry matter. The obtained values were inferiors to the values found by Novais *et al.,* (1982).

The variation in the levels, between extractants and fertilizers source observed at the same place was caused by capacity differences in extractant in extracting the fertilizers. It was reflected in the magnitude of difference in the critical levels. When extractants are compared, higher values were obtained by the Mehlich-1 and Bray-1 extractants for natural sources, than for TP in both locality. With reference to differences between soils, higher levels of P were found in Bom Despacho, which is likely to be associated with buffering capacity of P as reflected in the soil different features. Carbonita soils have high capacity to fix P, as evidenced by the lower level of remaining P (Table 1), this justify the lower values of P found there.

Table: 5 Regression equations for the concentrations of phosphorous at by Mehlich-1 and Bray-1 extractant (0-20cm layer) in response to different sources and rates of phosphate at Carbonita and Bom Despacho, Brazil.

	Local source and Extractant	Equations	R2	Critical Level
Carbonita				mg/dm^3
ST				
	M	Y = 3.0641 + 0.009403 X	0.7079	-
	B	Y = 1.0761 + 0.016981*** X	0.9946	8.3
AR				
	M	Y= 01797 + 0.019050 * X	0.9818	6.4
	B	Y = 1.2756 + 0.006675 * X	0.9913	3.4
PP				
	M	y = -6.0313 +0.058700*** X	0.9260	8.3
	B	Y = 0.5454 + 0.011805*** X	0.9757	3.4
Bom Despacho				
ST				
	M	y = 0.4656 + 0.017250 * X	0.9951	7.7
	B	y = -0.9309 +0.027144 *** X	0.9408	10.4
AR				
	M	y = -2.9656 + 0.050391 *** X	0.9625	19.9
	B	y = 1.4945 + 0.008150 * X	0.6507	5.2
PP				
	M	Y = -1.1484 + 0.059544 *** X	0.8696	#
	B	Y = 0.4964 + 0.010085 * X	0.9923	#

Where : M = Mehlich -1; B = Bray – 1; ST = Triple Superphosphate; AR = Araxa phosphate and PP is Patos of Minas phosphate.
Also,
*Significant at 5% level of probability.
*** Significant at 0,1% level of probability.
- No result was obtained for the critical level (No significant coefficient)
No result obtained for the regression equation in relation to fertilizer applied.

Table:6 Effect of two types of phosphate on volume and height of *Eucalyptus grandis* at Carbonita and Bom Despacho as influeced by the combination of Araxa rock and triple superphosphate

Treatment		Carbonita		Bom Despacho	
AR	TP	Volume	Height	Volume	Height
kg/ha	g/hole	m^3/ha	m	m^3/ha	m
1000	0	81.43	7.33	127.12	9.59
1000	100	106.81	7.90	187.27	10.02
1000	200	132.71	8.33	235.26	11.65
1000	400	146.08	8.60	239.04	11.53
0	0	9.13	2.10	52.29	5.61

Combined applications of phosphate from soluble fertilizer (TP) and the natural phosphate of Araxa (AR) and there effects on volume and height of Eucalyptus (Table 6). Combining the soluble P (TP) and less soluble source (AR) resulted in better eucalypt growth performance (Table 6). In Bom Despacho stem volume and tree height was higher than the observed values at Carbonita. In Carbonita, application of AR in the hole promote gain in volume by 79%, when it was the compared with combined application of AR and 400g/canopy of ST. At Bom Despacho, the gains in volume were promoted relatively by the combination of AR with 400g/canopy of TP, with respect to the AR treatment with the AR alone it was 80%. Similar trend was also observed for dry matter and shoot height. The application of AR at carbonita soils would increase the volume, but in a less expressive way when compared with Bom despacho, this might be attributable to the behavioral differences in AR at the two localities and its solubilization. In Carbonita, the solubilization rates were higher than in Bom Despacho, less P was taken up by the trees(14.99 versus 18.72 kg/ha) because of soil higher P-fixing capacity and stronger water restriction for tree growth. In soils with high P-fixing capacity, the phosphate ion is adsorbed on Fe and Al hydrous-oxides as a more stable structure becoming unavailable to plants (Novais and Smyth, 1999; Stevenson and Cole, 1999). Also, from the standpoint of plant nutrition, the P in soils can be considered in terms of pools. Only a small fraction of the P occurs in water soluble forms at any time, and a small portion of the insoluble P-fraction appears to be more available to plants

Table 7: P dry matter yield by Eucalyptus grandis at Carbonita as affected by two types and different rates of phosphates.

Treatment AR	TP	Leaves	Branches	Canopy	$x^{-1}/$	Stem	Back	Trunk	$x^{-2/}$	Total-$^3/$	Forest Floor
kg/ha	g/hole		t/ha				t/ha			t/ha	
1000	0	3.48	4.06	7.54	21.82	22.07	4.14	27.00	78.18	34.54	12.33
1000	100	4.99	5.20	10.19	20.01	35.53	5.22	40.75	79.99	50.94	12.65
1000	200	4.58	5.33	9.92	19.37	36.09	5.17	41.26	80.63	51.18	11.97
1000	400	5.68	6.61	12.29	22.67	35.58	6.35	41.93	77.33	54.22	13.76
0	0	2.67	2.02	4.69	43.95	4.71	1.28	5.99	56.05	10.68	7.34

The effect of combination of both AR and TP on leaves, branches, canopy, bark and stemwood, for both Carbonita and Bom Despacho is as presented in tables 6, 7and 8 respectively. At Carbonita , increasing the rates of TP produced an increase in the values of parameters observed except at 200 g/hole, where values for leaves, canopy ,back, and forest floor had decreasing values when compared with 100 g/hole of TP applied(Table 7). However, the rates of AR were kept at constant of 1000kg/ha except in the control experiment, where there is no application of any type of phosphate on the treatment. Equally, at Bom Despacho , increasing rates of TP gave increases in values of leaves, branches and canopy, whereas stemwood and bark values were conflicting(Table). The trends of increases were not linear.

Table 8: P dry matter production by Eucalyptus grandis in Bom Despacho, as affected by rates of types of P fertilizers.

Treatment NP	TP	Leaves	Branches	Canopy	x-1/	Stem	Back	Trunk	x-2/	Total 3/	Forest Floor
Kg /ha	g/hole		t/ha				t/ha			t/ha	
1000	0	2.44	3.27	5.71	15.40	28.22	3.13	31.35	84.60	37.06	7.27
1000	100	3.47	6.82	10.29	13.73	59.25	5.42	64.67	86.27	74.96	7.80
1000	200	3.85	7.03	10.08	16.49	49.94	5.18	55.12	83.51	66.00	9.19
1000	400	4.04	7.61	11.65	16.67	52.94	5.27	58.21	83.33	69.86	8.38
0	0	2.21	3.61	5.81	26.3	14.58	1.71	16.29	73.70	22.10	9.53

Table 9. Estimation of maximum production attainable by Eucalypts from natural phosphate sources and Triple superphosphate, 2 years after planting at Carbonita and Bom Despacho, MG. Brazil.

Local Source	Maximum Production	Rate of P_2O_5 to obtain maximum production	Rate of P_2O_5 to obtain maximum production at 90%	Equivalent rate of P_2O_5 to obtain 90% maximum production	Equivalent Triple superphosphate-[1]/ (EqST)
			t / ha		%
Carbonita					
AR	48.57	0.783	0.326	0.328	101
FP	38.13	0.607	0.244	0.130	54
AF	37.39	0.330-[2/]	-	0.178-[3/]	54-[3/]
Bom Despacho					
AR	62.06	0.752	0.453	0.220	49
AF	50.02	0.330-[2/]	-	0.168-[3/]	52-[3/]

Where ,
-[1]/ =Percentile relationship between the rates of Triple superphosphate and tested sources in terms of P2O5 , to obtain the same production.
-[2]/= Single rates tested in the experiment.
-[3]/ = Equivalence of a test.

At Bom Despacho, there was better efficiency for the whole range of TP rates tested(Table 9) . Efficiency tended to become increasingly differentiated, when the quantities of fertilizers applied were increased. From the response, TP would provide greater efficiency. Thus, the equivalent ST (EqST) of AR to 90% of the maximum production would be little more than 100% (Table 9), demonstrating the full equivalence between fertilizer sources in Carbonita .For FP, EqST was conducted only in Carbonita, since the response to rates of this fertilizer source was not significant in Bom Despacho. At Carbonita, TP was more efficient in total dry matter production than that of FP. For the entire range of rates tested, FP had a value of 54% EqST, showing the worst performance of phosphate in the same locality compared with AR . Oliveira, *et al.,* (1984) found, an average values of 50% Eqst values for AR for corn, wheat and soybean in different cultivation in cerrado savannah soil, and for FP it was about the 45% . But, Geodert and Lobato (1984) observed values of about 33% EqST for AR, in a cultivation sequence of wheat, soybean, (two years)., rice , sorghum and grass-andropogon (three years) in e savanna soil in the case of FP, EqSt was around 45%. In both sites (Carbonita and Bom Despacho), TP tends to be a better P-source than AF (Table 9) as indicated by the lower amount needed to obtain the maximum biomass yield. Although, as stated earlier, phosphate fertilizer recommendation for growing Eucalypts is a function of many factors (soil type, species type, cropping pattern and cropping system), a blanket recommendation of 60-70kg/ha of triple superphosphate is acceptable in growing Eucalypts in the cerrado areas (Barros and Novais, 1996).

4. Conclusions.

In both sites, there were great similarities in the recovered P values, independent of the extractant used and the soil layer considered. More extraction by Mehlich-1 and Bray-1 were observed in soils that received application of Araxa phosphate. Combined fertilizer sources (Araxa and triple superphosphate) promoted expressive increases in volume and height of the aerial parts of eucalypts, in the two localities. The equivalence ST (EqST) in Carbonita was approximately 100% for NP and 54% for FP. In Bom Despacho, the EqsT of 49% was obtained for NP. For FP. the EqST, calculated for the single rate tested, was 54% in Carbonita, and 52% for Bom Despacho.

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References:

Amberger, A. (2006). Soil fertility and plant nutrition in the tropics and subtropics. International Fertilizer Industry Association. International Potash Institute. www.ferilizer.org and www.ipipotash.org

Awodun, M. A (2007) Effect of goat manure and urea fertilizer on soil , growth and yield of okra (Abelmoschus esculentus (L) Moench). International Journal of Agricultural Research 2(7) 632 – 637.

Awodun, M. A; Barros, N. F; Novais R. F and Dantas S. V (2012) Effect of phosphorus fertilizer on biomass, phosphorus and calcium uptake by Eucalpts. New York Science Journal 5 (11).

Barberis, E. F., Ajimone, M.; Scalenghe. R.; Lammers, A.; Schwwertmann, U.; Edwards, A. C. ; Maguire, R.; Wilson, M. J.; Delgado, A. and Torrent, J. (1996). European soils over fertilized with phosphorous. Part 1. Basic properties. Fert. Res. 45; 199 – 207.

Barros, N .F.,Novais ,R. F., Neves, J.C. L. and Gomes,J. M. (1982). Interpretaçao de análises químicas de solo para o crescimento de Eucalyptus spp. . Revista Arvore, Vicosa .v6, N^1 p 38-44.

Barros, N. F. and Novais, R. F. (1996).Eucalypt Nutrition and fertilizer regime in Brazil. In; Nutrition in Eucalypts.{eds} Peter, M. Attill and Mark, A. Adam. CSIRO. Pp 335-355.

Barros, N.F.; Neves, J.C.L and Novais,R.F. (2005).Fertilidade de solos , nutrient e producao florestal. Visao agricola , Piracicaba,v 4.p.76-79.

Braga, J. M (1980). Availiaçao da fertilidae do solo. Vicosa . UFV. Imprensa Universitaria. Parte 1: Analise quimica 87p.

Dell, R. (1996). Diagnosis of nutrient deficiencies in Eucalypts. In: Nutrition of Eucalypts (eds) Peter, M. Attwill and Mark, A. Adams. CSIRO. 439 Pp

Eliason, R; Lamb, J. L and Rehm, G. W. (2001) .Colorimetric and ICP measurement of P extracted by Mehlich-3 procedure. In: Annual meetings abstract [CD-ROM] ASA, CSSA and SSSA, Madison. WI.

Embrapa. (1979).Manual de metodos de analyses de solo. Rio de Janeiro Servico National de Levantamento e Conservaçao de Solos.

Fabres, A. S. (1986). Diponibilidade de fosforo em solos e concentraçoes criticas de diferentes fracoes de fosforo em plantas de alface cultivadas em amostras de diferentes solos. Vicosa UFV, Imprensa. Universitaria. 39p. (Tese M. S.)

Fernandes, B. (1967).Retençao e movimento de agua no solo. Vicosa. UFV. Impresa Universitaria. 48p (Tese. M.S).

Fixen, P. E and Grove, J. H. (1990). Testing soils for phosphorous. P. 141-180. In R. L. Westerman (ed) Soil testing and plant analysis. SSSA. Madison. WI

Fonseca, D. M. (1987). Niveis criticos de fosforo em amostras de solos para o estabelecemento do Andropogon gayanus , Brachiaria decumbens e Hyparrhenia rufa .Vicosa. UFV. Imprensa Universitaria. 146p (Tese M.S)

Fonseca, S.M.F; Alfenas, A.C.; Alfenas, R.F.; Barros, N.F and Leite,F.P. (2007). Cultura do eucalipto em areas montanhosas. SIf. UFV, Vicosa. Pp43.

Fullin, E .A. (1986). Avaliaçao do fosforo disponivel do solo pelo matodo da resina trocadora de enions. Vicosa. Vicosa. UFV. Impresansa Universitaria. 76p (Tese M. S).

Gartley, K. L and Sims, J. T(1994). Phosphorous soil testing; Environmental uses and implications Common. Soil Sci.Plant Anal. 25; 1565 – 1582.

Goedert, W. J. 1984. Availaçao agronomica de fosfatos em solo de cerrado.R.Bras. Solo. Campinas. 8. 97- 102.

Goedert, W. J., Sousa, D. M. and Rein, T. A. (1986). Principies metodologicos para avaliacao agronomica de fonts de fosforo .Planltina, DF ,EMBRAPA-CPAC. 23p {Documento, 22}.

Gonçalves, J .L.M., Raij, B. Van., Gonçalves, J. C.(1997). Florestais. In: Raiji,B. Van., Cantarella, H., Quaggio, J . A.,Furlani,A.M.C. Recomendação de adubação de calagem para o estado de São Paulo. 2 Ed. Compinas: Institut Agronômico de Compinas, p 247-259. { Boletim Técnico, 100 }

Gonçalves,J. L. M.; Stape, J. L.; Beneditti, V.; Fessel, V. A G.; and Gava, J.L. (2004). An evaluation of minimum and intensive soil preparation regarding fertility and tree nutrition. In(eds): Gonçalves. J. L. M and Benedetti, V.; translation by Ken Mc. Forest Nutrition and Fertilization. Piracicaba: IPEF. 421p.

Grierson,P. F., Paul,S., Generose, N., Simone, R. And Nick, B. C.(2004). Phosphorous Dynamics and mobilization in plants. In: Below- ground Interactions in Tropical Agroecosystems, Concepts and models with multiple plant components. {Eds} M. Van Noorwijk, G. Cadish and C.K Ong. CAB International. 440 pp. www.cabi-publishing.org.

Johnston, A . E. (2000). Soil and plant phosphate. International Fertilizer Association. Paris. Pp 46. www.ferilizer.org

Leandro, S. S.; Sidnei, K. R.; Anderson, C. R.; Danilo, R.S. and Fabio, H. G. (2003). Estimation methods of phosphorous availability for rice flooded soils in Rio Grande do Sul. Brazil. R. Bras. Ci. Solo, 33 : 207 -216.

Lopes, A. S. (1983). Solos sob cerrado: caracteristicas propriedades e manejo . Piracicaba, Associaçao Brasileira para a Pesquisa da Potassa e do Fosfato. 162p.

Maguire, R. O.; Foy, R. H.; Bailey, J.S. and Sims, J. T. (2001a). Estimation of the phosphorus sorption capacity of acidic soils in Ireland. Eur. J. Soil Sci. 52: 479- 487.

Mendonca-Santos, M. L.; Santos, H. G.; Coelho, M. R.; Bernardi, A. C.; Marchado, P. L.; Manzatto, C. V. and Fidalgo, E. C. (2006). Soil and Land Use in the Brazilian Amazon. In: Soil Biodiversity in Amazonian and other Brazilian Ecosystem. {eds} F. M.S. Moreira; J. O. Siqueira and L. Brussaard. CAB International. Pp 12 -42. www.cabi-publishing.org

Mokwunye, A .V., Chien, S.H. and Rhodes, E.(1986). Phosphorous reaction with tropical Africa soils. In; Mokwunye, A.U and Viek, P.L.G. {eds} Management of nitrogen and phosphorous fertilizers in sub-saharan Africa. Martinus Nijhoft. The Netherlands. Pp 253-281.

Mokwunye, A. V. and Vlek, P. (1986). Management of nitrogen and phosphorus in Sub-Saharan Africa. Development in Plant and Soil Sciences. M. Nijhoff Publishers, Dordrecht, The Netherlands.

Neves, J. C. L (1983). Aspectos nuticionas em mudas de eucalyptus spp tolerancia ao alummino e niveis de fosforo no solo Vicosa, UFV, Impresa Universitaria.87p (Tese. M.S)

Novais, R. F. ; Barros, N. F. ; Neves, J. C and Couto, C. L. (1982). Niveis criticos no fosforo para o eucalipto. Revista Arvore. Vicosa, 6 29-37.

Novais, R.F. and Smyth, J. T (1999). Fosforo em Solo e Planta em Condiçoes Tropicas. Universidade Federal de Vicosa. Vicosa. Brazil.

Oliveira, E. L . ; Muzilli, O. ; Igue, K. and Tornero, M. T. T.(1984). Avaliaçao agronomica de fosfatoss naturais. R. Bras. Ci Solo. Campinas. 8. 63-71

Pote, D. H.; Daniel, T. C.; Nichols, D. J.; Moore, P. A.; Miller, D. M. Jr. and Edwards, D. R. (1996b). Relationship between phosphorous levels in three Ultisols and phosphorous concentrations in runoff. J. Environ. Qual. 28: 170 – 175.

Prasad, K.G., Gupta, G. N., Mohan, S., Subramanian, V. and Manivachakam, P.(1984). Fertilization in *Eucalyptus grandis* on severely truncated soil. Indian Forester. Dehra Dun.110; 1033-48.

Quaggio, J. A. And Raij, B 1983. Metodos de analyses de solo para fins fertilidade. Campinas, Instituto Agronomico. 39p.(Boletim Tecnico,81).

Resende, A.V., Furtini, A. E., Alves, V. M. C., Curi, N. J., Muniz, J.A., Faquin, V and Kinpara, D. J.(2007). Phosphate efficiency for corn following Brachiaria grass pasture in the cerrado region. Better Crops with Plant Foods. Vol.xci {91} No 1.pp 17-18.

Resende, M.; Bahia, A. F. C. and Braga, J. M. (1987) . Mineralogica de argilla de latosssols estimada por alocaçao a patir do teor total de oxidos do ataque sulurico. R. Bras. Ci. Solo Campinas. 11: 17 – 23

Sims, J. T and Gartley, K. L. (1996). Nutrient management handbook for Delaware Coop: Bull; 59; Univ. of Delaware, Newark.

Sims, J. T.; Hodges, S. and Davis, J. (1998a). Soil testing for phosphorous; Current status and uses in nutrient management programs. P. 13 – 20; In J. T. Sims {ed} Soil testing for phosphorous Environmental uses and limitations. Southern Coop. Ser. Bull. 389. SERA-IEG 17 USDA-CSREES Regional Committee. Available at http://sera17.ext.vt.edu/publications/sera17-index.htm {verified 9 July 2004}.

Stevenson, F. J and Cole , M. A (1999). Cycles of soil. Carbon, Nitrogen Phosphorous, Sulfur Micronutrients. 2nd Edition pp 427. John Wiley & Sons Inc.

Vettori, L. (1969). Metodos de analyses do solo. Rio de Janeiro . Equipe de Pedologia e fertilidade do solo. Rio de Janeiro, Ministerio da Agricultura. 24p. (Boletim Tecnico,7).