

Short communication

Solubilization of Phosphorus in Phosphate Fertilizers After Treatment With Different Organic Residues

ABSTRACT

Phosphorus is an element of low mobility in soil. It is combined with iron compounds, aluminum and calcium, and organic matter. Inorganic compounds in the soil phosphorus are conditioned by pH, type and quantity of minerals in the clay fraction. This study aimed to evaluate the influence of three types of organic waste and the incubation time in the solubilization of three sources of P in the soil of the northeastern semiarid region. The treatments were arranged in a factorial 3 x 3 x 7, and a solo, 3 sources of phosphorus (P), 3 organic waste and 7 incubation times. The treatments were arranged in a randomized block design with three replications. All soil samples were determined: pH, Ca and P concentrations, 10, 20, 30, 40, 50, 70 and 90 days of incubation. The data were submitted to ANOVA and Tukey test to compare the average of treatments. For factor incubation time regression equations were set at the level of 1% probability. The organic waste more efficient in reducing the pH and solubilize phosphate was *Leucaena*; The biofertilizer was the most efficient source of phosphate in phosphorus available for soil.

Keywords: fertilizer, availability, soil, biofertilizers.

1. INTRODUCTION

The soils of the Brazilian semiarid region contain low levels of phosphorus (P), one of the elements that most limit productivity in this region. Consequently, to obtain high yields, the addition of phosphate fertilizers is required. It is known that only a fraction of the P applied to the soil, varying from 15 to 25% is used, and the rest remains in the soil, being part adsorbed by the colloids, part combined with the soil components, remaining in insoluble form and, also, another part immobilized by microorganisms [1].

Practically, there are no detailed studies on the desorption of P in soils of the northeastern semiarid, perhaps as a consequence of the lack of use of fertilizers, since, the P is an element whose use is quite expensive in agriculture and presents great power of adsorption to soil colloids, which highlights a need to use alternative sources, such as fertilizers of organic origin, which present lower costs than conventional fertilizers and greater residual effect.

However, since this source of P has low solubility, one of the alternatives for this is to increase the activity of the microbiota that participates in the solubilization of P in the soil, thus increasing the production of organic acids and other products of microbial metabolism [2,3], which can be increased with the addition of organic compounds to the soil [4].

Through this process, there is a slow release of phosphorus of phosphate sources (FF), but continuous, in contrast to soluble fertilizers that provide high content of soluble phosphorus immediately after its application.

In this way, it was tried to evaluate the influence of three types of organic residues and the incubation time in the solubilization of three P sources in the Northeastern semi-arid soil.

2. MATERIAL AND METHODS

The experiment was conducted in the Laboratory of Physics and Soil Management of the Department of Agroecology, of the Federal Institute of Alagoas, Câmpus Piranhas-AL, in 2016.

It was selected a Luvisolo soil characteristic and with greater predominance in the region, three sources of phosphorus: a biofertilizer of rocks, a natural phosphate (Fertipar) and the simple superphosphate, three organic residues: one legume (*Leucaena leucocephala*), one earthworm humus and tanned bovine manure.

Vegetable residues were ground in forage, humus and manure sieved in a 2 mm sieve. These materials were applied to soil samples, collected in the 0-20 cm layer. After collection, the soil was air-dried, stripped and sieved in a 2 mm mesh and submitted to chemical analysis (Table 1), according to [5]. The pH in water was determined in the ratio 1: 2.5 soil: solution.

Table 1: Chemical characteristics of the soil used in the experiment. Piranhas. IFAL, 2016.

pH	P	Ca ²⁺	Mg ²⁺	Al ³⁺	Na ⁺	K ⁺	H+Al
mg dm ⁻³		cmol _c dm ⁻³					
6.90	11.00	12.50	3.20	0.00	0.07	0.85	1.65

The available phosphorus was determined by colorimetry using ascorbic acid as a reducing agent after extraction with 0.05 mol L⁻¹ HCl solution and 0.025 mol L⁻¹ H₂SO₄ solution (Mehlich). The exchangeable potassium and sodium were determined by flame photometry, after extraction with Mehlich-1, while the calcium, magnesium and exchangeable aluminum was be extracted with 1mol L⁻¹ KCl and determined by titrimetry. The potential acidity (Al + H) was evaluated by extraction with 0.5 mol L⁻¹ calcium acetate at pH 7.0.

Table 2: Main characteristics of the organic residues used in the experiment. Piranhas. IFAL, 2016.

Residues organic ¹	Parameters						
	K	Mg	Ca	P ₂ O ₅	C	N	C/N
	g kg ⁻¹						
Leucena	3.60	18.10	38.50	4.50	500.00	26.00	19
Humus	12.80	3.88	5.80	8.70	190.00	15.00	12
Bovine manure	14.28	4.65	9.35	5.75	315.50	21.10	15

The dose of 600 kg ha⁻¹ of P₂O₅ was applied. The organic residues were submitted to nitric-perchloric digestion for subsequent determination of Ca and Mg contents by complexometry, P by colorimetry and K by flame emission photometry [5]. Total organic carbon was determined by the method of [6]. The N content was determined in 100 mg of sample digested with sulfuric acid in the presence of a mixture of copper sulphate and potassium

sulphate, by the kjeldahl method [5] (Table 2). Fertilizers were characterized according to methodology described in [5] (Table 3).

Table 3. Principal characteristics of the phosphate fertilizers used in the experiment. Piranhas. IFAL, 2016.

Phosphate fertilizers ^{1/}	Parameters						
	P ₂ O ₅ total	P ₂ O ₅	P ₂ O ₅	P ₂ O ₅ CNA+ water	MgO	CaO	SiO ₂
	-----%						
SS	18.7	-	10.3	-	-	12.0	-
BFR	25.6	-	16.6	-	5.0	15.0	-
FN	27.7	-	19.0	-	-	22.8	12.3

^{1/} SS = Simple Superphosphate; BFR = Rock of Biofertilizer; FNF = Fertipar Natural Phosphate

It was used as experimental unit plastic bags with a capacity of 500 ml with 100 g of soil. After mixing the phosphates, residues and soils, these will be maintained in the field capacity, using distilled water, and incubated for 90 days. Up to 50 days of incubation, samples were taken every 10 days. After 50 days, the samples were taken at intervals of 20 days, completing the 90 days of incubation. Immediately after the withdrawal of samples the same were submitted to pH and P analysis according to [5]. The available P was extracted with 0.5 mol L⁻¹ sodium bicarbonate solution, with pH adjusted to 8.5 in the ratio 1:10 (soil: solution) [7]. The obtained extract was purified with activated charcoal, filtered and an aliquot of clarified extract was used for determination of P by colorimetry, using the phosphomolybdic complex method according to [8].

The experiment consisted of a factorial 3x3x7 (phosphate, residue, time), with three replicates, being the treatments were arranged in a randomized block design. The data were submitted to analysis of variance and, afterwards, the Tukey test was applied to compare the means of the treatments. For the incubation time factor, regression equations were adjusted, at a 1% probability level.

3. RESULTS AND DISCUSSION

The analysis of variance indicated a difference (P = 0.01) for the pH value and Ca and P contents as a function of the factors studied and for all interactions tested (Table 4).

Table 4. Test F in function of the effects of the factors organic residues (R), phosphorus sources (FF) and incubation times (T) for the variables pH, contents of P and Ca. Piranhas. IFAL, 2016.

FV	Parameters	
	pH	P
Organic Residues (R)	46.65**	5.58**
Phosphorus Sources (FF)	53.85**	19.43**
Tempo (T)	14.53**	145.54**
R x FF	8.41**	14.32**
T x R	13.08**	70.64**
T x FF	3.78**	67.62**
R x FF x T	3.02**	148.29**
CV (%)	1.96	3.55

** significant at the 1% probability level.

Of the added residues, that of Leucena resulted in lower mean pH values relative to the phosphorus sources (FF) used (Table 5). This behavior may be a reflection of increased microbial metabolism with production of acidifying compounds [9]. The leucine residues present higher C / N ratio [10,11] compared to other residues and, therefore, greater resistance to decomposition [12].

Table 5. Mean of incubation times of pH values, P content for the type of residue applied and the source of P used. SS = Simple Superphosphate; BFR = Biofertilizer of Rock; FNF = Fertipar Natural Phosphate. Piranhas. IFAL, 2016.

Residues	SS	BFR	FNF
pH			
Leucena	7.18 a B	6.79 b B	7.20 a A
Humus	7.56 a A	7.25 b A	7.21 b A
Bovine manure	7.62 a A	7.28 b A	7.33 b A
P (mg dm ⁻³)			
Leucena	27.51 b A	32.83 a A	32.02 a A
Humus	26.56 a A	23.12 a B	26.18 a B
Bovine manure	27.15 b A	31.30 a A	19.56 c C

Means followed by the same lowercase letter in the line do not differ from each other by the Tukey test at the 5% probability level; Means followed by the same capital letter in the column do not differ from each other by the Tukey test at the 5% probability level.

This higher resistance to decomposition, besides a higher content of N, resulted in a greater decrease of the pH of the soil to the detriment of the residues of humus and bovine manure. The higher acidity observed in treatments with Leucena residue resulted in a higher available content of P only when associated with the biofertilizer (Table 5), and bovine manure provided, on average, lower release of P, presenting differences of the other residues in the phosphates of simple superphosphate and natural phosphate.

The content of P available from the other phosphates is independent of the type of residue used. One of the conditions for the solubilization of phosphates is the existence of acidic soil conditions [13].

The greater decrease of the pH of the soil and increase of the availability of P of the phosphates when in the presence of residues of leguminosa, may be due to the higher ammoniacal N content in these. Organic waste has a higher concentration of N [14] which after oxidation produces acidification of the environment due to the transformation of ammonium into nitrate. As is known, acidification is one of the necessary conditions for increased solubilization of phosphates [13]. The solubilization of P may also result, of the production of CO₂ and organic acids from the mineralization of C-organic and the production of enzymes and chelating and complexing compounds by the microbiota. These factors may exert direct solubilizing action on phosphates. The reaction of CO₂ with water, in basic media, releases H⁺ and HCO₃⁻ ions being able to solubilize Ca and Mg carbonates and phosphates [15,16].

As for P, there is a great fluctuation in the levels released, in relation to the incubation time. For the three sources used, it was initially observed a slow release of P, in the first 10 days, occurring, from there great increase in the available P content, reaching the maximum value between 30 and 50 days of incubation (Figure 1). Some researchers studying the kinetics of P release by phosphate solubilizing microorganisms, observed variations in solubilized P contents giving rise to several peaks of maximum concentration [17,18,19,20]. These changes in P concentration may be a consequence of their precipitation with organic

metabolites [17,20] and / or of the formation of compounds with the excreted organic acids, which are subsequently used as energy source or nutrient, which can occur several times in the middle [18]. Another alternative to explain this behavior is the difference between the release and the assimilation of P by microorganisms.

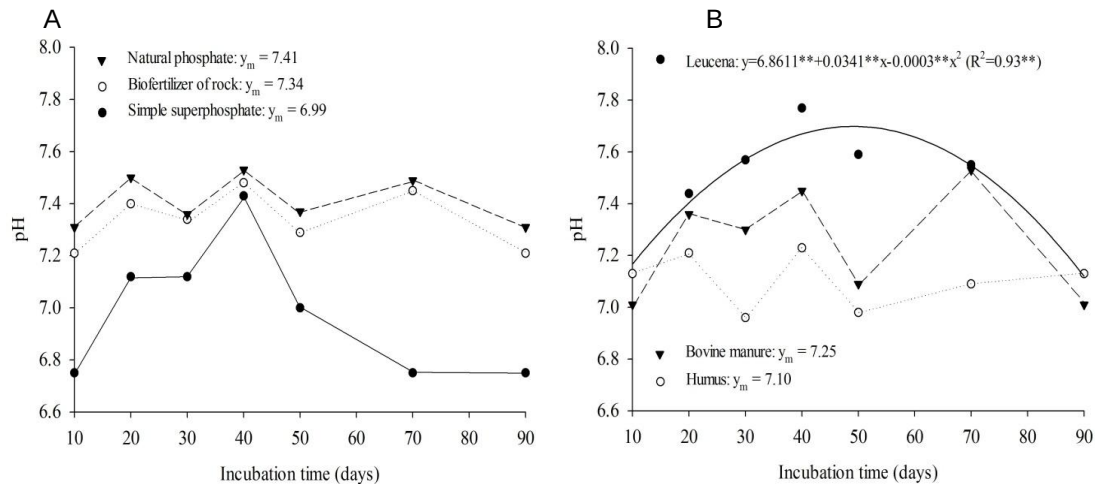


Figure 1. Application of biofertilizer phosphorus sources, natural phosphate and simple superphosphate (A); and leucine residues, humus and bovine manure (B) on pH change as a function of incubation time.

The upward trend observed at the beginning of the incubation may reflect a microbial solubilization of the added phosphate, while the subsequent drop may reflect microbial immobilization in response to increased microbial metabolism. Similar results were observed by [4], using as carbon source soybean straws, corn and sugarcane bagasse, and [21] after addition of glucose. In addition, the decrease in P concentration in the solution may be associated with its attachment to the colloidal particles [13].

Regression equations were adjusted using dependent variables, pH (Figure 1) and P (Figure 2), and the incubation time as an independent variable. Quadratic equations were fitted for most treatments. In relation to soil pH, their values remained constant throughout the incubation time for all treatments.

Leucena

Humus

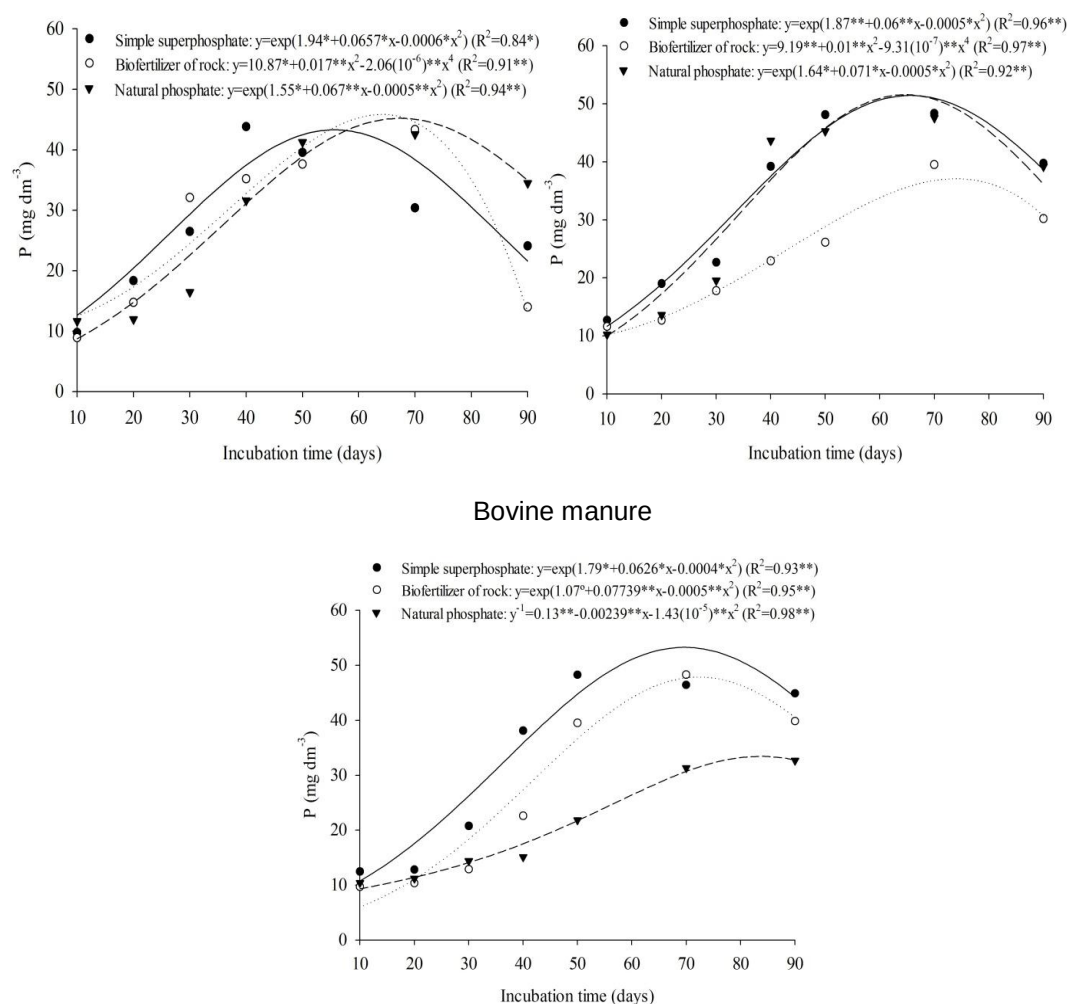


Figure 2. Application of legume residues, humus and bovine manure in the availability of P as a function of incubation time.

4. CONCLUSION

The most efficient organic residue in reducing pH and solubilizing phosphate was Leucena.

The biofertilizer was the most efficient source of phosphate to make phosphorus available to the soil.

In the first 10 days, it was found that the release of P was slow for the three sources of P. From there, we observed an increase in the P content available.

202 **COMPETING INTERESTS**

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204 Authors have declared that no competing interests exist.

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