Phosphorus availability and plant production in a Ferralsol from South Brazil

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Abstract

The use of phosphate fertilizer has promoted changes in phosphorus fractions and availability in soil, that highlights the requirement of more studies to understand phosphorus dynamics in soil, and to develop cultivation strategies to increase crop grain yield under phosphate fertilization. The work aimed to evaluate changes in soil phosphorus availability in sequential crop seasons, under effects of phosphate fertilizer sources and cover crop plants. The experiment was carried at Technological Federal University of Paraná, Dois Vizinhos, PR, Brazil. The soil is a Ferralsol, with high level of available P. Experimental design was a factorial 3x8, in randomized blocks, with three replicates and 5x5 m plots. Treatments were composed of natural phosphate and soluble phosphate, and a control. During winter season, the seven cover crops were: vetch, white lupin, radish, ryegrass, black oat, clover and pigeon pea, and a witness with no cover crop. Brazilian Ferralsol, with high level of available P, does not increase plant grain yield with sources of phosphate fertilization. Available P in soil changes markedly with phosphate fertilization, especially in the surface layer (0-5 cm). Important results are expected in soil P availability after winter cover crops.

Key Words

Soluble phosphate, natural phosphate, cover crops, organic acids

Introduction

The use of soil conservation systems, like no-tillage, besides the promotion of better productivity, maintain the environment in a more stable condition, but it causes changes in the dynamics of organic matter and nutrients in soil. No-till has produced great changes in phosphorus (P) fractions in soil, increasing organic fractions and accumulating organic and inorganic P in near surface layers, as result of no mobilization or from the releasing of organic compound that can compete for P adsorption sites in soil (Rheinheimer 2000).

Absorption of P by plants is dependent of the stored P in soil solid phase and of the releasing index to soil solution (Tisdale *et al.* 1985). Phosphorus concentration in soil solution is called intensity factor, and the amount stored in solid phase, linked to adsorption sites and possibly released to soil solution when that fraction is depleted, is called quantity factor (Novais & Smyth 1999). However, the quantity factor is composed of P fractions of different releasing kinetics, that do not permit a simple correlation between the factors intensity and quantity, to estimate the availability of this nutrient for plant absorption. On this way, it is important to know the forms of P in soil solid phase, their dynamic behavior, and the possible contribution to maintain the available levels for plants.

Tropical and subtropical soils, predominant in Brazil, are normally very weathered soils, with great amounts of kaolinite and oxides, with more than 25% of them being very deficient in available P (Sanchez & Logan 1992). The content of total P and its distribution in fractions varies according to parent material and soil management practices, that makes the P availability very variable in each soil type, region, or management practices adopted.

When a phosphate fertilizer is applied to soil, physical-chemical reactions occurs, that promotes incorporation of phosphate into complex substances, that control the availability of P in soil (Kaminski & Peruzzo 1997). There is a necessity, therefore, to better understand the dynamics of P associated to organic compounds production and decomposition in soil, on the way to develop management strategies to maintain or increase crop grain yield, maximizing the use of P linked to these compounds (Rheinheimer 2000).

The work aimed to evaluate changes in soil phosphorus availability in sequential crop seasons, under effect of phosphate fertilizer sources and cover crop plants. However, only the first season's results are reported here.

Material and Methods

Present work was carried at Technological Federal University of Paraná, Dois Vizinhos, PR, Brazil, located in South Brazil, at latitude 25º42'S, longitude 53º08'W and altitude of about 561 m. The soil of the

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experimental area is a Ferralsol (WRB-FAO 1998). Soil chemical analysis is presented on Table 1. It shows that soil P level is classified as high and base saturation is good for this soil, from surface to 20 cm depth layer.

Before the experiment was established, the area was cultivated under no-tillage system for seven years, with commercial crops over the summer, like corn and soybean, and cover crops over the winter, like vetch and oat.

The experiment began in December, 2008, with bean planting. Experimental design was a factorial 3x8 in randomized blocks, with three replicates and 5x5 m plots. Treatments on the summer bean crop were: natural phosphate (NP, 9% of soluble P_2O_5) and soluble phosphate (SPS, 17% of soluble P_2O_5), applied at recommended rate for the crop (135 kg of P_2O_5/ha), and control (witness) without phosphate. Potassium fertilization was applied at sowing (40 kg of K_2O/ha) and nitrogen was applied 20 days after germination (40 kg of N/ha).

Table 1. Chemical soil results before experiment establishment in the summer of 2008/2009. UTFPR, Dois Vizinhos, PR, Brazil.

Depth layer	pH $CaCl_2$	OM	P (resin)	Al^{3+}	H+Al	Ca^{2+}	Mg^{2+}	K^+	V
---- cm ----		g/dm^3	mg/dm^3	----------- cmol$_c$/dm^3 ------------					%
0-5	5.4	40.2	8.11	0.00	3.42	5.40	2.69	0.50	71.5
5-10	5.2	40.2	9.73	0.00	3.68	5.62	2.98	0.28	70.7
10-20	5.0	26.8	4.80	0.08	3.97	4.32	2.13	0.13	62.4

Bean dry mass production at flowering, and grain yield were measured. Dry mass was determined with samples dried at 65ºC for 72 hours. After the crop material was milled through a 2 mm sieve, it was evaluated for nutrient tissue accumulation, by Tedesco *et al*. (1995) methodology. Grain yield was determined by harvesting the plot central area, and after grain separation, it was weighed and corrected to 13% moisture. During the following winter season, cover crops were planted on that area, being: vetch (*Vicia sativa*), white lupin (*Lupinus albus*), radish (*Raphanus sativus*), ryegrass (*Lolium multiflorum*), black oat (*Avena strigosa*), clover (*Trifolium repens*), pigeon pea (*Cajanus cajan*), and a witness without a cover crop. The cover crops were planted in May, 2009. Grass cover crops received 40 kg of N/ha 20 days after germination. On the cover crops, dry mass production was measured at flowering and nutrient tissue accumulation, with the same methodology used for bean.

Soil P availability was evaluated before experiment establishment, as table 1, and after each crop season, in the depth layers 0-5, 5-10 and 10-20 cm. Available P was measured with anion exchange resin methodology. The data were submitted to ANOVA analysis and significant means were compared by t test (LSD) at 5%, by the program SAS 8.2 (SAS Institute 2001).

Results and Discussion

The original soil showed a high level of available P in all evaluated layers, from surface to 20 cm, which probably was enough for a good bean development, as this crop does not demand high amounts of P from the soil (Embrapa 2005). The data in table 2 illustrates this, because the amount of P accumulated in plant tissue at flowering stage was about 5.0 kg/ha, a very low quantity compared to the amount applied via fertilizer. However, the main idea of the work is to evaluate what will happen with the amount of P applied via fertilizer after the cover crop winter season, this explains why the higher fertilization rate was used before bean cultivation. Dry mass accumulation in plant tissue and other nutrients evaluated does not differ statistically between sources of P.

Table 2. Dry mass production and nutrient accumulation on bean plant tissue under sources of phosphate fertilizer. UTFPR, Dois Vizinhos, PR, Brazil.

Treatment	Dry mass	Nutrients on plant tissue (kg/ha)				
	kg/ha	N	P	K	Ca	Mg
Witness	1404 ^{ns}	46.0 ^{ns}	4.3 ^{ns}	40.1 ^{ns}	31.0 ^{ns}	7.2 ^{ns}
Super Phosphate Simple	1507	50.1	5.6	42.6	31.9	8.9
Natural Phosphate	1281	39.8	4.6	36.0	27.6	7.8
CV %)	17.9	24.9	20.8	33.9	22.4	15.1

^{ns} Not significant by t test (LSD) at 5% of error probability.

Bean grain yield was increased a little bit by phosphate application (Figure 1), although the difference was not significant statistically. However, it is important to emphasize that the bean crop season of 2008/2009 was a drought, with three months of almost no precipitation, between December/2008 and February/2009, this had a negative influence on the results of grain yield. The potential production is much higher than that obtained in the experiment, mean of 1295 kg/ha, as farmers of the same region had obtained mean grain yield of about 1800 kg/ha in years of normal precipitation.

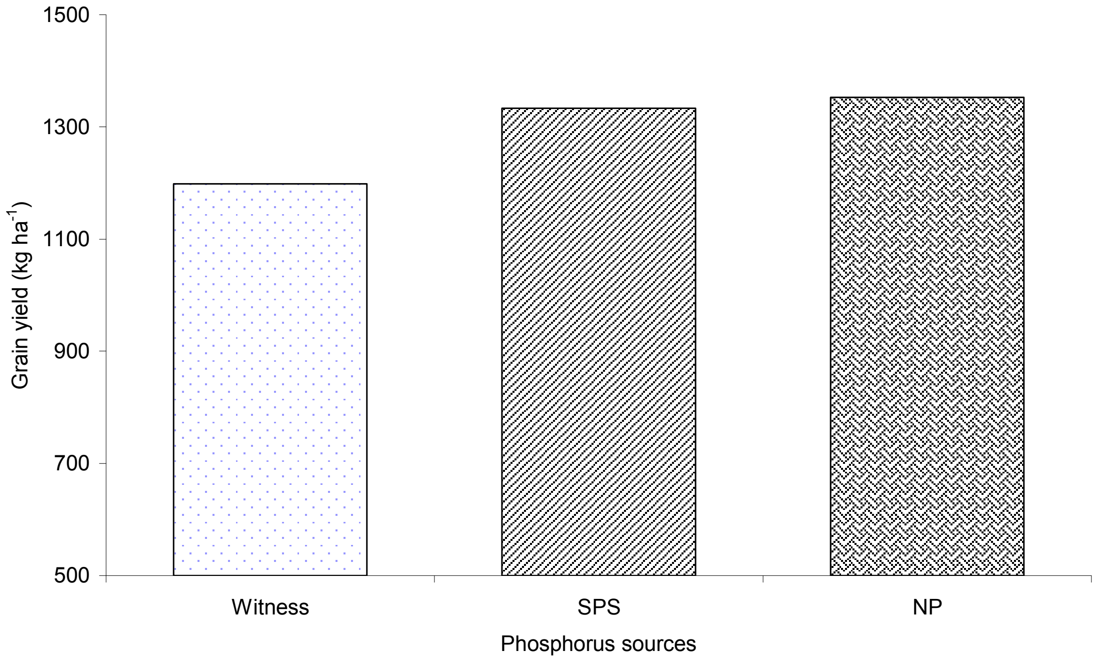

Figure 1. Bean grain yield under sources of phosphate fertilization, in a Ferralsol from South Brazil. UTFPR, Dois Vizinhos, PR. (Difference not significant by t test (LSD) at 5%).

Soil available P increased substantially under phosphate fertilization, especially on the 0-5 cm layer, with higher availability with NP fertilization, compared to SPS fertilization and witness (Table 3). In deeper layer, small changes were observed in this first crop season, more significant results are awaited in the next summer season, once cover crops were cultivated in the area. Cover crop species were used to promote changes in P availability, by releasing organic compounds in soil, from roots or shoot dry mass, that could act by competing with phosphate for the soil adsorption sites, so increasing available P in soil solution (Guppy *et al.* 2005).

Table 3. Levels of available phosphorus, by resin of anion exchange, in soil layers after bean cultivation, under sources of phosphate fertilizers. UTFPR, Dois Vizinhos, PR, Brazil.

Depth layer	Without fertilization	Natural phosphate (NP)	Soluble phosphate (SPS)
---- cm ----	-------------------- mg/dm^3 --------------------		
0-5	8.18	16.50	12.47
5-10	2.66	3.93	4.71
10-20	1.39	1.79	2.15

Higher amounts of dry mass were obtained with white lupin, independent of fertilizer use (Table 4). Ryegrass and black oat has produced great dry mass amount, also. Pigeon pea did not growth in the winter season, because it is susceptible to low temperatures (frost occurred in the period), which explains the amount produced, being similar to witness. Clover was not efficient in dry mass production, and vetch and radish produced good amounts of dry mass for this region and soil type. It will be interesting to see if those species were efficient in solubilizing soil P, by what will be evaluated in the next months (November-December/2009).

Table 4. Cover crops dry mass production under phosphate fertilization during the winter season of 2009. UTFPR, Dois Vizinhos, PR, Brazil.

Cover crops	Witness	Natural phosphate	Super Phosphate Simpl	Mean
	-- kg/ha	--		
Witness	2213 d*	2613 bc	1933 b	2253 e
Vetch	4480 cd	4680 abc	4907 b	4689 d
White lupin	13627 a	9293 a	14373 a	12431 a
Radish	6840 bc	7853 a	5827 b	6840 cd
Ryegrass	8853 b	9253 a	11760 a	9956 b
Black oat	6093 bc	7267 ab	11200 a	8187 bc
Clover	2040 d	1667 c	1893 b	1867 e
Pigeon pea	2027 d	1813 c	2467 b	2102 e
CV (%)	35.8	49.3	37.2	39.3

* Values followed by the same letter in columns are not different by t test (LSD) at 5% of error probability.

Conclusion

Brazilian Ferralsol, with a high level of available P, did not increase plant grain yield with sources of phosphate fertilization, however, the summer crop season was very dry. Available P in soil changes by phosphate fertilization, especially in the surface layer (0-5 cm). Important results are expected by the analysis of soil P availability after winter cover crops.

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