



The Impact of Phosphorous Applications and Incubation Periods on P- Desorption Characteristics with Successive DMT-HFO-P Extractions on P Fixing Soils

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Authors' contributions

This work was carried out in collaboration between all the authors. Author VAO designed the study and wrote the protocol. Author EN wrote the first draft of the manuscript. Author PCJ managed the literature searches and analyses of the study while author ASC performed the spectroscopy analysis and managed the experimental processes. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The overall objective of this study was to establish the rates and how much of the transformed or fixed Phosphorus can be available to plants over time, having determined the extent of Phosphorus fixation by both Rustenburg and Loskop soils.

Methodology: Therefore, the impact of applied Phosphorus rates (0, 25, 50, 100, and 200 mg kg⁻¹) and incubation period (1, 120, and 240 days) on the Phosphorus desorption rates of a red-sandy clay soil (high P fixing) and a red-sandy loam soil (low P fixing), were investigated. Cumulative and

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sequential P extractions/desorption were carried out for 1, 7, 14, 28, and 56 days per treatment combination to determine Phosphorus (P) transformations.

Results: About 30 – 60% of Phosphorus added was transformed into less stable P pools within one day and 80-90% after 120 days. The transformation of P applied to less labile P pools was faster in the red-sandy clay soil (high P fixing) than in the red-sandy loam soil (low P fixing). The cumulative DMT-HFO-P extraction curves of the Rustenburg and Loskop had not reached plateaux, indicating that desorption rate could proceed for a much longer period than the 56 days. This is important for crops such as tobacco due to residual effects of the added Phosphorus fertilizer and thus lower application rates.

Conclusion: Much as Rustenburg soil is reflected to be a high P fixing, the P release rates are still more able to meet most of crops requirements; however, importantly is may depend on how much of the soil volume is exploited by the root system of a particular crop.

Keywords: Sequential P extraction; P desorption; P fractionation; P adsorption; P transformation; P fixation.

1. INTRODUCTION

Phosphorus deficiency in the tropics and other relative to higher weathered soils is usually aggravated by a high potential to fix phosphate in different ways making it less available to crop plants [1-4]. As phosphate fertilizer is an expensive input, it is essential not only to know the most cost effective phosphate application rates but also to make maximum use of the initial and applied fertilizer P in the soil [4-6]. When considering the efficient use of applied and the natural P content of a soil, knowledge of the soil P adsorption and desorption reactions are important aspects to consider in the investigations [7,8]. The conventional routine chemical extraction of soil P removes only a small fraction of the so-called easily plant-available P from the total soil P pool [4,9]. Such extractants cannot be used to assess the potential P supply of a soil due to its P desorption rates on a short or long term basis. The principle of using a Dialysis Membrane Tube filled with Hydrous Ferric Oxide (DMT-HFO) is a more suitable method to carry out successive P extractions or extract P over a longer period from soils [1,4]. This method could constitute a convenient laboratory method to characterize the capacity of soil to supply P, and to investigate the kinetics of P release from the initial and applied fertilizer P in a specific soil over a period of time. Such a method simulates the processes involved in the slow P uptake by plant roots from a soil better, because it removes P from the soil solution constantly without destroying the soil sample [10].

This method is also suitable for evaluation of plant-available P because it takes into account the changes within the soil P pools over a period of time. According to [10], the system is

mechanically stable for over 500 hours. After the desired time of contact between the soil suspension and P sink, the sink is easily separated from the soil suspension with no loss of soil material. This technique has important advantages over the other similar techniques such as the resin method [1,8,10]. Previously the two South African soils from Rustenburg a red-sandy clay soil (Ferric Luvisol - high P fixing) and Loskop a red-sandy loam soil (Ferric Acrisol - low P fixing) were used to investigate the changes of the applied P and the distribution of the applied P to different P fractions as influenced by different levels of applied P and incubation time [11]. Since the pH in both soils ranged from medium acidity to low alkalinity, it was therefore assumed that added P could be adsorbed and/or fixed to varied degrees by Al- and Fe-oxihydroxides, soil organic matter, layer silicate clays, or precipitated as Ca and Mg phosphates [4].

The results of sequential P fractionations showed that in soils, solution and labile P decreased with time of incubation, while there were corresponding increases in adsorbed, occluded and residual P. In the Loskop soil the transformation and distribution of the added P to different P pools were slower than in the Rustenburg soil, which also had a higher capacity to change the added P into less labile P forms. The noted differences could explain the reportedly higher levels of P fixations (adsorptions and/or precipitations) by the Rustenburg soil than by the Loskop soil. Although a larger proportion of the added P was transformed into more stable (immobile) P pools, it did not mean that this non-labile P could not become available to the plants over time due to P desorption [4,12]. Therefore, having determined the extent of P fixation in both soils, it

became important to establish the rates and how much of the transformed or fixed P can be available to plants over time, having determined the extent of Phosphorus fixation by both soils.

2. MATERIALS AND METHODS

2.1 Site Location and Study Description

The two soils obtained from Rustenburg, ARC-Institute for Industrial Crops (25.7° S / 27.3°E, North West Province), and the affiliated experimental station at Loskop near Groblersdal (25.2°S / 29.4 °E, Mpumalanga Province) in South Africa were used for the experiments. The bulk samples from the two soils were dried in a forced air oven at 40 °C, and ground to pass a 2 mm sieve. Each bulk sample was thoroughly mixed and stored at room temperature. P treatments consisted of different P application rates (0, 25, 50, 100, and 200 mg kg⁻¹) applied as KH₂PO₄ to a 500 g (0.5 kg) sample of the two soils. After thorough mixing the soils were brought to field capacity before commencing with the different incubation periods (1, 120, and 240 days). The samples replicated three times were stored in boxes and placed randomly in a climatic room where they were incubated at 20°C for Rustenburg, ARC-Institute for Industrial Crops.

The Rustenburg soil was identified as Ferric Luvisol and the Loskop soil as Ferric Acrisol (FAO, 2006). Both soils have been under cropping for the last 5 years, and fertilized as recommended for different crops such as cotton, tobacco and sunflower among others. At the end of each incubation period a set of 75 samples were forced air dried and then subjected to the DMT-HFO-P extractions for 1, 7, 14, 28, and 56 days as described in [8] method. Basically the method consisting of filling a dialysis membrane tube with HFO, which extracts P from the surrounding solution by precipitating P as -HFO-P. This was done to determine the total P extractable after each incubation period. To perform the extractions, the DMT-HFO tubes were placed in wide necked plastic bottles with 80 cm³ of a 0.2 cmol.kg⁻¹ of CaCl₂ and 0.3 cmol.kg⁻¹ (meq 100 g⁻¹) of KCl solution as supporting electrolytes and 1 g of soil. These samples were then gently shaken (horizontally) for 1, 7, 14, 28, and 56 days. The tubes were replaced with new ones after every 14 days. The extracted P was determined according to the method of [13].

2.2 Data Analysis

The data was analysed statistically using a "GenStat" version 13 package. The analysis of variance (ANOVA) was used to determine the statistical differences, while the least significant differences (LSDs) were determined by the LSD (Fisher) tests at 5% confidence level. The extracts and percent recovery graphs are presented as smooth curves constructed through different regression fits of the data using 'Microsoft Excel' programme's power function: $y = cx^b$ to produce the best fits for each set of data. Desorption rates were computed by differentiating the regression equations. The percentages of the applied P recovered were calculated as: % P recovered = $(P_x - P_0)/P_1 * 100$; where P_x was P in the xth fraction of the P treatment, and P_0 was P in the 0th fraction of the initial no P (P0) treatment, while P_1 was the applied P level of the xth fraction [14].

3. RESULTS

Some of the mineralogical, physical and chemical characteristics of Rustenburg and Loskop soils are presented in Table 1. Characterization procedures/methods were done according to [15]. These selected properties show that Rustenburg soil is a sandy-clay while the Loskop soil is a sandy-loam and Kaolinite is the dominant clay mineral in both soils. The pH values show that the soils are near neutral in their reactions. Differences in Mg and OC contents in both soils were noted. However, the other differences in the physical and chemical characteristics are probably due to the differences in the clay content [11]. The initial P contents (Bray 1) were low for both soils.

3.1 The Impacts of the Applied P and Incubation Periods on the Successive DMT-HFO Extracted P from the Rustenburg and Loskop Soils

The results of how the successive DMT-HFO-P extractions influenced by the P and incubation treatments are presented in Tables 2a-b, 3a-b and Figs. 1, 2, 3 and 4. According to the ANOVA and LSD values, there were highly significant responses ($P = 0.01$) in the successive DMT-HFO extracted P, from all the different Phosphorus treatments. The data fitted to regression equations and the R² values indicated very good correlations between treatments and P extractions.

Table 1. Some chemical, physical, and mineralogical, characteristics of Rustenburg (R) and Loskop (L) soils

Soil samples	R	R	R	L	L	Chemical properties (mg kg ⁻¹)	R	R	R	L	L
Depths(cm)	30	60	90	30	60		30	60	90	30	60
Sand (%)	42	38	34	81	72	Total N	486	419	347	206	163
Silt (%)	7	7	9	0	1	O.C.	6700	5800	4400	4100	3900
Clay (%)	51	55	57	19	27	P (Bray1)	5.0	3.0	0.0	12.5	1.0
Textural class	Sandy-clay	Clay	Clay	Sandy-loam	Sandy-clay-loam	P (Bray2)	8.0	4.5	0.5	16.5	1.0
						Total P	265.0	202.0	95.8	152.8	97.5
Clay mineralogy (%)						K	250	178	83	198	100
Kaolinite	52	54	40	37	26	Ca	910	853	690	640	720
Quartz	29	35	18	52	74	Mg	683	720	830	200	240
						pH H ₂ O	6.87	6.82	6.60	6.84	6.47

Table 2a. Changes in the successive DMT-HFO extracted P with the added P after 1 day of incubation of the Rustenburg soil

Added P (mg kg ⁻¹)	P-recoveries	1	7	14	28	56	Average P	Total-P
0	Extracted P	3.22 ^a	6.24 ^b	7.77 ^{bc}	10.70 ^{cd}	12.18 ^{cd}	8.02	40.14
25	Extracted P	7.50 ^{bc}	11.93 ^{cd}	13.97 ^d	24.47 ^g	28.50 ^h	17.27	86.37
	%P Recovered	17.12	22.76	24.80	55.08	65.28	37.01	
50	Extracted P	17.92 ^{ef}	21.00 ^f	26.73 ^{gh}	31.77 ⁱ	38.75 ^j	27.23	136.17
	%P Recovered	29.40	29.52	37.92	42.14	53.14	38.42	
100	Extracted P	26.57 ^{gh}	35.72 ^j	45.18 ^{kl}	52.68 ^m	65.00 ^p	45.03	225.15
	%P Recovered	23.35	29.48	37.41	41.98	52.82	37.01	
200	Extracted P	46.18 ^l	61.50 ⁿ	72.85 ^q	81.23 ^r	96.77 ^s	71.71	358.53
	%P Recovered	21.48	27.63	32.54	35.27	42.30	31.84	
Total	Extracted P	101.40	136.40	166.50	200.85	241.20	169.25	846.35
Average	Extracted P	20.28	27.28	33.30	40.17	48.24	33.85	
Average	%P Recovered	22.84	27.35	33.17	43.62	53.38	8.14	

N.B. The successive DMT-HFO extracted P values with the same superscripts are not significantly different at LSD (Fisher) P = 0.01 confidence level

Table 2b. Changes in the successive DMT-HFO extracted P with the added P after 1 day of incubation of the Loskop soil

Added P (mg kg ⁻¹)	P-recoveries	1	7	14	28	56	Average P	Total-P
0	Extracted P	6.30 ^{ab}	8.42 ^b	10.50 ^{bc}	12.75 ^c	14.70 ^{cd}	10.53	52.67
25	Extracted P	13.93 ^{cd}	20.50 ^e	24.03 ^f	32.25 ^h	33.97 ⁱ	24.94	124.68
	%P Recovered	30.52	48.32	54.12	78.00	77.08	57.61	
50	Extracted P	27.38 ^{fg}	30.17 ^{gh}	35.58 ^{gh}	40.35 ^{jk}	45.65 ^k	35.83	179.13
	%P Recovered	42.16	43.50	50.16	55.20	61.90	50.58	
100	Extracted P	46.68 ^{kl}	53.67 ^m	60.05 ^{np}	71.05 ^r	77.53 st	61.80	308.98
	%P Recovered	40.38	45.25	49.55	58.30	62.83	51.26	
200	Extracted P	67.22 ^q	80.17 ^t	92.80 ^v	102.50 ^w	115.87 ^y	91.71	458.56
	%P Recovered	30.46	35.88	41.15	44.88	50.59	40.59	
Total	Extracted P	161.50	192.95	222.95	258.90	287.70	224.80	1124.00
Average	Extracted P	32.30	38.59	44.59	51.78	57.54	44.96	
Average	% P Recovered	35.88	43.24	48.75	59.09	63.10	50.01	

N.B. The successive DMT-HFO extracted P values with the same superscripts are not significantly different at LSD (Fisher) P = 0.01 confidence level

3.1.1 Rustenburg soil

The DMT-HFO extracted P from the Rustenburg soil for different extraction times as influenced by P application rates and incubation periods are presented in Tables 2a, 3a and Figs. 1 and 2. Where no P was added, little P was extracted as DMT-HFO-P but significantly more P was extracted with increasing P application rates. Much as the amount of DMT-HFO extracted P increased with the increasing amounts of added P, it is noted that the percent P recovered were not consistent [11]. Fig. 1 illustrates the amount of extracted P over different periods of extractions; indicate that less Phosphorus was extracted from Rustenburg soil compared to the Loskop soil (Tables 2b, 3b; Fig. 3). The P desorption rates from the samples that received different Phosphorus application had significant

variation (Fig. 2). There were significant decreases in the desorption rates after one day of extraction from the different P application rates, which varied from 8.40 mg kg⁻¹ day⁻¹ at the highest P rate (200 mg kg⁻¹) to only 1.10 mg kg⁻¹ with no P application at the start of the incubation (Fig. 2). After 240 days of incubation the desorption rates decreased to 4.47 mg kg⁻¹ day⁻¹ from the highest P application rate and to only 0.77 mg kg⁻¹ day⁻¹ with no P application (Fig. 2). More important, are the very significant decreases in P desorption rates over the first 14 days of extractions indicating that a fair amount of applied P could be extracted over the first 14 days with DMT-HFO. For the longer DMT-HFO extraction periods (28-56 days), desorption rates were less than 1 mg kg⁻¹ day⁻¹ and very little differences in desorption rates were found from the different P applications.

Table 3a. Changes in the successive DMT-HFO extracted P with the added P after 240 days of incubation of the Rustenburg soil

Added P (mg kg ⁻¹)	P-recoveries	1	7	14	28	56	Average P	Total-P
0	Extracted P	2.85 ^a	4.50 ^{ab}	5.53 ^{ab}	6.87 ^{bc}	8.92 ^{bc}	5.73	28.67
25	Extracted P	4.30 ^{ab}	5.70 ^{ab}	7.25 ^{bc}	9.70 ^c	12.40 ^{cd}	7.87	39.35
	%P Recovered	5.80	4.80	6.88	11.32	13.92	8.54	
50	Extracted P	5.27 ^{ab}	10.92 ^{cd}	15.25 ^{de}	20.93 ^f	25.60 ^{gh}	15.59	77.97
	%P Recovered	4.84	12.84	19.44	28.12	33.36	19.72	
100	Extracted P	8.17 ^{bc}	15.00 ^{de}	19.85 ^{ef}	27.47 ^{gh}	36.13 ^j	21.32	106.62
	%P Recovered	5.32	10.50	14.32	20.60	27.21	15.59	
200	Extracted P	14.62 ^{de}	23.13 ^g	31.50 ^{hi}	42.08 ^k	53.63 ^m	33.00	164.96
	%P Recovered	5.89	9.32	12.99	17.61	22.36	13.63	
Total	Extracted P	35.20	59.25	79.40	107.05	136.70	83.51	417.57
Average	Extracted P	7.04	11.85	15.88	21.41	27.34	16.70	
Average	% P Recovered	5.46	9.36	13.41	19.41	24.21	57.48	

N.B. The successive DMT-HFO extracted P values with the same superscripts are not significantly different at LSD (Fisher) P = 0.01 confidence level

Table 3b. Changes in the successive DMT-HFO extracted P with the added P after 240 days of incubation of the Loskop soil

Added P (mg kg ⁻¹)	P-recoveries	1	7	14	28	56	Average P	Total-P
0	Extracted P	4.13 ^a	5.82 ^{ab}	6.50 ^{ab}	8.55 ^b	12.17 ^c	7.43	37.17
25	Extracted P	12.13 ^{bc}	14.80 ^{cd}	17.67 ^{de}	24.17 ^f	27.75 ^g	19.30	96.52
	%P Recovered	32.00	35.92	44.68	62.48	62.32	47.48	
50	Extracted P	13.43 ^{cd}	20.85 ^{ef}	25.83 ^{fg}	30.50 ^{gh}	38.58 ^j	25.84	129.19
	%P Recovered	18.60	30.06	38.66	43.90	52.82	36.81	
100	Extracted P	18.73 ^{de}	33.43 ^{hi}	40.33 ^{jk}	52.50 ^{mn}	63.17 ^p	41.63	208.16
	%P Recovered	14.60	27.61	33.83	43.95	51.00	34.20	
200	Extracted P	35.20 ^{hi}	49.63 ^l	60.50 ^{np}	76.17 ^s	92.00 ^r	62.70	313.50
	%P Recovered	15.54	21.91	27.00	33.81	39.92	27.64	
Total	Extracted P	83.60	124.55	150.85	191.90	233.65	156.91	784.55
Average	Extracted P	16.72	24.91	30.17	38.38	46.73	31.38	
Average	%P Recovered	20.18	28.87	36.04	46.04	51.51	36.53	

N.B. The successive DMT-HFO extracted P values with the same superscripts are not significantly different at LSD (Fisher) P = 0.01 confidence level

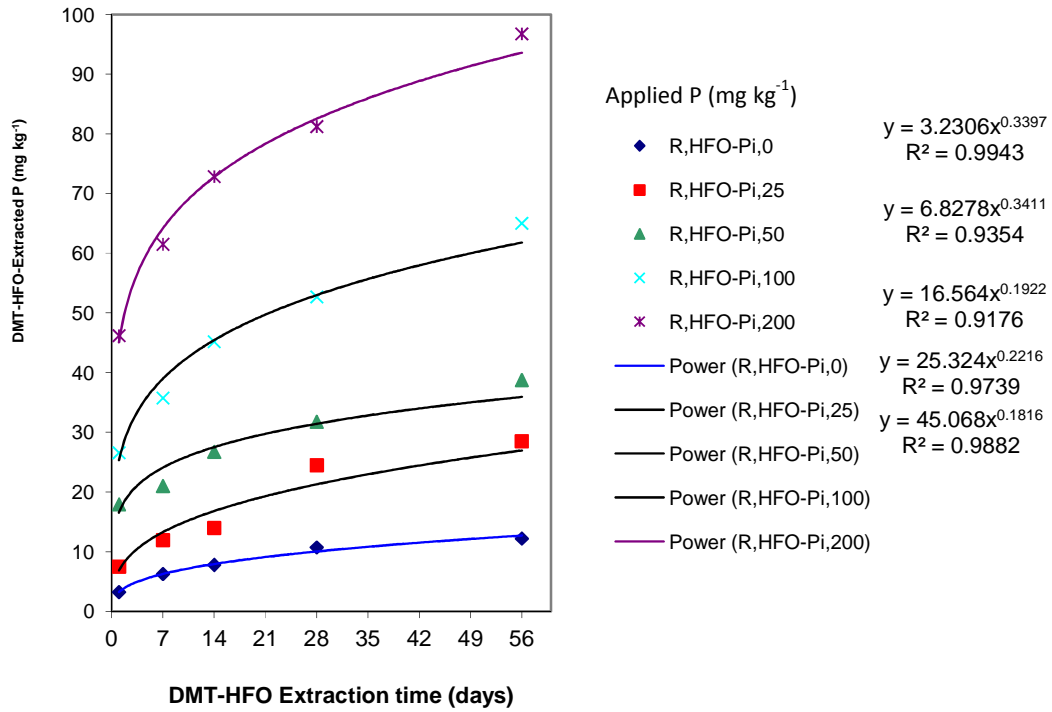


Fig. 1a

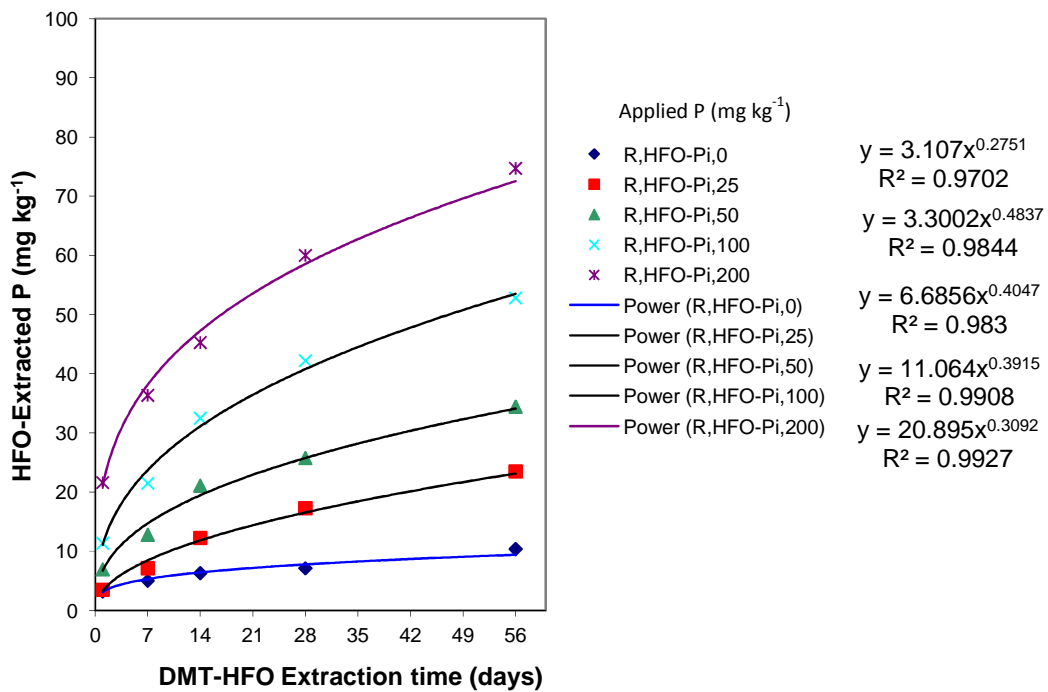


Fig. 1b

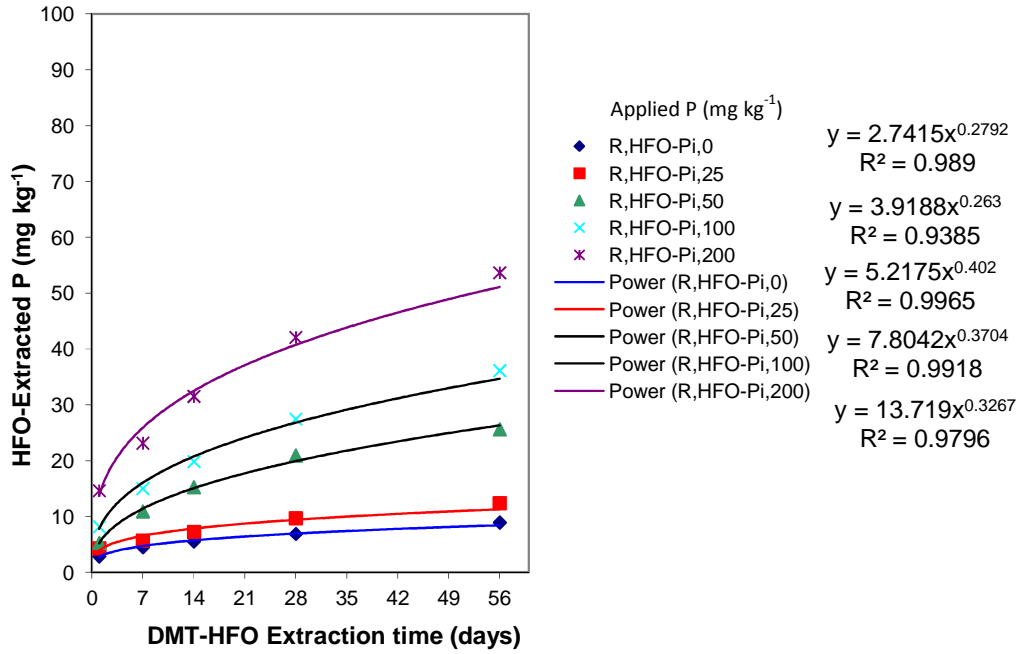


Fig. 1c

Fig. 1. The effects of the applied P on successive DMT-HFO extractable Pi after (1a) 1 day, (1b) 120 days and (1c) 240 days of incubation of Rustenburg soil

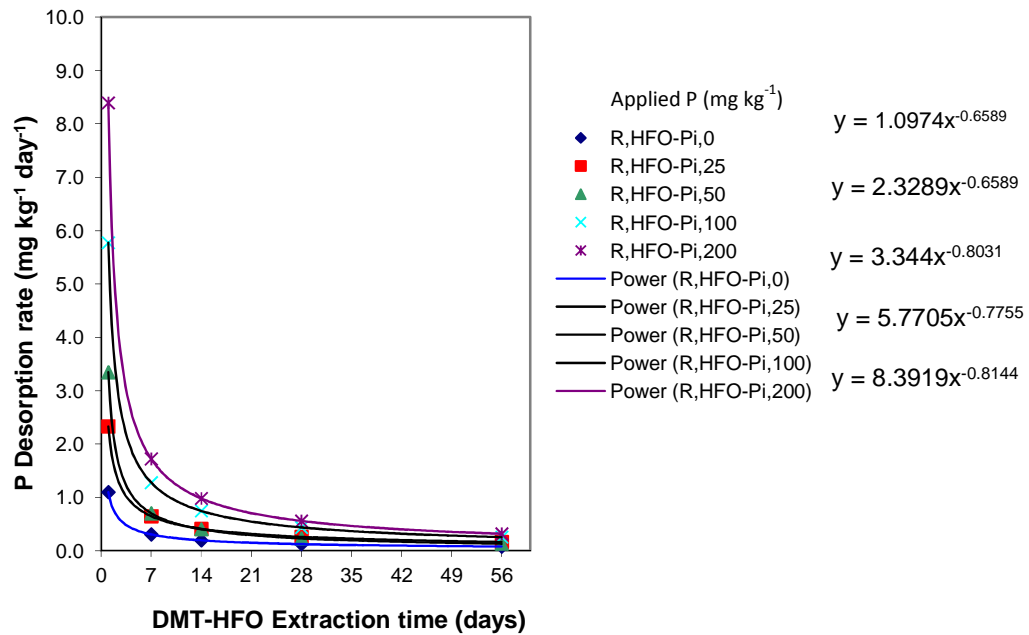


Fig. 2a

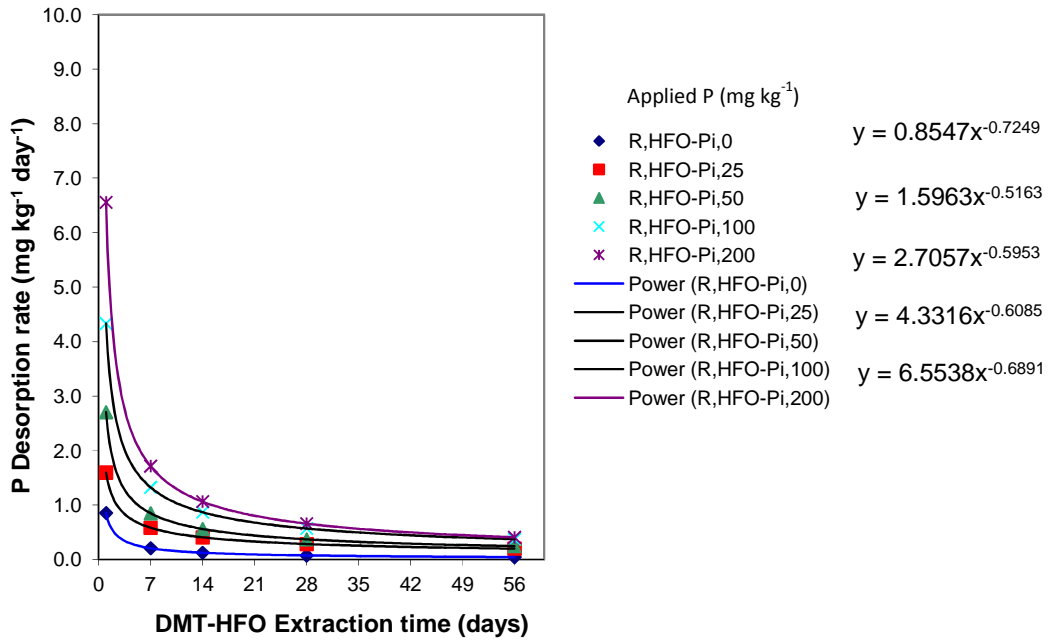


Fig. 2b

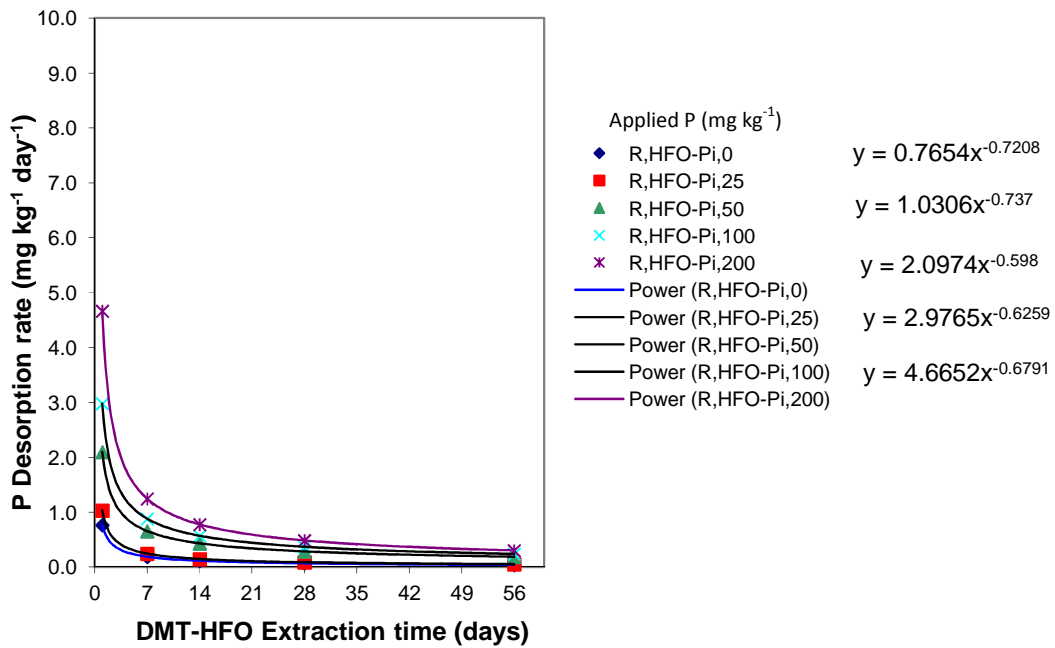


Fig. 2c

Fig. 2. The effects of the applied P on DMT-HFO-Pi desorption rates (mg kg⁻¹ day⁻¹) after (2a) 1 day, (2b) 120 days and (2c) 240 days of incubation of Rustenburg soil

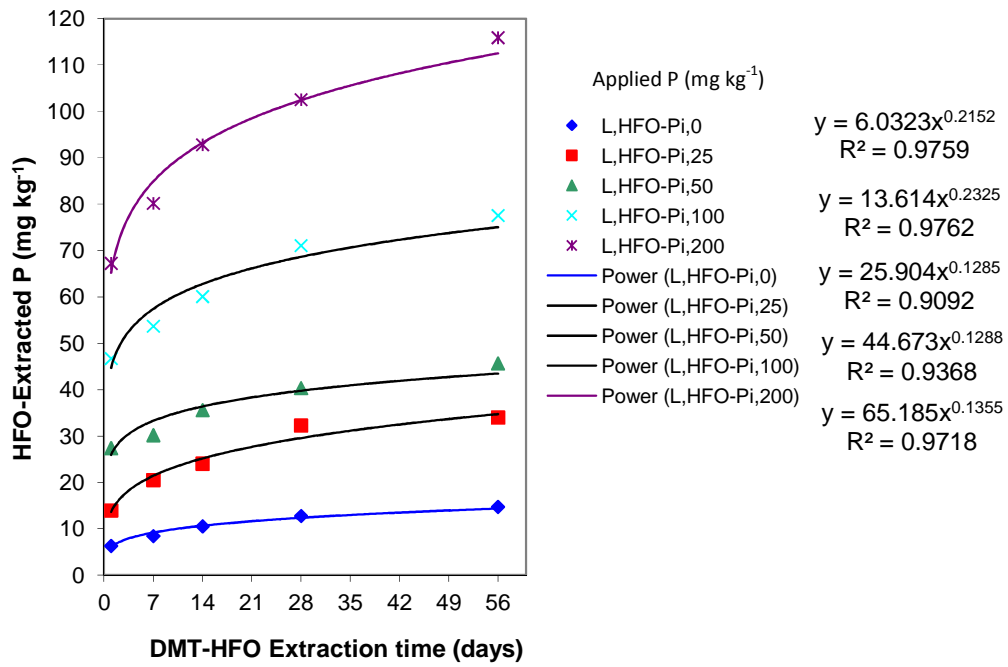


Fig. 3a

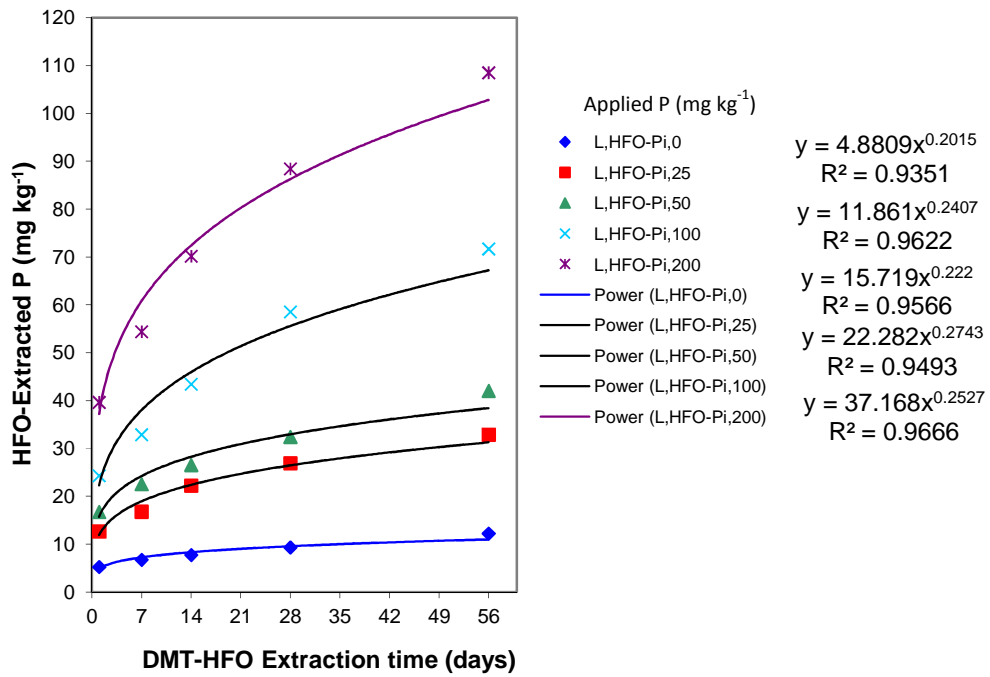


Fig. 3b

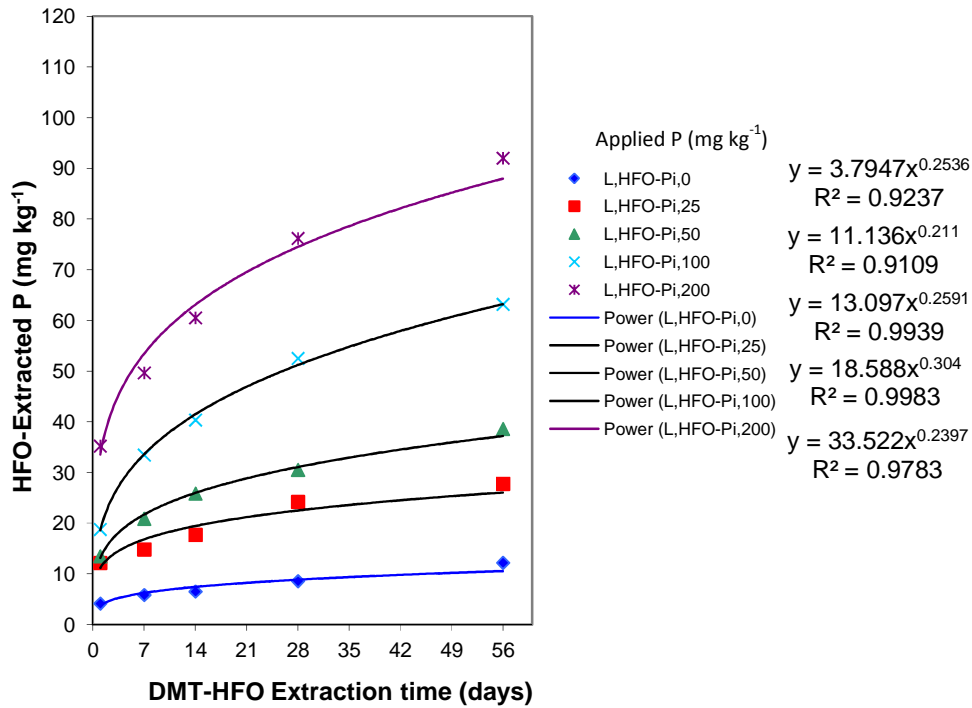


Fig. 3c

Fig. 3. The effects of the applied P on successive DMT-HFO extractable Pi after (3a) 1 day, (3b) 120 days, (3c) 240 days of incubation of Loskop soil

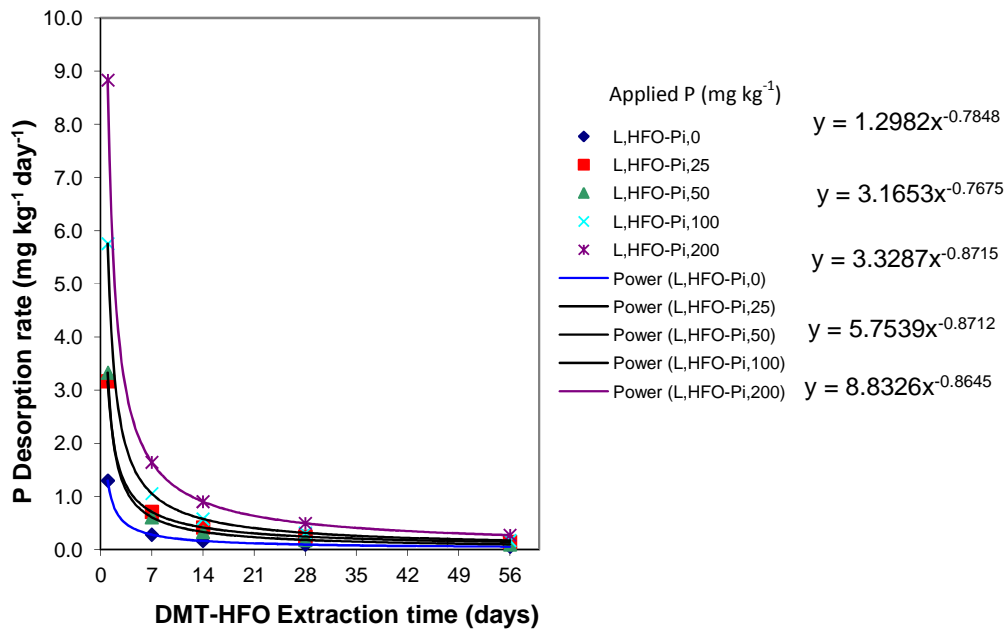


Fig. 4a

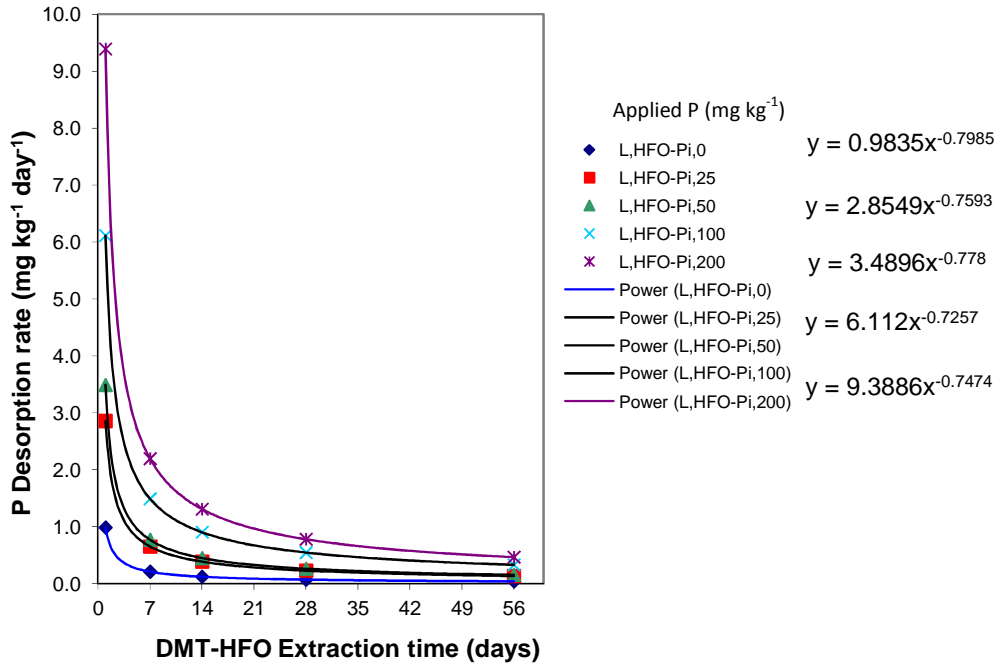


Fig. 4b

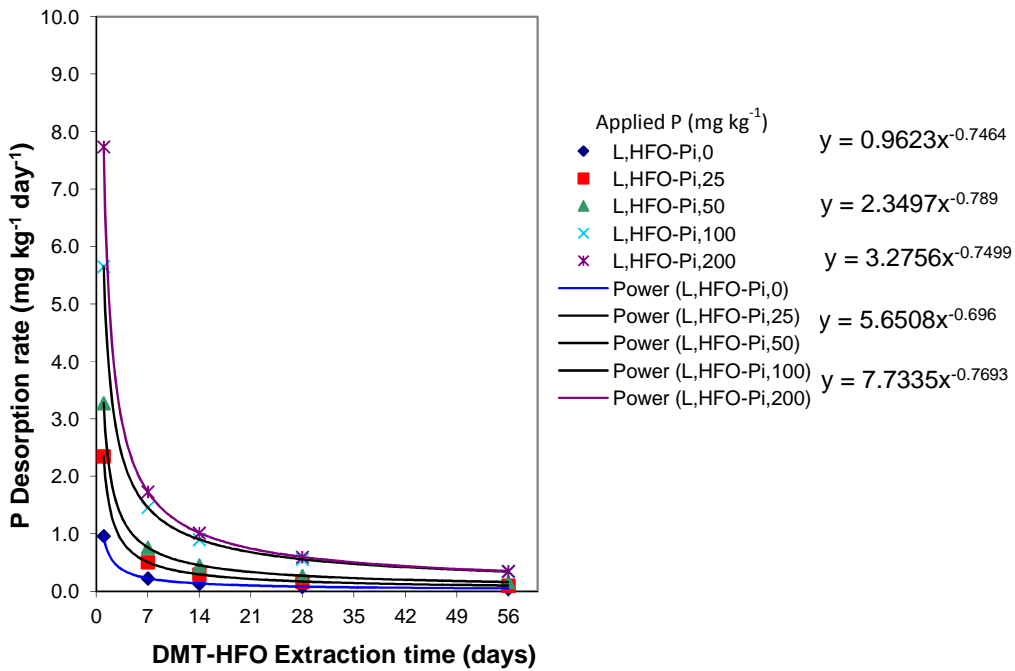


Fig. 4c

Fig. 4. The effects of the applied P on DMT-HFO-P desorption rates (mg kg⁻¹ day⁻¹) after (4a) 1 day, (4b) 120 days, (4c) 240 days of incubation of Loskop soil

3.1.2 Loskop soil

Tables 2b, 3b and Figs. 3 and 4 present the DMT-HFO extracted P as influenced by P application rates and incubation periods for Loskop soil. As was for the Rustenburg soil, all the P treatment levels influenced the extractable P very significantly ($P = 0.01$). More still, as it was for the Rustenburg soil, where there were no P additions, the amount of (DMT-HFO) P extracted did not vary much over the extraction time, but the extracted P increased with increasing rates of P applications. Again, the percentage of added P that was recovered after 56 days of extraction, decreased with increasing P application rates and incubation times. The recovery rates were however; much higher than for the Rustenburg soil. This clearly illustrates the differences in the amount of labile (added) P that become stable (adsorbed/fixed) between the two soils. The P desorption rates from the Loskop soil (Fig. 4) showed similar trends as the Rustenburg soil. However, at the early stages of extractions, desorption rates were higher than for the Rustenburg soil. In this soil up to $7.73 \text{ mg P kg}^{-1} \text{ day}^{-1}$ could still be extracted from the samples that received 200 mg kg^{-1} P after 240 days of incubation. The decreases in desorption rates were similar after 14 days of extractions. Little changes in desorption rates were evident for longer extraction periods. Desorption rates were also lower than $1 \text{ mg P kg}^{-1} \text{ day}^{-1}$ after 14 days of extractions (Fig. 4).

4. DISCUSSION

4.1 Assessment of P Desorption Rates in the Two Soils by the Use of Successive DMT-HFO-P Extractions

In the study, the cumulative P extraction curves had not levelled off for either soil, indicating that P desorption could continue for longer periods than the 56 days used (Tables 2a-b and 3a-b; Figs. 1 and 3) [4,16] found that in some soils, the cumulative P extraction curves reached plateaux where no more P could be recovered, while others continued to release P slowly. This property could be relevant for the crops in the field with respect to the residual effect of added fertilizer P. Thus, knowledge of the type of cumulative P extraction curve of the soil, i.e. whether it reaches a plateau or continues to release P could be important in the management of fertilizer applications. In a related experiment, [4,17] observed that soil extractable (labile) P

alone, may not provide adequate information on P status of the soil especially in terms of the long-term capacity of the soil to supply P for plant growth and concluded that the successive soil P extraction procedure carried out using Fe oxide-impregnated paper strips (or in this case DMT-HFO) provided a convenient laboratory method for characterizing P desorptions from soils by simulating plant P uptake, and therefore for identifying the residual effectiveness of added fertilizer P [4,18].

In practice this P release rate can be evaluated when it is considered that a cotton crop removes approximately 15 kg P ha^{-1} to produce $1,000 \text{ kg ha}^{-1}$ seed cotton yields (maximum yield $4,500 \text{ kg ha}^{-1}$), while flue cured tobacco also requires up to 15 kg P ha^{-1} for a $1,000 \text{ kg ha}^{-1}$ yield (maximum yield $4,000 \text{ kg ha}^{-1}$). Both these requirements can be met by the two soils, since both soils are able to release between $0.4\text{-}0.5 \text{ mg kg}^{-1} \text{ day}^{-1}$ after 56 days of successive extractions. This represents a P delivery rate of approximately between 1.7 and $2.2 \text{ kg P ha}^{-1} \text{ day}^{-1}$ (for a 30 cm layer of soil with a density of $1,500 \text{ kg m}^{-3}$). The results show that although the Rustenburg soil is considered to be a high P fixing soil the P release rates are still high enough to meet the cotton and tobacco crops requirements (these are the major commercial crops grown in the two areas). The problems rather could be attributed to the root systems of the crops grown, since if the roots do not develop extensively enough to be able to exploit the soil volume well, plants may experience P deficiencies, although the P releasing rates are adequate.

Further, at this P release rate of $2.2 \text{ kg P ha}^{-1} \text{ day}^{-1}$ after 56 days DMT-HFO extractions may seem low, but it should also be realised that in practice in the field the crop requirements at the beginning of the growing season is small and the extraction rates (P uptake) will thus be smaller. It means that if less P had been extracted during the first 14 days of extractions, the desorption rates would not have decreased so much within the first 14 days but over a longer period. This assumption is made because over the 240 days of incubation there were less P extracted between 28 and 56 days but the changes in desorption rates were quite similar. The total amount of P extracted would also indicate that both soils were able to supply enough P over the growing seasons for both cotton and tobacco crops.

The noted increases with the DMT-HFO successive extractions suggest that the biologically more stable P pools (i.e. adsorbed and insoluble P fractions) play major roles in contributing to the labile P_i pool in order to supply the P requirements of the crops over a prolonged period. It should also be noted that routine soil extractable (labile) P alone (e.g. Bray 1 or 2), does not provide adequate information on the P status of the soil especially in terms of the long-term capacity of the soil to supply P for plant growth. Therefore, the successive DMT-HFO-P extraction procedure could provide a convenient laboratory method for characterizing P desorptions from soils by simulating plant P uptake. It is also useful for identifying the residual effectiveness of added fertilizer P. It is therefore foreseen that such a determination could be done once for a specific soil and then the data could be used in future to evaluate the status of the soil and how it should be amended to comply with the P demand of a crop over the growing season.

In this laboratory method 100% of the total soil volume was extracted. But, in practice the root system does not occupy 100% of the soil total volume [12]. Further, a lot more P is desorbed between 1 and 14 days of extractions while in practice in the field the plant roots would just be developing. Therefore, in order to implement this procedure a model to describe root development that represents the percentage of the soil exposed will be necessary to fine-tune this principle.

5. CONCLUSIONS

The core of this study was to investigate the rate of transformation of the applied Phosphorus and the desorption rates. In both soils, for all doses of P added and for 1, 120 or 240 days of incubation, after about 42 days the curves show a slow increasing, a plateau. It was also observed that the TOTAL-P increases with increasing added P. At the end (56 days) however desorption rates were very low. This property could be relevant for the crops in the field with respect to the residual effect of added fertilizer P and therefore, could be important in the economical management of fertilizer applications rates. There was noted decrease in P recovery in both soils with increasing incubation time, but more especially for the Rustenburg soil, confirming that the Rustenburg soil has a higher P fixing/sorption capacity. Much as Rustenburg soil is reflected to be a high P

fixing soil the P release rates are still high enough to meet the cotton and tobacco plants requirements. However, the most important factor is how much of the soil volume is able to be exploited by a root system of a particular crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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