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Full Length Research Paper

Comparision of four phosphorus extraction methods on rice soils from Mali

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ABSTRACT

Inorganic forms of phosphorus in soils are largely tied up by aluminium (P-Al), iron (P-Fe) or calcium (P-Ca). Numerous selective extraction methods are available to evaluate the uptake of phosphorus by plants. However, a large variety of soil properties will affect the results making one single method in a selected area difficult to use and interpret. The aim of this study is to identify the methods most useful for the extraction of phosphorus in rice soils in Mali and assess which physical and chemical factors affect the results and determine the strength of the selected methods. Seven soils cultivated from the two main rice cultivation areas of Mali, i.e. Office Niger in the Niger Inland Delta and Longorola in the southernmost part of Mali are used in the study. The results obtained show that there are large differences between both soils and extraction methods in mobilised phosphorus. Bray I gave statistically identical values for the Danga soil. Bray I and DA-4 methods gave higher extraction rates on alluvial Seno type soil. Bray II gave high values on Danga, Seno aeolian and Longorola backwater soils. Bray II seems to be relatively less dependant on the physical and chemical properties (pH, organic matter).

Keywords: Phosphorus, Extraction methods, Mali, Rice, Soil.

INTRODUCTION

Rice cultivation is increasing in West Africa and Mali. Reviews of the conditions for rice cultivation in West Africa conclude that there are nutrient deficiencies to overcome, the most important being phosphorus (Sahrawat et al. 1998; Abe et al. 2010). However, other problems are also identified, such as sulphur and zinc deficiencies (Gerdestedt et al. 2009; Abe et al. 2010). There are two important rice growing areas in Mali, Office Niger in the Niger Inland Delta and the Longorola area near Sikasso in southernmost Mali. Rice cultivation was expected to increase twofold during the period 2007-2012 reaching 100 000 tons (Ministry of Agriculture 2009). In the year 2018 it was expected to reach 160 000 tons (Ministry of Agriculture 2009). The soils in inland valleys in West Africa are generally low in phosphorus (Issaka et al. 1996, Abe et al. 2010). At present the recommendations for fertilization are based on the response in yield (Haefele et al. 2003a, Haefele et al. 2003b, Haefele et al. 2004. To date there are few investigations on the available phosphorus stores in soil. This investigation aims to test different methods for the extraction of phosphorus in soils. The need for suitable methods is great, e. g. for the evaluation of different phosphorus fertilizers (Kone et al. 2011). Another reason is that global phosphorus reserves are limited and we need to use phosphorus in an economic way (Cooper et al. (2011). In spite of the increased total production of rice, the yield/hectare has increased only marginally in Mali (Ricepedia).

There is an abundance of methods available, mainly in two categories, selective extraction methods and the more recent ion exchange resin methods (Zheng and Zhang 2012). Numerous comparisons between methods on a variety of soils have been published (Kleinman et al. 2001); Wuenscher et al. 2015). This work is as another comparison of four methods on a selection of rice soils from Mali in Africa.

MATERIALS AND METHODS

For this purpose seven soils were sampled from the two main rice growing areas in Mali. The selection was made in a way to include as different soils as possible (Table 1).

Table 1. Charahacteristics of soils in the test, *Exchangeable cations **Not cultivated.

Soil	pH	TOC %	OM %	Density	Ca* Cmol/kg	K* Cmol/kg	Na* Cmol/kg	Clay %
Moursi 1	6.9	0.99	1.7	1.51	10.7	0.33	0.3	43
Moursi 2**	6.4	0.45	0.77	1.36	9.04	0.39	0.09	57
Danga	8.5	0.21	0.36	1.84	4.05	0.08	1.84	8
Dian	3.9	0.74	1.28	1.03	6.46	0.09	0.05	42
Seno alluvial	10.4	0.12	0.21	1.9	3.01	0.41	0.37	2
Seno eolian	6.5	0.08	0.14	N.D.	2.07	0.09	0.02	2
Backwater soil	4.3	1.02	1.75	N.D.	3.53	0.35	0.02	31

As seen in Table 1, the range of soils is very different ranging from strongly acidic to alkaline. One reason to explain this is the land-use history. Rice cultivation with suitably irrigated may decrease alkalinity short time period (van Asten et al. 2004). The exchangeable cations (Table 1) which were determined by DTPA extraction, varied from 2.00 to 5.99 meq/100 g and the exchangeable iron determined with the same method varied from 0.14 to 115 meq/100 g with, as expected the backwater soil having the highest value. The backwater soil, close to a wetland, is subject to more reducing conditions, mobilising Fe^{2+}. Iron toxicity is a common problem limiting rice production in West Africa (Sahrawat 2009). Although numerous extraction methods have been published (Kabala et al. 2018), for this study only four methods have been selected. The extraction methods used were Bray-I, Bray-II (Bray and Kurz, 1945), DA-4 and DA-10 (Beaudin 2006). The details of the methods are given in Table 2. The extractions were made on duplicate samples.

Table 2. Phosphorus extraction methods used in the study.

Method	Composition	Ratio Soil/ solution	Time
Bray-I	0.03 N NH_4F + 0.025 N HCl	01:10	1 min.
Bray-II	0.03 N NH_4F + 0.1 N HCl	01:10	1 min.
DA-4	0.05 N HCl + 0.025 H_2SO_4	01:04	5 min.
DA-10	0.05 N HCl + 0.025 H_2SO_4	01:10	5 min.

All the extractants dissolve P-Al, P-Fe and P-Ca through the action of the acids. The fluoride ions serve as complexants for aluminium and may precipitate as CaF_2. The alkaline extraction methods (Olsen et al. 1954) could also be suitable for acid soils according to Holford (1980) and Sims and Ellis (1983).

RESULTS AND DISCUSSION

The available quantities of phosphorus are measured in the soils using 7 ppm as a threshold value (Mehlich 1978).

Table 3 shows that the Bray II method extracts the largest amount in the soils taken from Danga, Dian, the Longorola backwater, Moursi 2 and Seno eolian.

These soils have a very variable pH, from 8.5 for Dian via 5.3 for Dian to 4.3 for Longorola backwater.

Moursi 2 and Seno eolian with pH 6.4 and 6.5 respectively seems to have a tendency for the most optimal availability of all nutrients.

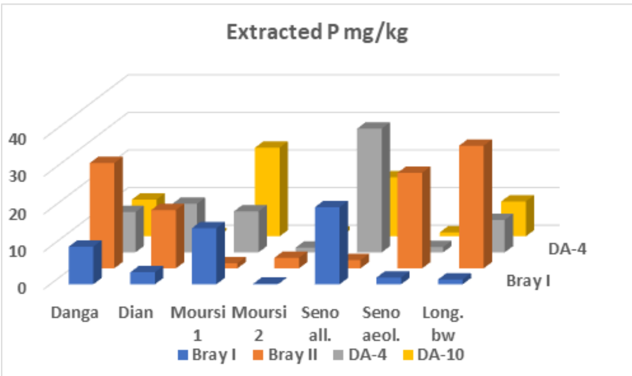

Figure 1. Staple diagram illustrating the extraction results for the seven soil samples using four methods.

Table 3. Results of the four methods of extraction used on seven soil samples, figures are given in ppm.

Soil	Bray I	Bray II	DA-4	DA-10
Moursi 1	14.9	1.33	10.9	23.6
Moursi 2	0.17	18:57	1.22	0.97
Danga	10	00:00	10.7	9.79
Dian	3.17	12:00	12.9	0.57
Seno alluvial	20.5	03:50	32.9	15.7
Seno eolian	1.78	25.4	1.41	1.04
Longorola backw.	1.26	32.6	8.59	9.29
Mean	7.4	15.4	11.2	8.7
F. pr %	<0.001	<0.001	<0.001	<0.001

Analysis by Newman-Keuls with a threshold of 5% shows that there are significantly different values obtained for the different soil types at the level of <0.001.

Table 4. Classification of the soils in relation to the overall mean.

Method	Bray I	Bray II	DA-4	DA-10
Available p**	7.40 (c)	15.4 (a)	11.1 (b)	8.40 (c)

The results in Table 4 make it possible to classify the results into three classes (a), (b) and (c). The Bray I and DA-10 methods provide statistically the same values for available phosphorus for all the soil types. Indeed, the Bray I and DA-10 methods give statistically equivalent available P values regardless of the soil type (7.4 and 8.4 ppm P. ass). They belong to class (a). On the other hand, there is not only a highly significant difference between the values obtained by the Bray II and DA-4 methods, relative to each other (15.39 and 11.12 ppm of P. ass), but also this same statistical difference is observed between each of these methods and the elements of the class (a) from the point of view of the capacity of extraction of the assimilable phosphorus. we can therefore conclude that the Bray II method represents class (bc) and DA-4 belongs to class (c).

Table 5. Soil classification according to the high average (10.68 ppm), *Least Significant Difference

Soils	Moursi 2	Seno eolian	Dian	Moursi 1	Longorola backwater	Danga	Seno alluvial
P available (ppm)	1.29d	7.41 c	8.04c	12.7b	12,9b	14.6b	17.8a

CONCLUSION

The soils used for the test were selected on the basis of having different characteristics i. e. with a pH from 4.3 to 10.4 and a clay content from 43% to 2%. The main finding is that no single extraction method is applicable for the large variety of rice soils in Mali. In this study, the Bray II method provides the largest available phosphorus values in the Malian rice soils followed by the DA-4 and DA-10 methods, both containing two acids. These acidic extractants are able to dissolve phosphorus tied to calcium compounds like hydroxyapatite. The results show very significant differences concerning soils and extractants and provides indications on which extractant to use for which soil. Further studies are needed to reveal the more detailed relationship between extractants and soil characteristics. The Bray II extraction is the method which seems relatively least affected by physical and chemical properties of soils tested here and if a single method is selected it would be the first alternative.

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