GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL 15, NO. 3&4, 2009: 279-282
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ALUMINUM AND IRON CONTENTS IN PHOSPHATE TREATED SWAMP RICE FARM OF MBIABET, AKWA IBOM STATE, NIGERIA

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(Received 2, October 2008; Revision Accepted 31, March 2009)

ABSTRACT

In 2006 aluminum and iron contents were determined in phosphate treated swamp rice farm of Mbiabet, Akwa Ibom State. The objectives were to determine the aluminum and iron contents, the effect of drying, phosphate and lime application in an acid sulphate soil grown to rice in Nigeria. The soil samples used were mud-clay from the bottom of the water-gate and cat-clay from the stream banks that bring water to the swamp. The third was from the unfertilized pond-mud taken from the Latin square of 36 x 5m, which had received surface limestone dressing of 50 kg/ha but with no phosphate. The phosphate fertilizer was applied at 122kg/ha^{-1} P_20_5. Various extractants used to extract Fe and Al showed highest concentration of Fe and Al in the sulphuric acid and dithionite and lowest in the sodium hydroxide citrate extractants. The total amount of Fe and Al removed by the fractionating solution represented 75 and 15 percent respectively. The average values of pH and KCl-extractable aluminum and iron at various depths showed that as the pH decreased the amount of extractable Fe and Al increased in both fresh and dried muds down the profile. Iron phosphate was more abundant than aluminum or calcium phosphate throughout the profile and there was no aluminum phosphate present below a depth of 8 cm. These results were consistent throughout the study period.

KEYWORDS: Aluminum and Iron contents, phosphate treated swamp.

INTRODUCTION

An acidic soil is one in which the concentration of hydrogen ion is greater than that of hydroxyl ions. Acidic soils are characterized by toxic levels of aluminum, manganese and iron. The growth of plants in such a soil must be due to tolerance of these conditions. Some acid tolerant plants such as rice grow much better in soil to which lime has been applied (Pearson 1993). The level of acidity which plants tolerate is also influenced by the supply of available nutrients and moisture. In Ceylon, a disease of rice known as bronzing was found to be caused by aluminum and iron toxicity (Aguilera and Jackson, 1968). Differential aluminum and iron problems have been reported among rice varieties (Birch, H. F. 1978). The detrimental effects of high soil acidity are traceable largely to exchangeable aluminum levels; thus, hydrolysis of Al^{3+} generates H^+ and buffers the increase in soil solution pH (Havlin *et al* 2006). Soil pH will not increase until sufficient lime is added to decrease the soluble Al^{3+}.

However, the problem of low pH leading to toxic levels of exchangeable Al and Fe and the deficiency of Ca and Mg in the soil can definitely be ameliorated by the use of Calcium Carbonate (limestone)

Indeed, the beneficial effect of lime in acid sulphate soils, (basically, soils of marine flood plains upon which drainage and aeration show definite and severe acidification) on the performance of rice, has been established (Clarkson, 1969, Watts, 1986; Hue and Amien, 1990).

The term “cat-clay” has been used to denote acid soil material in its oxidized form (Van der Spek 1950) showing straw-yellow mottling and streaks of basic ferric sulphate. Equally, Edlman *et al*., (1958) have proposed the term “mud-clay” to denote the non-drained, unoxidised soil with high potential acidity. Both forms of acid sulphate soils are of fairly widespread occurrence along the coastal and riverine regions of southern Nigeria.

The objectives of this study were to determine the aluminum and iron contents, the effect of drying, phosphate and lime application in an acid sulphate soil grown to rice in Nigeria.

MATERIAS AND METHODS

The experiment was conducted in April, 2006, at Mbiabet rice paddy, in Akwa Ibom State. The site is situated on 07°34′ and 07°36 East and 05°29′ and 05°31′ North. The soils are acid sulphate soils and are basically soils of marine flood plains and show definite and severe acidification due to the oxidation of sulphides (chiefly pyrites, FeS_2) which leads to the formation of sulphuric acid. These soils as Moorman (1963) reported, are not limited to marine flood plains exclusively, but other soils that bear FeS_2 deposits inland may show the same phenomena. Acid sulphate soils outside the recent or fossil marine plains are however scarce.

To determine whether all the KCL-extracted aluminum and iron, is capable of combining with added phosphate, a large excess of potassium dihydrogen phosphate was added to dried pond-mud and cat-clay and the mixture shaken for 1 hour. After removal of Saloid-bound phosphorus, the aluminum and iron phosphate contents were determined.

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Field Sampling and Laboratory Analyses

The soil samples used in the experiment were muds obtained from three sites within the pond system. The mud-clay was obtained outside the actual pond area from the bottom of the canal, through the spill way that brings water to the paddy. The cat-clay was obtained from the bunds which had been excavated during the construction of stream banks that control the main water from the reservoir. The unfertilized swamp mud was taken from the pond of Latin square 36 x 5m which had received a surface limestone dressing, but no phosphate. The samples were obtained with the aid of a plastic tube fitted with a rubber-stoppered position to facilitate the extraction of the cores at depths of 0 – 1, 1 – 2, 2 – 5, 5 – 8, 8 – 10 and 10 – 15 cm. In the three soil types examined, 30 soil samples were collected, 10 per each soil type. The idea was to obtain a representative sample of the three soil types for the analytical work. Fractionation of the inorganic phosphorus was done by the method of Enwezor and Moore (1996) Total phosphorus was determined after fusion with Na_2C0_3 and organic phosphorus was taken as the difference between the total phosphorus and the summation values of the inorganic forms obtained form the fractionation analysis. Aluminum was estimated by the aluminom method, any fluoride present being removed by repeated evaporation with nitric acid as recommended by Frink and Peech (1962). Iron was measured by the thioglycollic acid method. Extractable forms of iron and aluminum were removed with neutral normal potassium chloride, as recommended by Pratt and Bair (1961). The aluminum and iron are referred to as extractable rather than exchangeable because although in the swamp mud and mud-clay, the extraction was made under nearly neutral condition, with the cat-clay the extracting solution become very acidic. The soil pH was measured with a pH meter, using a soil to water ratio of 1:1, except in case of incubated water logged muds when the electrodes were inserted directly into the mud.

RESULTS

The data on iron and aluminum extracted from dried pond mud by the fractionating solutions are given in Table 1.

Table 1: Iron and aluminum extracted from dried pond mud by the phosphorus fractionating solutions. (Average of 10 samples)

Extracting solution	Form of P extracted	Fe extracted (cmol kg^{-1})	Al extracted (cmol kg^{-1})
NH_4Cl	Saloid-bound	5	854
NH_4F	Al – bound	124	879
Naou	Fe-bound	35	620
H_2S0_4	Ca – bound	740	948
$Na_2S_20_4$ - Citrate	Occluded	5680	1588
Total	-	6584	4889

Most iron was removed from the dried mud by the sodium dithionite-citrate extractant. The highest concentration of aluminum was found in the sulphuric acid and dithionite-citrate extracts and the lowest in the sodium hydroxide extract. Both ammonium chloride and ammonium fluoride removed considerable amounts of aluminum from the dried mud.

The total amount of iron and aluminum removed by the fractionating solutions represented some 85 percent and 16 percent respectively of the amounts which were dissolved by concentrated hydrochloric acid after igniting the mud.

Table 2: Distribution of immobilized phosphate in the phosphate-treated fresh mud, after adding potassium hydrogen phosphate (Average of 10 samples)

(Result in cmol kg^{-1}).

Forms of P	Mud-clay	Cat-clay	Swamp-mud
Saloid-bound	0	18	0
Al-bound	14	95	78
Fe-bound	215	38	95
Ca-bound	162	8	12
Total	391	159	185

The comparison of these values with those in Table 1 of the unfertilized fresh muds show that the mud-clay added phosphate was chiefly fixed as iron phosphate while the cat-clay and swamp mud fixation was chiefly due to both iron and aluminum. In the cat-clay, aluminum was more active than iron in this respect, while the swamp mud, the converse applied. Saloid-bound phosphorus only appeared in the cat-clay (Table 2).

The vertical distribution of pH and kcl- extractable Al and Fe.

Table 3: The distribution of pH and kcl- extractable aluminum and iron with depth in pond which had received 122kg/ha P_20_5 during the fertilizer trials (10 samples each of fresh mud and Air-dried mud).

(Results are in cmol kg^{-1} oven dry-mud)

Depth (cm)	Fresh mud(N= 10)			Air-dried mud* (N =10)		
	pH	Kcl-extractable		pH	Kcl-extractable	
		Al	Fe		Al	Fe
0 – 1	6.2	7	7	5.6	12	0
1 – 2	6.7	12	12	5.7	15	0
2 – 5	6.5	16	16	5.4	14	5
5 – 8	6.4	31	31	5.4	23	21
8 – 10	6.3	38	38	5.3	61	33
10 – 15	6.2	53	53	5.0	82	41

*Based on drying period of two weeks

Table 3 shows that as the pH decreased the amounts of extractable aluminum and iron increased in both fresh and dry muds down the profile. Over the drying period of 14 days, the muds became more acid and the extractable aluminum and iron values increased with increase in profile depth. All the extractable aluminum and iron were available to fix phosphorus.

In the superficial layer (0 – 1 cm), the presence of an oxidized surface layer was indicated by the relatively low pH value for the mud surface, while the relatively higher pH values for the top 2 cm of the profile obtained on drying the mud suggest the presence of calcium carbonate.

Table 4: Ability of KCL-extractable aluminum and iron in dried swamp mud and cat-clay to combine with inorganic phosphorus.

(Results in cmol kg^{-1} oven dry mud)

Analysis	swamp mud	Cat-clay
Al-extracted from mud by NKCL	135	285
Fe extracted from mud by NKCL	110	12
Al $P0_4$ – P theoretically equivalent to KCL-extracted Al	145	345
Fe $P0_4$ – P theoretically equivalent to the KCL-extracted Fe	68	10
Al $P0_4$ – P actually found in the phosphate saturated mud	158	315
$FeP0_4$ – P actually found in the phosphate saturated mud	65	7

The results showed that all the extractable aluminum and iron were available to fix phosphorus (Table 4). The results showed that drying the mud-clay and swamp-mud caused a decrease in both pH and extractable aluminum and iron, but was followed by an increase in the amount of extractable aluminum and iron in the cat-clay.

DISCUSSION

In the cat-clay, occlusion of phosphate did not take place and the aluminum phosphate increased at the expense of iron and calcium phosphate, but not to any great extent. This behaviour of the cat-clay on drying is apparently not a constant feature of the mud, as it has been shown from Table 1 and 2 and probably depends on variations in the iron content. Presumably, in the mud-clay, which had a relatively high extractable iron content, unlike the cat-clay, the exchange between aluminum-bound phosphorus and iron and calcium-bound phosphorus was highly masked by the occlusion of the inorganic forms on drying, through the formation of iron oxide films of the surface of the phosphate particles. These results are similar to earlier results (Hue and Amien 1990, Pearson 1993, Enwezor and Moore, 1996, FAO 1998).

Iron was slightly more active in this respect in the swamp-mud and aluminum in the cat-clay. Yuan *et al* 1960, Hesse 1963, Ubi and Osodeke 2007, using acid soils reported that iron and aluminum were chiefly responsible for the immediate immobilization of added phosphate. These authors also found that as time passed, the proportion of aluminum phosphate decreased with lime and iron phosphate increased in the swamp mud and cat-clay.

These differences in the behaviour of the muds on drying are reflected in the differences between the fixation capacities of the fresh and dried muds. This relationship was however expected in view of the ability of the extractable aluminum and iron to fix phosphorus.

CONCLUSION

The most significant change which occurred on incubating the water-logged dried muds, was the decrease in the amount of occluded phosphate in the mud-clay, phosphate loss amounted to 75 per cent, which was converted to iron, calcium and organic phosphates. Over the same period the amount of aluminum phosphate increased in pond-mud but not in the cat-clay.

The phosphate fertilizer added to the ponds was found to be totally immobilized in either the fresh or dried mud, although immobilization may perhaps be a misleading term to apply to the combination of phosphorus and iron as under water logged conditions, since iron phosphate can possibly be regarded as available phosphate. These soils are good for rice production when given adequate P concentration to enhance greater yields and better economic returns to the farmers.

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