

Original Research Article

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Management of Iron and Aluminium Toxicity in Acid Sulphate Soils of Kuttanad

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An incubation experiment was carried out at College of Agriculture, Padannakkad during 2015-2017 to examine suitable amelioration strategies for the iron and aluminium toxicity in acid sulphate soils of Kuttanad. The acid sulphate soils of Kuttanad region are having extreme soil pH and toxicity of Fe and Al can be ameliorated using amendments and hence can be made more productive. During the submergence period among the various parameters monitored, a steady increase was observed for pH, Ca and Mg of the soil. Application of phosphogypsum + ½ lime (T_2) showed the highest increase in soil pH and available calcium content and was highly effective in lowering the toxic concentration of Fe and Al in the acid sulphate soils of Kuttanad.

Introduction

Kuttanad of Alleppey district, the rice bowl of Kerala is a unique agricultural tract lying 0.6 to 2.2 m below the mean sea level on the west coast of India. It has a geographic area of 0.85 lakh ha. This comprised of 50,000 ha of rice fields, out of which 14,227 ha belongs to acid sulphate soils (typic sulfaquent) known as the kari lands which is the most problematic area of rice cultivation. Several parts of this area have subsoil layers containing pyrites which on drainage and oxidation produce severe acidity.

Iron toxicity commonly occurs in a wide range of acid soils, particularly in lowland rice with permanent flooding. Excess

concentration of reduced iron (Fe^{2+}) results in a range of nutrient disorders and results in deficiencies of other major and micro nutrients. Aluminum toxicity is also one of the major concerns of low rice productivity in lowland acid sulfate soils (Fageria and Carvalho, 1982). Aluminum toxicity affects about 40-70% of the world's arable land, which has the potential for food crop and biomass production. Aluminium toxicity impairs productivity in soils having low pH (below 5.0).

The occurrence of metal toxicity predominantly of iron and aluminium in many cases can be overcome by the addition of lime

(calcium carbonate), or slaked lime (calcium hydroxide), magnesium carbonate or other alkaline/liming materials to increase the soil pH and precipitate the toxic metals and thus increase plant growth. Phosphorus deficiency is another problem in these areas.

This is because of the high P fixation capacity of the soil due to the occurrence of high concentration of iron and aluminium. Availability of phosphorous is decreased in extreme acidic condition (Suswanto *et al.*, 2007).

Since the acid sulphate soils of Kuttanad is an important problematic area with extreme acidity, toxicity of iron, aluminium coupled with deficiency of phosphorous, application of different amendments and other nutrients should be used for successful cultivation in these area.

Materials and Methods

An incubation experiment was conducted using the soil sample collected from 'Kari' lands of Kuttanad at College of Agriculture, Padannakkad as a preliminary study prior to the pot culture experiment. The study was conducted using four different treatments at two levels of submergence (5cm and 10 cm). The treatments were designed based on the recommendations of KAU POP 2011 *viz.* lime (T_1); phosphogypsum + $\frac{1}{2}$ lime (T_2); magnesium carbonate + $\frac{1}{2}$ lime (T_3) and control (T_4). The treatments were applied in factorial combination and the design was CRD.

The treatments were incorporated kept under submergence. The analysis of various parameters was done at 30, 60 and 90 days after submergence. The samples were analyzed for pH, available nutrients such as Ca, Mg, Fe and Al as per the standard procedures.

Results and Discussion

The results of the incubation study showed that the treatments had significant effect on soil pH, available calcium, magnesium, iron and aluminium throughout the submergence period.

Soil pH was found to be increasing during the course of incubation study. The level of submergence at 5cm and 10cm and the interaction between treatments and levels of submergence were non-significant whereas application of different amendments showed significance (Table 1). At 30 days after incubation application of lime T_1 (@ 500 kg ha $^{-1}$) showed maximum increase (5.85) in pH. This may be due to the ability of lime to neutralize the pH. After 60 and 90 days of submergence (5.81, 6.61 respectively) phosphogypsum @ 500 kg ha $^{-1}$ + $\frac{1}{2}$ lime (as per KAU POP) showed dominance in pH which might be attributed to the higher amount of Ca present in the treatment receiving combination of phosphogypsum and lime. Both phosphogypsum and lime are highly effective amendments in reducing the soil acidity on submerged condition. Similar results of lime and phosphogypsum in increasing the soil pH were reported by Lee *et al.*, (2007), Suswanto *et al.*, (2007) and Shamshuddin *et al.*, (2015).

The available Ca was found to increase during the period of incubation. The treatments showed significant effect throughout the incubation period. The levels of submergence and interaction between levels of submergence and treatments were non-significant with respect to availability of Ca. Application of phosphogypsum + $\frac{1}{2}$ lime (T_2) showed significantly superior available Ca after 30, 60 and 90 days of incubation (475, 551, 653 respectively). It may be because of the higher availability of Ca applied through phosphogypsum and enhanced pH due to lime (Table 2).

Table.1 Changes in pH of soil incorporated with different amendments

Treatments	pH 30 days after incubation			pH 60 days after incubation			pH 90 days after incubation		
	L ₁	L ₂	Mean	L ₁	L ₂	Mean	L ₁	L ₂	Mean
T ₁	5.75	5.94	5.85	5.79	5.79	5.79	6.25	6.43	6.34
T ₂	5.74	5.32	5.53	5.84	5.81	5.82	6.52	6.71	6.61
T ₃	5.26	4.79	5.03	5.15	5.28	5.22	6.23	6.12	6.17
T ₄	3.57	3.48	3.53	4.25	4.49	4.37	5.51	5.81	5.66
Mean	5.08	4.88		5.26	5.34		6.13	6.27	
Comparison	SE(m)	CD (5 %)		SE(m)	CD (5 %)		SE(m)	CD (5 %)	
L	0.095	NS		0.16	NS		0.096	NS	
T	0.14	0.41		0.23	0.69		0.14	0.41	
Lx T	0.19	NS		0.32	NS		0.19	NS	

Table.2 Changes in available Ca (mg kg⁻¹) of soil incorporated with different amendments

Treatments	Ca 30days after incubation			Ca 60days after incubation			Ca 90days after incubation		
	L ₁	L ₂	Mean	L ₁	L ₂	Mean	L ₁	L ₂	Mean
T ₁	342.50	344.58	343.54	526.70	529.98	528.34	553.97	599.38	576.67
T ₂	478.17	472.50	475.33	536.50	551.23	543.87	617.30	690.63	653.97
T ₃	343.75	364.58	354.17	492.48	493.32	492.90	521.88	532.72	527.30
T ₄	311.50	334.42	322.96	392.90	394.05	393.47	378.97	381.88	380.43
Mean	368.98	379.02		487.15	492.15		518.03	551.15	
Comparison	SE(m)	CD (5 %)		SE(m)	CD (5 %)		SE(m)	CD (5 %)	
L	13.12	NS		18.46	NS		29.45	NS	
T	18.56	56.12		26.11	78.96		41.65	125.93	
Lx T	26.24	NS		36.93	NS		58.89	NS	

Table.3 Changes in available Mg (mg kg^{-1}) of soil incorporated with different amendments

Treatments	Mg 30days after incubation			Mg 60days after incubation			Mg 90days after incubation		
	L ₁	L ₂	Mean	L ₁	L ₂	Mean	L ₁	L ₂	Mean
T ₁	55.50	58.00	56.75	57.30	55.10	56.20	52.73	53.17	52.95
T ₂	69.17	64.87	67.02	62.07	58.80	60.43	64.83	62.67	63.75
T ₃	79.33	71.48	75.41	89.367	89.00	89.18	82.33	83.33	82.83
T ₄	38.13	37.33	37.73	43.40	35.97	39.68	33.83	33.67	33.75
Mean	60.53	57.92		63.03	59.72		58.43	58.21	
Comparison	SE(m)	CD (5 %)		SE(m)	CD (5 %)		SE(m)	CD (5 %)	
L	1.452	NS		2.28	NS		1.30	NS	
T	2.054	6.21		3.23	9.76		1.84	5.56	
Lx T	2.904	NS		4.56	NS		2.60	NS	

Table.4 Changes in available Fe (mg kg^{-1}) of soil incorporated with different amendments

Treatments	Fe 30days after incubation			Fe 60days after incubation			Fe 90days after incubation		
	L ₁	L ₂	Mean	L ₁	L ₂	Mean	L ₁	L ₂	Mean
T ₁	369	325	347	266	294	280	161	160	161
T ₂	312	321	316	244	277	260	158	161	159
T ₃	456	426	441	463	378	421	294	295	294
T ₄	543	529	536	551	581	566	366	390	378
Mean	420	400		381	382		245	251	
Comparison	SE(m)	CD (5 %)		SE(m)	CD (5 %)		SE(m)	CD (5 %)	
L	12.6	NS		23.58	NS		40.57	NS	
T	17.9	54.19		33.34	100.83		57.38	173.50	
Lx T	25.34	NS		47.16	NS		81.14	NS	

Table.5 Changes in Al (mg kg^{-1}) of soil incorporated with different amendments

Treatments	Al 30days after incubation			Al 60days after incubation			Al 90days after incubation		
	L ₁	L ₂	Mean	L ₁	L ₂	Mean	L ₁	L ₂	Mean
T ₁	157.83	151.43	154.63	168.37	133.77	151.07	162.43	160.73	161.58
T ₂	145.97	142.47	144.22	132.20	127.84	130.02	103.93	106.76	105.35
T ₃	255.30	246.31	250.81	231.60	158.82	195.21	198.93	179.63	189.28
T ₄	326.40	298.87	312.63	316.10	314.83	315.46	236.70	225.83	231.26
Mean	221.38	209.77		212.07	183.82		175.50	168.24	
Comparison	SE(m)	CD (5 %)		SE(m)	CD (5 %)		SE(m)	CD (5 %)	
L	20.07	NS		30.03	NS		18.72	NS	
T	28.38	85.83		42.47	128.42		26.47	80.07	
Lx T	40.14	NS		60.06	NS		37.45	NS	

Fig.1 pH as influenced by treatments in the incubation experiment

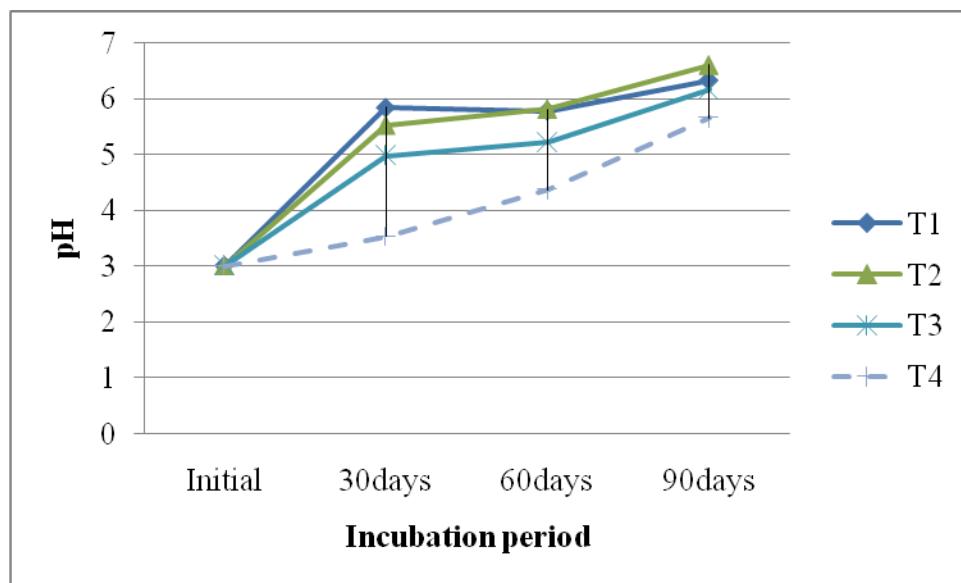
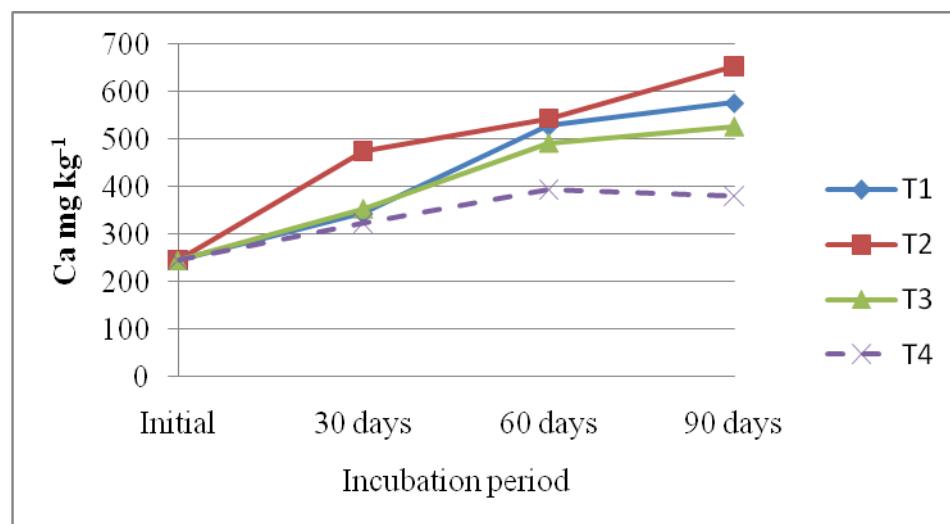


Fig.2 Ca as influenced by treatments in the incubation experiment



Moreover calcium present in phosphogypsum is readily soluble form and thereby enhancing its availability in soil (Deepa, 2008; Lee *et al.*, 2006; Azman *et al.*, 2013).

The treatments were highly significant with respect to availability of Mg whereas the levels of submergence and interaction between levels of submergence and

treatments were found to be non-significant. The application of magnesium carbonate + ½ lime (T₃) was recorded as the superior treatment with regard to available Mg. This may be because of the availability of Mg through the treatment. Suswanto *et al.*, (2007), Shamshuddin *et al.*, (2015) and Castro *et al.*, (2016) also reported that application of ground magnesium limestone containing Mg

increased the availability of magnesium. Iron and aluminium concentration in the soil showed a decreasing trend throughout the incubation period. The treatments showed significant effect in reducing the toxic levels of iron and aluminium content in the soil from 536 mg kg⁻¹ to 161 mg kg⁻¹ (Table 3 and 5).

The levels of submergence (5 and 10 cm) and interaction between the levels of submergence and treatments showed non-significance for iron and aluminium content.

Since the pH of the soil increased significantly with the application of amendments and submergence the concentration of iron and aluminium showed remarkable reduction. This is in conformity with the antagonistic interaction of these ions. Tran and Vo (2004) reported that Fe may be reduced in flooded condition from Fe³⁺ to Fe²⁺ but flooding will cause increase in the soil pH which results in concomitant reduction of soluble Fe (Table 4).

The present study also showed that flooding causes increase in pH from the initial value which may result in reduction of in Fe content here the soil reduction results in conversion of Fe³⁺ to soluble Fe²⁺ forms but the enhanced pH reduce the flux.

Ponnamperuma and Nhung (1965) also reported that activities of water soluble Al³⁺ and Fe²⁺ decreases for each unit increase in pH. Application of lime alone and combination of lime and phosphogypsum showed superior effect in reducing their toxic concentration in soil. Increase in Ca and Mg added through amendments also favours the reduction of toxic Fe and Al. Azman *et al.*, (2014) also reported that after the application of lime Fe and Al concentration will decline whereas Ca and Mg will increase. Phosphogypsum is a very good source of Ca amendment (Mrabet *et al.*, 2003) it also

alleviate the aluminium toxicity and increases plant growth (Alva and Sumner, 1989).

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