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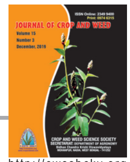

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Acidity amelioration practices for improving primary and secondary soil nutrient availability under rice cultivation in acid sulphate (Vaikom Kari) soils of Kuttanad

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ABSTRACT

The experiment was conducted in farmer's field of Vaikom Kari soils of strongly acidic nature in Kallara panchayat in Kottayam district from November 2014 to March 2015. The experiment was laid out in RBD with seven treatments in three replications with rice var. Uma (MO-16). The treatments included burnt lime shell, dolomite and rice husk ash (RHA) applied as two splits- as basal + 30 DAS or as basal + one week before third dose of fertilizer application or PI (panicle initiation) and a control without ameliorants. The ameliorated plots showed higher organic carbon status compared to control. Burnt lime shell as basal + one week before PI and dolomite treatments recorded higher soil available N at seedling stage and at tillering and PI stages, any treatment except control could register higher available N in the soil. Any liming material applied as basal + 30 DAS improved soil available P status. No significant effect of treatments on available K was observed. Burnt lime shell or dolomite treatments resulted in higher availability of Ca while dolomite treatments registered higher availability of Mg in the soil. At all stages except harvest, the control plots recorded significantly higher status of available S. Significant and positive correlation of pH with available Ca was observed at all stages of crop growth. Dolomite was found to be superior compared to burnt lime shell or rice husk ash with respect to soil pH as well as available nutrient status in ameliorating soil acidity in Vaikom Kari soil. Split application of dolomite as basal dose and at 30 DAS proved more effective than application as basal dose and one week prior to fertilizer application at panicle initiation stage.

Keywords: Acidity amelioration, dolomite, Fe toxicity, burnt lime shell, primary nutrients, rice, rice husk ash, secondary nutrients, Vaikom Kari

The geographical area of Kuttanad which is the rice bowl of Kerala is distributed in and around Vembanad lake in Alappuzha, Kottayam and Pathanamthitta districts of the state. Vaikom Kari soils of Kuttanad are deep black in colour, heavy in texture, poorly aerated and ill drained with severe acidity and periodic saline water inundation. The soils are low in available nutrient status and also contain toxic concentrations of iron (Fe), aluminium (Al) and unidentified toxic organic compounds (Chattopadhyay and Sidharthan, 1985). Burnt lime shell (calcium oxide) is the most common liming material used for ameliorating acidity in Kerala. However, due to ecological constraints, its collection and extraction are restricted in many places and its availability is also limited leading to high cost. Dolomite (calcium magnesium carbonate), which is comparatively a cheaper liming material, imported from the neighbouring states, is also being used. Another potential liming material is rice husk ash (RHA), a waste product from rice mills, which is cheap and environment friendly. The study was undertaken to evaluate these materials (burnt lime shell, dolomite and RHA) as soil acidity ameliorants in *kari* soils for improving nutrient availability towards enhancing rice yield.

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MATERIALS AND METHODS

The experiment was conducted in farmer's field in Kallara panchayat in Kottayam district during November 2014 to February 2015. The experiment was laid out in RBD with seven treatments in three replications with high yielding medium duration rice var. Uma. The treatments included burnt lime shell, dolomite and rice husk ash (RHA) applied as two splits- as basal + 30 days after sowing (DAS) or as basal + one week before third dose of fertilizer application or PI (panicle initiation) and a control without ameliorants. The treatments were T_1 - Burnt lime shell in two splits as basal and at 30 DAS (KAU, 2016); T_2 - Burnt lime shell in two splits as basal and one week before third dose of fertilizer application ; T_3 - Dolomite in two splits as basal and at 30 DAS; T_4 - Dolomite in two splits as basal and one week before third dose of fertilizer application; T_5 - Rice husk ash in two splits as basal and at 30 DAS; T_6 - Rice husk ash in two splits as basal and one week before third dose of fertilizer application and T_7 - Control. Soil samples were also collected before each fertilizer application at seedling stage (20 DAS), tillering stage (35 DAS), PI stage (60 DAS) and harvest

Table 1: Procedures followed for soil analysis

Soil parameter	Procedure of analysis	Instrument used	Reference
pH	Soil water suspension (1:1)	pH meter	Jackson (1973)
EC	Soil water suspension (1:1)	Conductivity meter	Jackson (1973)
Organic carbon	Chromic acid wet oxidation method	Titration	Walkley and Black (1934)
Available N	Alkaline permanganate method	Titration	Subbiah and Asija (1956)
Available P	Bray No.1 extraction	Spectrophotometer	Bray and Kurtz (1945) and Jackson (1973)
Available K, Ca and Na	Neutral normal ammonium acetate extraction	Flame photometer	Hanway and Heidal (1952)
Available Mg	Neutral normal ammonium acetate extraction	Atomic absorption spectrophotometer	Hanway and Heidal (1952)
Available S	Calcium chloride extraction and turbidimetry	Spectrophotometer	Tabatabai (1982)

and chemical properties were analysed as per Table 1. The data on the chemical properties of soil before the experiment are given in Table 2.

RESULTS AND DISCUSSION

Initially, the soil was strongly acidic (Table 2) and the treated plots showed an increase in soil pH over the initial value which decreased at harvest (Table 3). Among the liming materials, burnt lime shell and dolomite treatments were more effective in reducing soil acidity and ensuring sufficient availability of nutrients in the soil. This was reflected in higher uptake of nutrients with these treatments. Rastija *et al.* (2014) also observed improved soil chemical properties including higher pH due to application of dolomite. The decrease in soil pH at harvest is a clear indication of temporary effect of liming materials on soil pH which warrants liming during every crop season. However, the soil EC was increased in general during the cropping period (but below critical limit of 1 dS m^{-1}) with a drastic increase at harvest (Table 3) though the effect of treatments were not significant.

High organic carbon status is observed in *kari* soil. Thampatti (1997) recorded higher OC content of 10 to 30% in *kari* soil. In this experiment also, organic carbon status was high (3.18 to 4.89%). A slight increase in OC content from initial status (Table 2) from seedling to tillering stage and a decrease at harvest was noticed (Table 4). The treatments had significant effect only at PI stage when higher OC content was shown by burnt lime shell and RHA treatments.

Among the primary nutrients, initial N and P status in the soil was low and K status was medium (Table 2) (Venugopal *et al.*, 2013). Although the *kari* soil has higher OC content, available N status is generally low due to poor microbial activity (Koruth *et al.* 2013). This corroborates with the findings of the present experiment. Compared to the initial status, N and P availability was improved in the soil at all stages of experimentation (Table 5) but K availability was decreased at seedling stage and increased at tillering stage but showed a drastic reduction at PI and harvest stages over the initial status. Marykutty (1986) observed that application of burnt lime shell increased soil pH and available N and P but decreased availability of K in the soil.

Available N was decreased from seedling to tillering stage, which showed a slight increase at PI stage and again was decreased at harvest stage but above the initial status. A sharp increase in available P status was observed from seedling to tillering stage in all the treatments which was maintained at PI stage and reduced drastically at harvest stage which might be due to the reduction in soil pH at harvest. The low availability of P initially in the soil (Table 2) could be due to P fixation by Fe and Al sesquioxides which is a consequent of extreme soil acidity which was also reported by Tisdale *et al.* (1993), Audebert and Sahrawat (2000) and Dixit (2006). Available K status was increased from seedling to tillering stage but declined at PI and harvest stages.

With respect to primary nutrients, significant effect of treatments was observed only on N and P status. All the ameliorated plots had higher N and P contents than the control plots (no liming). This point to the fact that amelioration practices can improve the availability of N and P in the soil. Significant and positive correlation of soil pH with available N at seedling and tillering stages was observed (Table 7). Ono (2012) and Alexander (1977) reported that flooding and liming increased the pH and promoted N mineralization in soils. Soil pH also had significant and positive correlation with available P at tillering and PI stages. Rastija *et al.* (2014) also established enhancement of P availability by dolomite application. However, the treatments failed to express significant effect on soil available K during the cropping period. A drastic reduction in available K compared to the initial status was observed at harvest which might be due to toxic levels of available Fe in the

Table 2: Initial pH, EC and nutrient status of the soil of the experimental site

Soil parameters	Unit	Content	Rating
pH	-	4.68	Strongly acidic
EC	dS m^{-1}	0.22	Low
Organic carbon	%	4.33	High
Available N	kg ha^{-1}	275.97	Low
Available P	kg ha^{-1}	4.20	Low
Available K	kg ha^{-1}	168.67	Medium
Available Ca	mg kg^{-1}	110.00	Low
Available Mg	mg kg^{-1}	47.10	Low
Available S	mg kg^{-1}	973.90	High
Available Fe	mg kg^{-1}	509.20	High
Available Mn	mg kg^{-1}	9.26	High
Available Zn	mg kg^{-1}	3.71	High
Available Cu	mg kg^{-1}	5.41	High
Available B	mg kg^{-1}	0.32	Low
Available Na	mg kg^{-1}	53.10	Low
Available Al	mg kg^{-1}	49.30	Below toxic limit

Table 3: Effect of acidity amelioration practices on soil pH and EC

Treatments	pH				EC (dSm^{-1})			
	Seedling	Tillering	PI	Harvest	Seedling	Tillering	PI	Harvest
T_1	5.80	6.13	5.40	4.17	0.77	0.60	0.57	2.00
T_2	5.63	5.07	6.07	4.37	0.80	0.60	0.77	1.93
T_3	5.63	5.47	5.13	3.97	0.67	0.67	0.63	1.83
T_4	5.43	5.07	5.53	4.17	0.67	0.70	0.53	1.77
T_5	5.00	5.03	5.03	3.57	0.47	0.43	0.63	1.77
T_6	5.10	4.70	4.80	3.87	0.33	0.40	0.67	1.90
T_7	4.50	4.53	4.60	3.63	0.73	0.87	0.77	1.97
SEm (±)	**0.15**	**0.08**	**0.09**	**0.15**	**0.10**	**0.14**	**0.09**	**0.08**
LSD (0.05)	**0.469**	**0.258**	**0.289**	**0.456**	**0.300**	**-**	**-**	**-**

Table 4: Effect of acidity amelioration practices on organic carbon status in the soil

Treatments	Organic carbon (%)			
	Seedling	Tillering	PI	Harvest
T_1	4.26	4.30	4.20	3.48
T_2	4.20	4.89	3.83	3.81
T_3	3.78	3.89	3.72	3.43
T_4	3.38	3.98	3.88	3.18
T_5	4.34	4.58	4.33	3.50
T_6	4.24	4.18	3.53	3.42
T_7	3.83	4.26	3.29	3.19
SEm (±)	**0.26**	**0.37**	**0.13**	**0.30**
LSD (0.05)	**-**	**-**	**0.414**	**-**

Table 5: Effect of acidity amelioration practices on available N, P and K status in the soil, kg ha^{-1}

Treatments	Available N				Available P				Available K			
	Seedling	Tillering	PI	Harvest	Seedling	Tillering	PI	Harvest	Seedling	Tillering	PI	Harvest
T_1	359.59	345.04	388.87	307.23	4.60	18.86	19.19	6.83	120.85	153.42	98.07	46.64
T_2	437.81	366.31	380.50	276.66	4.33	14.58	15.35	6.23	116.18	160.60	82.80	49.39
T_3	423.43	347.05	363.78	317.78	4.93	18.05	17.20	4.14	121.00	157.81	94.31	52.60
T_4	401.63	320.31	407.73	342.87	4.10	12.63	13.80	5.95	139.71	173.36	98.96	52.33
T_5	354.55	397.22	418.14	326.14	4.43	17.51	14.57	7.92	120.77	187.48	107.22	60.45
T_6	372.34	401.41	347.05	292.69	5.30	13.96	12.65	4.89	113.80	177.96	101.81	70.93
T_7	283.55	238.34	234.16	230.21	3.83	8.62	9.53	5.75	112.63	135.97	94.74	68.62
SEm (±)	**20.12**	**26.99**	**27.12**	**39.00**	**0.40**	**1.14**	**1.04**	**0.93**	**8.93**	**12.06**	**5.91**	**5.74**
LSD (0.05)	**62.001**	**83.155**	**83.568**	**-**	**-**	**3.502**	**3.204**	**-**	**-**	**-**	**-**	**-**

Table 6: Effect of acidity amelioration practices on available Ca, Mg and S status in the soil, mg kg^{-1}

Treatments	Available Ca				Available MgAvailable S							
	Seedling	Tillering	PI	Harvest	Seedling	Tillering	PI	Harvest	Seedling	Tillering	PI	Harvest
T_1	484.40	497.30	375.97	128.53	69.00	67.80	51.87	41.47	489.23	227.70	318.40	578.97
T_2	412.10	399.30	452.67	175.70	62.63	54.30	43.30	32.60	323.40	414.90	301.63	467.20
T_3	350.00	527.60	361.50	161.30	137.00	184.67	207.07	128.30	602.83	454.53	462.03	538.57
T_4	350.60	430.23	505.57	178.57	139.30	123.07	148.93	159.17	423.03	469.87	289.13	595.93
T_5	273.33	219.63	170.33	108.67	92.63	71.40	50.80	42.27	503.83	405.83	377.47	541.63
T_6	315.80	184.70	226.63	111.07	96.93	81.20	50.10	33.83	574.60	511.00	356.67	512.87
T_7	180.47	142.27	151.50	39.34	60.17	49.20	32.67	22.70	627.30	536.03	489.60	646.30
SEm (±)	**26.72**	**26.87**	**22.61**	**14.23**	**7.87**	**6.10**	**8.66**	**8.94**	**54.63**	**38.43**	**20.77**	**49.79**
LSD (0.05)	**82.342**	**82.803**	**69.672**	**43.838**	**24.266**	**18.783**	**26.693**	**27.558**	**168.324**	**118.399**	**63.989**	**-**

Table 7: Correlation analysis of soil pH versus available nutrients in soil

Variables correlated with soil pH	Seedling	Tillering	PI	Harvest
Available N	0.556**	0.112	0.532*	0.134
Available P	0.186	0.629**	0.454*	0.178
Available K	0.298	-0.068	-0.331	-0.401
Available Ca	0.898**	0.780**	0.801**	0.659**
Available Mg	0.282	0.252	0.120	0.152
Available S	-0.367	-0.790**	-0.595**	-0.172

** significant at 0.05 level **significant at 0.01 level*

Table 8: Effect of acidity amelioration practices on yield attributes and yield

Treatments	Yield attributes			Yield and harvest index		
	Panicle no. m^{-2}	Sterility (%)	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index
T_1	293.33	8.93	26.00	7.58	8.51	0.48
T_2	285.00	9.33	24.33	6.46	7.09	0.47
T_3	288.33	8.40	26.33	7.92	8.56	0.48
T_4	263.33	9.27	24.33	7.02	7.17	0.49
T_5	266.67	8.00	25.67	7.59	8.00	0.47
T_6	263.33	8.67	25.67	6.98	8.60	0.46
T_7	198.33	16.87	23.00	4.31	6.30	0.41
SEm (±)	**10.62**	**0.43**	**0.76**	**0.28**	**0.30**	**0.01**
LSD (0.05)	**32.730**	**1.315**	**2.335**	**0.851**	**0.909**	**-**

soil.Ottow *et al*. (1983), Yamauchi (1989) and Sahrawat *et al*. (1996) had proved the occurrence of several nutrient disorders and deficiencies in soil including that of K due to Fe toxicity. In acid sulphate soils, K deficiency is associated with the formation of the sulfide mineral oxidation product jarosite, which acts as an infinite sink for K in the upper sulfuric horizon and reduces available K for plant growth (Keene *et al.,* 2004). Malvi (2011) reported that under high Na level, Na competes with K ions leading to K deficiency which was also observed in this experiment. The results necessitate elimination of Fe toxicity by liming and application of recommended dose of K for realizing higher yield of rice in acid sulphate soils.

Regarding secondary nutrients, the initial status of Ca and Mg were low whereas that of S was very high (Table 2) (Venugopal *et al.*, 2013). The deficiency of Ca and Mg might be due to higher Fe status in the soil. Ottow *et al*. (1983), Yamauchi (1989) and Sahrawat *et al*. (1996) had reported the deficiency of Ca and Mg due to Fe toxicity. The deficiency of Ca could be corrected by the application of burnt lime shell and dolomite upto PI stage with a reduction at harvest stage (Table 6). The Ca content again went below the critical level of sufficiency at harvest for all the treatments. Among the treatments the control plots followed by RHA treatments registered lower available Ca status. Significant and positive correlation of pH with available Ca was observed at all stages (Table 6).

Considerable improvement in the status of available Mg above the level of sufficiency was observed at all stages of experimentation in dolomite applied plots. With regard to other ameliorants, a slight increase above the initial status in available Mg was observed upto tillering stage which was maintained upto PI stage but it was declined at harvest (Table 6). The decline in Ca and Mg availability at harvest stage might be due to the removal of these nutrients by the crop and due to reduction in soil pH at harvest. Marykutty (1986) observed that application of burnt lime shell decreased exchangeable H^+ and Al^{3+} and increased soil pH and exchangeable Ca and Mg in the soil.

Available S was reduced from the initial status at all stages of experimentation. The reduction in S availability might be due to the low redox potential of submerged rice soils resulting in reduction of sulphates to sulphides, some of which are toxic (H_2S) and others low in solubility (FeS and ZnS) as reported by Ramasamy (2014). Moreover, slower mineralization of organically bound S decreases the availability of S to rice in submerged soils. Higher soil available S was recorded with the control (no liming) during all stages of the crop which might be due to high acidity in the control. Soil amelioration practices could bring down the availability of S in the soil at all stages of experimentation. However, available S content showed an increase at harvest stage over the level at PI stage irrespective of treatments. Drying of soil at harvest might have resulted in oxidation of S to available SO_4 increasing the availability as observed in the present experiment. Soil pH was negatively and significantly correlated with available S at tillering and PI stages (Table 7). The effect of liming material on yield and yield attributes are presented in Table 8. Acidity amelioration resulted in improvement of rice yield. The lowest grain yield and straw yield were registered by the control and higher grain yield was obtained by the application of lime or dolomite or RHA as basal + 30 DAS.

The results of the study revealed the superiority of dolomite for ameliorating soil acidity in Vaikom Kari soil compared to burnt lime shell or rice husk ash with respect to soil pH as well as available nutrient status. Split application of dolomite as basal dose and at 30 DAS was proved more effective than application as basal dose and one week prior to fertilizer application at panicle initiation stage.

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