



Effect of various soil amendments on soil pH and exchangeable Ca at different depths in the identification of a suitable liming material for tannia (*Xanthosoma sagittifolium* L. Schott) in an Ultisol, Kerala, India

K. Susan John* and R.T. Remya Raj

Division of Crop Production, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram-695017, Kerala, India

Abstract

Tannia (*Xanthosoma sagittifolium* L. Schott) is an important tropical tuber crop coming under the group of aroids. It is usually grown as intercrop in plantations and fetches good remuneration. When this crop is grown in the acid laterite soils (Ultisols), widespread occurrence of Mg deficiency was very common resulting in the complete devastation of the crop. The reason attributed was the acidity due to excess Al^{3+} ions in the subsoil layers which causes the decay of roots and hence adversely affecting the absorption of water and nutrients. This crop being an indicator plant for Mg deficiency, the symptom is manifested as interveinal chlorosis coupled with drying of the whole plant. The present study was undertaken to screen a better soil amendment to tackle the problem of subsoil acidity induced multi nutrient disorder in tannia. The present study was done using five liming materials viz., calcite, dolomite, gypsum, calcium silicate and calcium oxalate at quantities ranging from 50-1000g both under controlled condition in lysimeter and in field. After application of treatments, soil samples drawn continuously for 6-7 months from four different depths viz., 0-15, 15-30, 30-45 and 45-60 cm were analysed for pH, CEC and exchangeable Ca. The data generated were statistically analysed for the independent and interaction effect of treatments (liming materials, rate of application, depth of sampling and interval after application) and results on the mean effect, changes over initial and at the end of 6-7 months of application with respect pH and exchangeable Ca for the above treatments were described. The results from both situations revealed that, calcite, dolomite and gypsum were equally effective. Among the three, dolomite being a source of both Ca and Mg, even at lower quantities as 250 g was found better in enhancing both pH (1.54 units over initial) and exchangeable Ca (1.559 cmol (+) kg soil⁻¹ over initial) to the maximum extent especially at lower depths up to 60 cm to a period of 4-5 months after application.

Keywords: Tannia, Subsoil acidity, Mg deficiency, Liming materials, Exchangeable Ca

Introduction

Among the tropical tuber crops, aroids viz., elephant foot yam, taro and tannia are valued as nutritious as well as therapeutically valuable tuberous vegetables grown mainly as intercrops in coconut as well as in banana and rubber plantations of Kerala. Since coconut is a major

crop grown both on plantation scale and component crop in the homesteads of Kerala, raising intercrops like aroids is a common practice by farmers. Among the aroids, tannia known as new cocoyam (*Xanthosoma sagittifolium* L.Schott) is the most remunerative as its cormelfetches good price in local markets and is having good export potential.

*Corresponding author
E-mail: susanctri@gmail.com; Tel: +91 9446324298

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Tannia is cultivated for edible tubers (corms and cormels) and young leaves. The tubers and young leaves are highly nutritious having substantial quantities of protein, vitamins and minerals in addition to starch/energy. Compared to taro, tannia is preferred by people due to the absence of itching and lack of too much of mucilage in the tubers, good cooking quality as well as better taste. Since the starch granules in tannia tubers are relatively large, they are mainly used for the production of industrial starch. In some places, flesh scrapings of corm and cormels are pulped and used as anti-coagulants, anti-tetanus and anti-venom agents against tarantula, scorpion and even snake bites.

When tannia was grown in acid laterite soils (Ultisols), the crop will be having luxuriant vegetative growth up to 3-4 month after planting (MAP) if other growth conditions like soil moisture, sunlight and relative humidity are adequate. After that, the crop starts showing clear and distinguishable symptoms in the foliage characteristic of Mg deficiency in the form of interveinal chlorosis of older leaves followed by cupping inward and drying up of the tip and margins of the entire leaf. In severe cases, the entire foliage will dry up resulting in complete devastation of the crop without any tuber formation and development. In most of the situations, this is accompanied by expression of K deficiency symptoms as characteristic marginal drying and necrosis of lower leaves extending to the leaf tip resulting in complete drying and falling off and Ca deficiency in the form of crinkling of younger leaves with reduction in leaf size and difficulty of leaves to emerge.

The above observations were substantiated through the analysis of soil and leaf samples which in turn indicated that, the soils (Ultisols) where the crop was grown was acidic to very strongly acidic with a pH range of 4.5-5.0 and quite deficient in Mg, Ca and K. This very low pH indicates the excess availability of Al^{3+} ions and toxic levels of Al do inhibit the root growth of the plant inducing the non-availability of secondary nutrients especially Ca and Mg. This may also cause water stress resulting in the occurrence of nutritional disorders due to Mg, Ca, and K in Ultisols or laterite soils even after the grand growth period is crossed. Moreover, as Mg, K and Ca are prone to leaching under tropical conditions, they will become unavailable to the plant especially during the critical vegetative growth and at the initiation of tuber bulking. As the amount of basic cations especially Mg available in the soil during the critical growth stages may not be sufficient to meet the crop demand (Susan John et al., 2006). As Tannia is an indicator plant for Mg deficiency having lower Mg and excess Ca contents in Mg deficient tannia leaves, the effect of subsoil acidity is manifested as Mg deficiency (Cable, 1995). Nair et al., (2018) already reported the prevalence of strongly acid condition in the surface and subsurface soils of Kerala.

After recognizing the problem in tannia as subsoil acidity induced multi nutrient disorder involving nutrients like K, Ca, and Mg, in order to screen a suitable soil ameliorant for this crop to manage subsoil acidity, the present study was carried out with liming materials like lime, dolomite, gypsum, calcium silicate and calcium oxalate. As there are many reports (Anikwe et al., 2016; Thomas and Hargrove, 1984; Shainberg et al., 1989; Rashid and James, 1980) indicating the usefulness of different liming materials in correcting surface and subsurface acidic conditions, these five liming materials containing Ca and Mg with different quantities at different depth of application were tested in the present study.

Materials and Methods

This basic study was undertaken based on the results of experiments conducted to rectify the soil acidity related nutritional disorders associated with the manifestation of the foliar symptom and consequent tuber initiation and development problems. The primary objective was to identify a suitable liming material to correct the subsoil acidity, so that, the crop can be saved from the existing nutritional disorder.

Here, the experiments were conducted both under field as well as under controlled condition in lysimeter tanks of 1 m³ volume using five different liming materials *viz.*, calcite, dolomite, gypsum, calcium silicate and calcium oxalate at different rates containing calcium oxide (CaO) to the tune of 56, 33.2, 32.2, 32.6 and 43.8% respectively. The liming materials used, their rate of application as well as the depth of sampling both under lysimeter and field condition are given in Table 1.

These soil samples were analysed for pH (pH meter, Systronics), CEC and exchangeable Ca (Page et al., 1982). In the case of lysimeter studies, pH, exchangeable Ca and CEC was determined initially from the surface (0-15 cm) soil. After application of the above treatments in lysimeter, pH was measured for a period of 7 months continuously from the above four depths, Ca for a period of 6 months continuously from the above four depths and CEC only initial and after 5 months from the surface soil.

In the field situation, the initial samples were analysed for pH, and exchangeable Ca from the surface soil and pH and Ca were analysed from the above four depths for a period of 6 months continuously from the first month of application onwards. Statistical analysis of the data was carried out for independent and interaction effect of treatments *viz.*, liming materials (calcite, dolomite, gypsum, calcium silicate, calcium oxalate) soil depth (0-15, 15-30, 30-45, 45-60 cm), quantity (50,100,150 and 200g in the case of calcium silicate and calcium oxalate and 250,500,750 and 1000g in the case of calcite, dolomite, and gypsum), intervals (initial, 1,2,3,4,5,6,7

Table 1. Liming materials used, rate and depth of soil sampling

Method	Liming material	Quantity/tank	Depth
Lysimeter	Calcite	500g	0-15,15-30,30-45and 45-60cm
	Dolomite	500g	0-15,15-30,30-45and 45-60cm
	Gypsum	500g	0-15,15-30,30-45and 45-60cm
	Calcium silicate	100g	0-15,15-30,30-45and 45-60cm
	Calcium oxalate	100g	0-15,15-30,30-45and 45-60cm
Field	Calcite	@ 250,500,750 1000g m ⁻³	0-15,15-30,30-45and 45-60cm
	Dolomite	@ 250, 500,750 1000 m ⁻³	0-15,15-30,30-45and 45-60cm
	Gypsum	@ 250, 500,750 1000g m ⁻³	0-15,15-30,30-45and 45-60cm
	Calcium silicate	@ 50, 100,150, 200g m ⁻³	0-15,15-30,30-45and 45-60cm
	Calcium oxalate	@ 50, 100,150 200g m ⁻³	0-15,15-30,30-45and 45-60cm

months after application (MAA) in the case of pH, initial and one month interval continuously up to 6 MAA in the case of exchangeable Ca and initial and 5 MAA in the case of CEC using Genstat (2010).

The basic soil parameters of the soil of the experimental plot under field condition is given below: Soil type: sandy clay loam, pH: 4.3-4.9, Organic Carbon: 0.53 -0.70 %, Available N: 175 kg ha⁻¹, Available P: 68 kg ha⁻¹, Exchangeable K: 193 kg ha⁻¹, Exchangeable Ca: 0.74 cmol (+) kg⁻¹ soil, Exchangeable Mg: 0.56 cmol (+) kg⁻¹ soil, Available S: 7.3-12.4 ppm, Available Fe: 21 ppm, Available Cu: 0.34 ppm, Available Mn : 8.3 ppm, Available Zn: 2.6 ppm, Available B: 0.68 ppm

Results and Discussion

The results of the experiments carried out both in lysimeter and under field condition with the above liming materials in the screening of the best soil amendment for tannia in the Ultisols of Kerala are detailed below:

1. Lysimeter

The initial soil samples analysed from the surface for the five treatments as shown in Table 1 as well as control indicated the pH as near neutral with a mean value of 6.89 and ranged from 6.37 to 7.31. Similarly, the

Table 2. Initial pH, CEC and exchangeable Ca of the soil under lysimeter experiment

Liming material	Lysimeter (0-15 cm)		
	pH	Ca (cmol (+) kg ⁻¹ soil)	CEC
Calcite	6.37	4.31	12.06
Dolomite	6.88	4.53	13.03
Gypsum	6.73	5.72	13.25
Calcium Silicate	7.07	4.99	10.86
Calcium oxalate	6.98	5.33	16.51
Absolute control	7.31	5.96	14.34
Mean	6.89	5.14	13.34

exchangeable Ca indicated a mean value of 5.14 cmol (+) kg⁻¹ soil with ranges as 4.31 to 5.96 cmol (+) kg⁻¹ soil and CEC in the range of 12.06-16.51 cmol(+) kg soil⁻¹ with a mean value of 13.34 cmol(+) kg soil⁻¹.

Effect of liming materials

Changes in pH

The mean pH determined over a period of 7 months indicated the effect of the liming materials as same on pH except for calcium silicate which has resulted in a significantly low pH compared to the other four liming materials. This in turn corroborates to the findings of Thomas and Hargrove (1984) revealing the effect as complete absorption and retention of the added Ca through the replacement of exchangeable Al³⁺ ions. The overall improvement in pH over initial was seen with calcite and gypsum only, to the tune of 3.44 and 1.29%. This increase might have been due to the movement of labile Ca down the soil decreasing the Al in the subsoil layers as well as due to the formation and precipitation of AlSO₄ as reported by Pavan et al., (1984). As regards to the pH after 7 months of its application, it was seen that, the change in pH was statistically similar for all liming materials except for calcium silicate which resulted in a

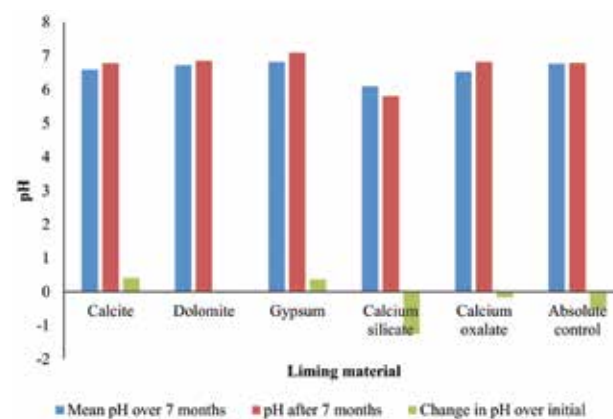


Fig.1. Changes in pH under different liming materials over a period of 7 months

significantly low pH. The change in pH over the initial showed increase in the case of calcite and gypsum. The change over initial as well as the % change is given in Fig.1.

Changes in exchangeable Ca

The overall mean soil exchangeable Ca over the 6 months indicated significant effect of liming materials on soil exchangeable Ca with gypsum resulted in significantly higher Ca may be the effect of self-liming as reported by Reeve and Sumner (1972). Calcium silicate resulted in significantly low available soil Ca on par with that of calcium oxalate, calcite and dolomite. At the end of 6 months of application, no significant effect of liming materials was seen on soil exchangeable Ca. However, gypsum followed by dolomite, calcite and calcium oxalate resulted in comparatively high soil Ca. Over the initial Ca, at 6 MAA, the Ca content was seen depleted with all liming materials in the order as control, the highest followed by calcium silicate, calcium oxalate, gypsum and then dolomite and calcite (Table 4). The comparatively low Ca associated with calcium silicate might have been the effect of restricted Ca movement with calcium silicate as reported by Mahilum et al., (1970).

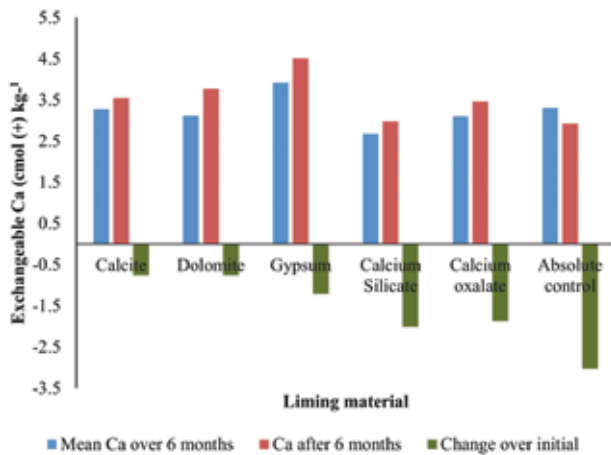


Fig. 2. Changes in exchangeable Ca under different liming materials over a period of 6 months

Changes in soil CEC

After 5 months, the CEC estimated showed a drastic reduction compared to initial in the case of all liming materials viz., calcite, dolomite, gypsum, calcium silicate, calcium oxalate and absolute control to the tune of 1.91, 20.80, 43.09, 14, 40.94 and 24.27% respectively. Edmeades (1982) in a range of New Zealand soils reported that, there will not be much retention of cations other than calcium in the exchange sites due to liming and hence cannot expect an increase in CEC.

Effect of depth

In the case of soil pH, over these 7 months, the pH was significantly higher in 15-30 cm and was on par with

0-15 cm depth. The soil pH was significantly lowest at 45-60 cm depth. The exchangeable Ca at 0-15 cm was significantly the highest and the Ca content at 15-30 cm depth was on par with that at 30-45 cm. The soil depth of 45-60 cm significantly registered the least soil exchangeable Ca. High pH and exchangeable Ca noted in the surface 0-30 cm depth was apparently more as the liming materials reacted with the surface soil and less moved to lower layers during the seven months of incubation as seen in an experiment in a tropical soil profile by Rashid and James(1980).

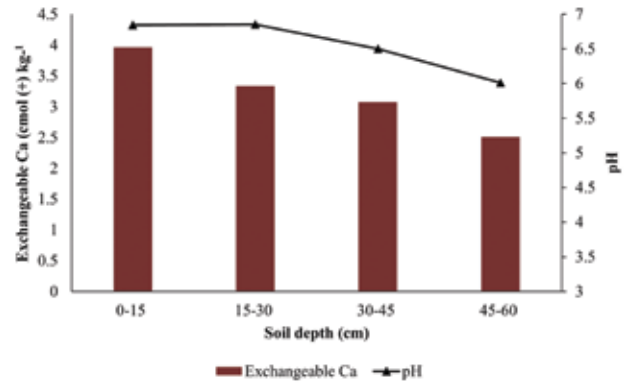


Fig. 3. Changes in pH and exchangeable Ca under different liming materials over period of time at different depths

Quantity of liming materials

In the lysimeter tanks, we used two quantities of the liming materials viz., calcite, dolomite and gypsum @ 500g each and calcium silicate and calcium oxalate @ 100g each. Over these months, the overall pH under these quantities differed significantly with 500g resulted in significantly the highest soil pH. Similar was the effect on soil exchangeable Ca too. Qaswar et al., (2020) reported high pH values, exchangeable cations including Ca and consequently low exchangeable Al and exchange acidity with high lime rates.

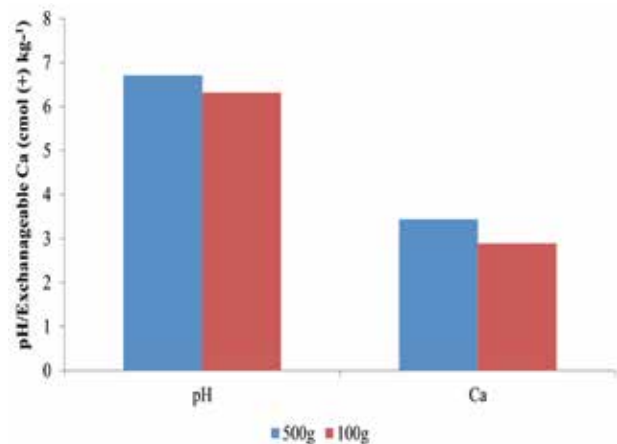


Fig. 4. Changes in pH and exchangeable Ca under two rates of different liming materials over a period of 7 months at different depths

Months after application of liming materials

After application of the different liming materials, samples were drawn and analysed for pH up to 7 months and exchangeable Ca up to 6 months. Statistical analysis of the data for the effect of intervals alone and lime interval interaction on both pH and exchangeable Ca indicated significant effect of intervals alone on both pH and Ca and the interaction was non-significant.

It was seen that, the pH after 4, 5 and 7 MAA was on par with that of the initial which in turn was highest among the different intervals. The pH recorded at 1 MAA was significantly lower and was on par with the pH at 2,3,4 and 6 MAA. In the case of exchangeable Ca at different intervals, the initial exchangeable Ca was significantly the highest. The Ca content at 5 and 6 MAA were significantly higher and were on par. During the other intervals, the Ca content was significantly lower and was on par. Similar findings of increase in soil pH and exchangeable cations were reported by da Costa et al., (2016) while taking observation at 48 and 60 months after application of liming materials in a tropical clayey Oxisol.

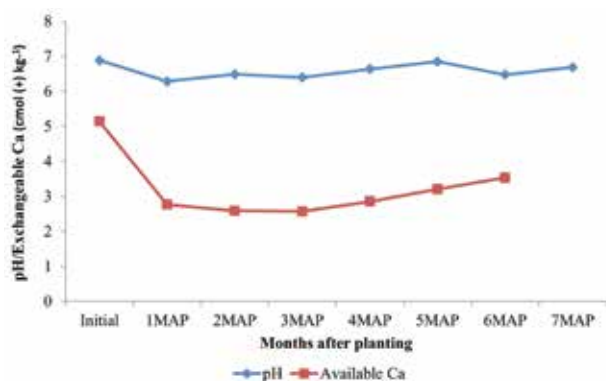


Fig. 5. pH and exchangeable Ca under two rates of different liming materials at different intervals at different depths

2. Field Condition

The effect of application of five different liming materials viz., calcite, dolomite and gypsum @ 250, 500, 750 and 1000g and calcium silicate and calcium oxalate @ 50, 100, 150 and 200g at four different depths as 0-15,15-30,30-45 and 45-60 cm from application for a period of 6 months continuously is described below based on the statistical analysis of the data in Genstat (2010).

The initial soil pH and exchangeable Ca at the four different depths are given in Table 3.

Table 3. Initial soil pH and exchangeable Ca of the experimental site at four depths

Depth (cm)	pH	Exchangeable Ca (cmol (+) kg soil ⁻¹)
0-15	5.25	0.59
15-30	5.34	0.61
30-45	5.04	0.44
45-60	4.62	0.18
Mean	5.06	0.46

The depth wise analysis of the initial soil samples for pH and exchangeable Ca indicated the mean pH and Ca of the initial soil samples as 5.06 and 0.46 meq 100g⁻¹ respectively. Both pH as well as Ca was found higher at 15-30 cm soil depth followed by 0-15, 30-45 and 45-60 cm.

Effect of liming materials

Table 4. Changes in pH under different liming materials over a period of 6 months

Liming material	Mean pH	pH after 6 months	Change in pH over initial	Percentage Change in pH over initial
Calcite	5.83	6.38	1.32	26.09
Dolomite	6.14	6.60	1.54	30.42
Gypsum	5.17	6.16	1.10	21.68
Calcium silicate	5.35	5.57	0.51	10.02
Calcium oxalate	5.04	5.39	0.33	6.44
Absolute control	4.95	5.48	0.42	8.30
CD(0.05)	0.188	0.363		

The effect of liming materials on pH over these 6 months indicated, dolomite followed by calcite as the best as the pH under these treatments were significantly the highest, followed by calcium silicate which was on par with gypsum which in turn was on par with calcium oxalate. At the end of six months, it is seen that, the highest increase in pH was for dolomite followed by calcite, gypsum, calcium silicate and calcium oxalate resulted in significantly the lowest even less than absolute control (Table 4). Susan John et al., (2013) reported dolomite as the best liming material for Ultisols of Kerala. In the case of exchangeable Ca, dolomite resulted in significantly higher exchangeable Ca followed by calcite on par with gypsum followed by calcium silicate and calcium oxalate, significantly the least even less than absolute control. After 6 months of the application of these amendments, it is seen that, dolomite, followed by calcite and gypsum resulted in significantly higher exchangeable Ca and were on par and then calcium silicate (Table 5). Anikwe

et al., (2016) had similar observations with dolomite, lime and gypsum under cassava in an Ultisol of Nigeria. Calcium oxalate resulted in significantly the least on par with absolute control and the same trend was seen in the case of increase in exchangeable Ca over these six months. However, the increase in Ca noticed with all these amendments was substantial. The substantially low pH and exchangeable Ca associated with calcium oxalate can be attributed to the reports of Uren (2018) that, in acid soils, the microbiological transformation of calcium oxalate to Ca through the formation of the intermediary product calcium bicarbonate which in turn is insoluble is a slow process.

Table 5. Changes in exchangeable Ca (cmol (+) kg soil⁻¹) under different liming materials over a period of 6 months

Liming materials	Mean exchangeable Ca	Ca after 6 months	Change in Ca over initial	Percentage Change in Ca over initial
Calcite	1.464	1.852	1.392	302.61
Gypsum	1.324	1.804	1.344	292.17
Dolomite	1.672	2.019	1.559	338.91
Calcium Silicate	1.078	1.340	0.88	191.30
Calcium oxalate	0.613	0.702	0.242	52.61
Absolute control	0.680	0.653	0.193	41.96
CD(0.05)	0.1969	0.540	-	-

Effect of depth of soil application

Though the application was done in surface and mixed well, the soil samples from four depths up to 60 cm were taken and analysed for pH and exchangeable Ca. The mean pH over the four different depths over the six months period with different quantities of the five different liming materials indicated significant difference among the four depths with 15-30 cm registering significantly the highest soil pH followed by 30-45 cm which was on par with 0-15 cm. The pH recorded at a soil depth of 45-60 cm was significantly the lowest. As regards to the pH after six months, it is seen that, there was no significant difference among the four depths. However, the order of decrease in pH was 15-30, 0-15, 30-45 and 45-60 cm. Over the initial pH, 45-60 cm recorded the highest soil pH followed by 30-45, 0-15 and 15-30 cm (Table 6). Abure (2022) observed substantially high pH in subsurface soils of 20-40cm depth corroborating to our findings. However, the highest pH over initial seen in 45-60 cm soil depth can be justified based on the findings of Wakene (2001) under northeastern soils of Ethiopia.

Table 6. Changes in pH under different liming materials over a period of 6 months at different depths

Depth (cm)	Mean pH	pH after 6 months	Change in pH over initial	Percentage Change in pH over initial
0-15	5.50	5.995	0.745	14.19
15-30	5.729	6.046	0.706	13.22
30-45	5.535	5.942	0.902	17.90
45-60	5.242	5.844	1.224	26.49
CD(0.05)	0.1746	NS	-	-

The same trend as in the case of soil pH was seen with soil exchangeable Ca showing significantly the highest at 15-30 cm, which was on par with 0-15 cm followed by 30-45 cm. The pH at 45-60cm was significantly the lowest. After 6 months of application of treatments, the exchangeable Ca was highest at 45-60cm followed by 30-45cm, 15-30cm and 0-15cm. The increase over initial was maximum at 45-60cm and decreased in the order of increasing depth (Fig. 6). Abure (2022) also reported increase in exchangeable cations with increase in soil depth and the reason being the high clay content and accumulation of basic cations in the subsurface layer.

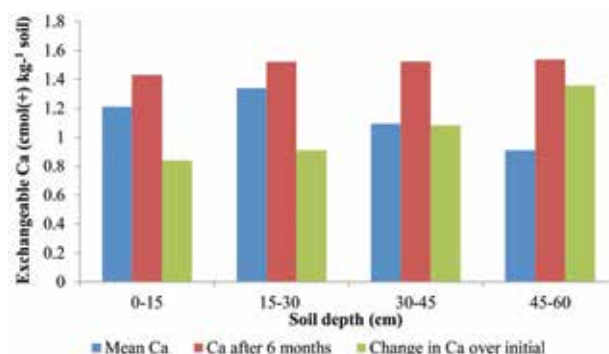


Fig. 6. Changes in exchangeable Ca under different liming materials over a period of 6 months at different depths

Our findings with different liming materials at various soil depths corroborates to the findings of Kisinyo et al., (2015) and Yorstand Ares, (2007) stating that, lime had no significant effect on soil pH, exchangeable Ca²⁺ and Al³⁺ in the subsoils at 20-40 and 40-60 cm depths and the reason being the slow solubility of lime and hence low mobility within the soil. The findings also conform to the report of Arya, (1990) that, very little changes in soil pH, exchangeable Ca²⁺ and Al³⁺ in the sub soil (12-85 cm depth) even after two and a half years after lime application at rates between 1.5-6.0 tons of lime per hectare.

Effect of quantity of application of liming materials

The mean pH over 6 months with different quantities of liming materials ranging from 0-1000g indicated significant effect on pH with significantly higher pH at

1000 g which was on par with 250,500 and 750 g of the liming materials. The significantly lower pH was noted with 50 g liming material, which was on par with 100,150, 200 g and control too. As regards to the pH after 6 months, it is seen that, 250 g resulted in significantly higher pH on par with 750 g followed by 500 g and 1000 g. There was no significant difference in pH among 50,100,150 and 200 g of the liming materials as they were on par in affecting the soil pH. Over the initial, 250 g caused the maximum increase followed by 750, 500 and 1000 g of the liming materials. Similarly, 250 g followed by 200 g and 100 g resulted increase in pH. The same trend was noted in the case of percentage increase in soil pH (Table 7).

Table 7. Changes in pH under various quantities of different liming materials over a period of 6 months at different depths

Quantity (g)	Mean pH	pH after 6 months	Change in pH over initial	Percentage change in pH over initial
0	4.955	5.345	0.285	5.63
250	5.913	6.624	1.564	30.91
500	5.811	6.176	1.116	22.06
750	5.844	6.593	1.533	30.30
1000	5.962	6.122	1.062	20.99
50	5.078	5.514	0.454	8.97
100	5.389	5.321	0.261	5.16
150	5.204	5.508	0.448	8.85
200	5.092	5.64	0.580	11.46
CD (0.05)	0.2315	0.4141	-	-

Though higher quantity resulted in an overall increase in pH, over the initial, the maximum increase was caused by the lowest quantity and this in turn conforms to the reports of Garbuio et al., (2011) in an Oxisol. Kisinyo et al., (2015) found that, lower lime rate (25% of the actual lime requirement) increased soil pH to highest peak in relatively shorter time and thereafter the pH began to decline compared to where half of the requirement was applied. This was likely because, Ca^{2+} ions in lower lime rate were depleted very fast, resulting in an increase in soil acidity. Similar results were reported by Sanchez (1976) who found that, the residual effect of lime depends on the amount of Ca^{2+} and/or Mg^{2+} ions still remaining in the liming material at any given time. They further indicated that, the exchangeable Ca^{2+} and Mg^{2+} increased with increasing lime rates while the exchangeable Al^{3+} decreased with increasing rates of lime.

As regards to exchangeable Ca, the mean over six months indicated significantly higher soil pH with 250 g of the liming materials on par with 500 g followed by 750 and

1000 g. Liming materials @ 50,100,150 and 200 g did not produce significant effect on soil exchangeable Ca. After 6 months of application, it was seen that, 250 g resulted in significantly higher exchangeable Ca on par with 750 g followed by 500 and 1000 g. The exchangeable Ca was significantly low with 50 g and was on par with 100 g, 150 g and 200 g. Over the initial 250 g caused the highest increase in exchangeable Ca, followed by 750, 500 and 1000 g. Similarly at the lower levels, 200 g followed by 250, 100 and 50 g caused increase in exchangeable Ca content of the soil and the same trend was followed in the percentage increase too (Fig. 7). The results indicated that, as the lowest rate of the liming material giving an exchangeable Ca content on par with the highest rates which may be attributed to the high available P content of the experimental soil (50-75 kg ha⁻¹) which in turn bound with phosphate making Ca unavailable as per the reports of Haynes and Ludecke (1981).

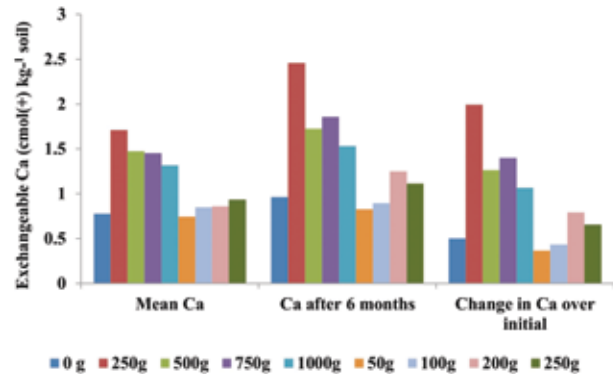


Fig. 7. Changes in exchangeable Ca under various quantities of different liming materials over a period of 6 months at different depths

Months after application of liming materials

The overall pH during the six intervals from initial indicated significant effect of months after application on soil pH with significantly higher at 6 MAA on par with 5 MAA followed by 4 MAA which was on par with 3 and 1 MAA and pH at 2 MAAs was on par with 1 MAA. As regards to the increase over initial as well as percentage

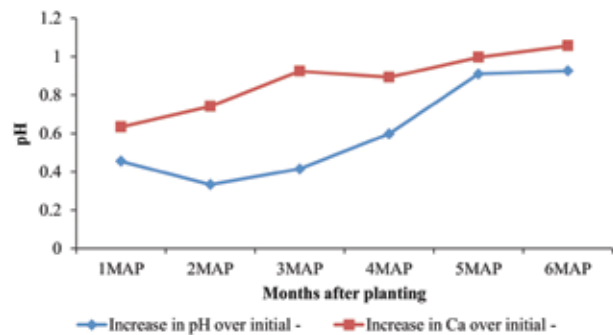


Fig. 8. pH and exchangeable Ca under two rates of different liming materials at different intervals at different depths

Table 8. Interaction effect of depth and quantity of liming materials on soil pH

Quantity (g) (Q)	Liming material	Depth (D) (cm)				Mean Q
		0-15	15-30	30-45	45-60	
0	Calcite, dolomite, gypsum	5.029	4.881	5.029	4.881	4.955
250		5.920	6.200	6.016	5.517	5.913
500		5.636	6.417	5.870	5.319	5.811
750		5.779	6.402	5.824	5.532	5.884
1000		5.823	6.335	6.125	5.565	5.962
50	Calcium silicate, Calcium oxalate	5.114	5.252	4.996	4.951	5.078
100		5.401	5.345	5.560	5.249	5.389
150		5.288	5.226	5.224	5.080	5.204
200		5.402	5.127	4.922	4.917	5.092
Mean (D)		5.567	5.850	5.616	5.289	
CD (0.05) D		0.1385				
CD(0.05) Q		0.2416				
CD(0.05) D × Q		0.3958				

increase over initial, the same trend was seen. As regards to the available Ca, there was significant difference among treatments and it is seen that, the exchangeable Ca at 6 MAA was on par with that at 5,4 and 3 MAA and the Ca at 1 MAA recorded significantly the lowest and the same trend was noted for both increase and percent increase over initial exchangeable Ca.

Interaction was noted for depth of sampling with quantity of application of liming materials for soil pH (Table 8). The pH observed was significantly higher for 500 g of the liming material at a depth of 15-30 cm which was on par with 250 g at 15-30 cm and 30-45 cm, 750 g at 15-30 cm and 1000 g at 15-30 cm and 30-45 cm. Absolute control at 15-30 and 45-60 cm recorded significantly lower soil pH which was on par with 50, 150 and 200 g of the liming materials at all depths and 100g at 45-60 cm depth. These results are in conformity with the findings of da Costa et al., (2016) that after 48 months, surface liming raised the pH of the soil in the surface layers to a depth of 0.20 m, with the same effect of spreading throughout the soil profile after 60 months of reapplying the lime.

Conclusion

One of the major consequences of soil acidity is the reduction in basic cations which are essential for plants resulting in phytotoxic concentrations of soluble aluminum affecting the growth and yield of crops especially in the case of crops like tannia which are very sensitive to subsoil acidity. To overcome this, liming of these types of soil is generally promoted as an effective management practice to increase soil pH, base cation concentrations, and ameliorate toxicity caused by aluminum and sometimes manganese. The present experiments were taken up both in controlled condition

and field condition to see the best soil ameliorant for the acid laterite soils having subsoil acidity. Among the different soil amendments used in various quantities and based on the observations recorded on soil pH and exchangeable Ca over a period of 6-7 months from different soil depths ranging from 0-60 cm, it was seen that, there was drastic changes especially under field conditions at deeper soil layers for liming materials like calcite, dolomite, and gypsum. The study revealed more pH and Ca increase up to 30 cm soil depth with the minimum quantity of 250 g when compared to higher quantities as after saturation of the exchange sites with Ca, further substitution of Al with Ca was not occurring in the exchange sites. Hence, it is understood that the profitability of liming differed with liming rate, being more profitable at lower liming rates. However, under acidic soil conditions, specific to each crop and each soil type, more research is required for an understanding of the appropriate lime rates to ensure overall profitability for producers and sustainable improvement of soil health.

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