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RESEARCH ARTICLE

Liming tropical high upland acid soils improves soil fertility and cardamom productivity

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ABSTRACT

Increasing the productivity of Indian cardamom is revolving around both soil and forest canopy management. Maintaining tropical acid soil fertility and its productivity is the prime concern for successful cardamom cultivation under ongoing deforestation of fragmented rainforest. A field experiment with two doses each (1 and 2 kg plant^{-1}) of burnt lime, dolomite and ground lime stone was carried out in an acidic soil. Results showed that all of the liming materials have had significant effect on correcting the soil acidity. Liming with dolomite at 2 kg plant^{-1} considerably improved soil chemical properties and increased the soil pH from very acidic to near neutral. Correction and improvement in the soil pH led to significantly enhance the growth and yield of cardamom. However, utmost care must be taken on the environmental implications of liming; particularly the ratio of soil Calcium and Magnesium as well as organic carbon loss and evolution of CO_2.

Keywords: cardamom, liming, nutrients, soil pH, yield

INTRODUCTION

Cardamom [*Elettaria cardamomum* (L.) Maton] farming in the tropical and subtropical Western Ghats (WG) regions is regarded one of the most remunerative and expensive production systems in India. Worldwide, the demand for cardamom has been increasing since its use has been recently expanded to industrial sides also (e.g., modern medicine, perfumery and etc.,). Most forest soils in high rainfall WG regions are acidic and nutrient limited, except, nitrogen and few other micro elements. Because of high rainfall and run off as well as biodiversity loss and land use changes, these ecosystems have lost their native productive capacity. The queen of spices (cardamom) is cultivated continuously since centuries in the cardamom hill reserves (CHR). The CHR soils are acidic owing to inherent soil forming factors as well as continuous application of fertilizers and chemicals (Murugan et al., 2011 & 2012). Hence, the concerns on the sustainability of the cardamom agroforestry system have been increasing because of the never-ending agricultural intensification and degradation of tropical evergreen forest cover (Murugan et al., 2012; Reyes et al., 2006). Variability in cardamom growth, development, and yield can also be attributed to changes in the microclimatic environment. There was a possible link and various dimensions between the intensive growing practices that were positively reflected in its local climate and production system (Murugan et al., 2022).

The livelihood of most farmers and planters in the CHR depend on this crop. Conventionally, cardamom used to grow as undergrowth of the evergreen forests without any nutrient addition and shade management, but the situation has been changed now. Erstwhile cardamom soils had closed nutrient cycling system, but after the intensification, the nutrient cycling system in the CHR forest was broken because of endless removal of forest cover. This way, the self-liming and closed nutrient cy-cling system do not exist in CHR system. Century old continuous cultivation of cardamom in the CHR has been reported to reduce the soil pH because of constant crop removal and uptake of alkali elements like Ca and Mg as well as heavy leaching and run off due to incessant intense rainfall and topography.

Since the CHR massif was dominated by charnockite, input from acidic parent material was bare minimum (Kumar and Sreejith, 2010; Catlos et al., 2011). The present study aimed to investigate the effects of different liming materials on increasing the availability of essential nutrients and yield of cardamom.

MATERIALS AND METHODS

A field study was conducted at the Cardamom Research Station, Kerala Agricultural University, Pampadumpara, India during 2013 to 2017. The test variety of cardamom PV-2 was selected for its potential yield and market - based attributes. The treatments included two rates of application every year; T1-Burnt lime 1 kg plant^{-1}; T2- Burnt lime 2 kg plant^{-1}; T3- Dolomite 1 kg plant^{-1}; T4- Dolomite 2 kg plant^{-1}; T5- Ground lime stone 1 kg plant^{-1}; T6- Ground lime stone 2 kg plant^{-1}; and T7-Control (without liming). All of the liming materials used in this experiment were of agricultural grades having a purity of >90%. The package of practices (PoP) of the KAU (KAU, 2016) was followed all through the crop season.

There were nine soil samples collected from each treatment in every year. Totally sixty-three soil samples were collected and analyzed in each year. Surface soil samples (0-15cm depth) from each treatment plot were collected and were analyzed for available macro and micro-nutrients. Biometric as well as yield parameters were recorded in each crop season and the data were processed statistically.

RESULTS

All of the liming materials had a significant effect on increasing the soil pH. Among the sources, dolomite considerably influenced the soil chemical properties and increased the soil pH from very acidic to near neutral. The soil pH improved significantly from 4.3 to 6.9 in the dolomite treated plots (@ 2kg plant^{-1}). During the first year of application, there was no significant effect with respect to the application of dolomite at 1 and 2 kg/plant. Subsequent application of a higher dose of dolomite markedly increased the soil pH. The soil pH showed an increasing trend for each year's application with respect to the addition of dolomite (@ 2kg plant^{-1}), (**Figure 1**).

The effect of liming on available phosphorous was significant, and application of 2 kg of dolomite plant^{-1} increased the availability from 2.05 mg/100g to 3.16 mg/100g (**Table 1**). A significant increase in available phosphorus content was observed for higher rates of dolomite application. Available potassium in lime treated soil also increased during the experimental period (46.9 to 75.1mg/100g).

Liming increased the availability of secondary plant nutrients (calcium, magnesium, and sulphur) in the soil. Data from pooled analysis (2013-17) showed that the addition of dolomite at 2 kg plant^{-1} resulted in 63.09, 75.70, and 6.66 % increases in Ca, Mg, and S availability, correspondingly, after the third year of application. Soil acidity is reduced by the reaction of bicarbonate ions with water, which generates OH^- ions. Calcium is involved in the exchange of H^+ and/ or Al^{3+} from soil colloids. In the presence of an OH^- rich environment, these latter are converted into H_2O and $Al(OH)_3$ respectively, enhancing the primary and secondary nutrient availability. Among liming materials, dolomite at 2 kg plant^{-1} notably influenced soil chemical properties and raised the soil pH to a near neutral level.

Cardamom yield was influenced by liming in all the seasons (4 years) and it was significantly higher for all the limed plots compared to the control plot (**Figure. 2**). A significant and progressive increase in yield was noticed for the application of dolomite. The yield improvement for the application of dolomite (2 kg plant^{-1}) was 68.37% over the control. The highest wet (2198 g plant^{-1}) and dry (500 g plant^{-1}) capsule yields were observed in dolomite (2 kg plant^{-1}) treated plots. The enhanced growth and yield of cardamom were likely due to the positive impact of liming on soil chemical and biological properties, particularly the rise in soil pH. The best response in terms of capsule yield was observed in 2016-17 as the highest fresh capsule yield (2763 g plant^{-1}) was given by that treatment.

DISCUSSION

Most cardamom soils are acidic; therefore, they are nutrient poor. The addition of soil amendments like liming materials makes the soils more fertile through increased bioavailability of P, K, Ca, Mg, and sulphur. Cardamom is considered a strong surface feeder and a luxury consumer of plant nutrients. The increased soil nutrient availability by liming enhanced the yield of cardamom considerably. Zhang et al. (2013) and Cardoso et al. (2013) both said that liming had a lot of good things to say about it.The rise in soil pH and the reduction of acidity sources have a close association with the presence of basic cations ($Ca2^{+}$ and $Mg2^{+)}$ and anions (CO_3^{2-}) in the liming materials. Calcium and magnesium bicarbonates are much more soluble and quite reactive in acid soils when it comes to replacing acid cations such as hydrogen (H^{+}) and aluminium ($Al3^{+}$) in soil colloidal complexes (Brady and Weil, 2008). The improvement of soil pH resulted in a significant increase in plant available nutrients (Gaume et al., 2001). Liming of acid soils dissolves calcium and magnesium phosphates and sulphates and allows nutrients to be more available for plant uptake, which leads to a higher yield. The cost benefit ratio of dolomite (2 kg plant^{-1}) treated plots was high (2.42) compared to control (1.11).

CONCLUSIONS

Correction of soil acidity through liming increased the availability of essential nutrients such as P, K, Ca, Mg, and S and improved the efficiency of applied fertilizers, leading to a significant increase in the yield of cardamom. At the time of application as well as afterwards, care should be taken to maintain adequate soil moisture in the field. The liming practice may be discontinued immediately after the soil pH has been increased to the desired or neutral levels. The frequency of subsequent lime applications should be done based on further soil test values. The obtained results indicated that the growth and yield of cardamom have been improved by liming along with N, P, K, Mg, S, and organic matter in the soil. For this reason, it is important to apply well-balanced nutrients to cardamom plants and soil amendments in order for them to grow and yield.

Table 1. Chemical properties of the soil (pooled data-2013-17)

Treatments	Available P (mg/100g)	Available K (mg/100g)	Available Ca (ppm)	Available Mg (ppm)	Available S (ppm)
T1	2.63	60.23	1884.30	247.60	1.25
T2	2.76	57.83	1885.60	253.30	1.32
T3	3.15	70.33	1987.30	279.30	1.44
T4	3.24	77.56	2084.00	284.00	1.50
T5	2.80	65.00	1915.00	263.00	1.36
T6	2.93	67.66	1926.30	267.00	1.38
T7	0.78	36.00	1421.30	222.60	0.66
CD (0.05)	1.66	3.496	6.06	2.76	1.51
CV	14.16	13.16	10.18	15.94	12.47

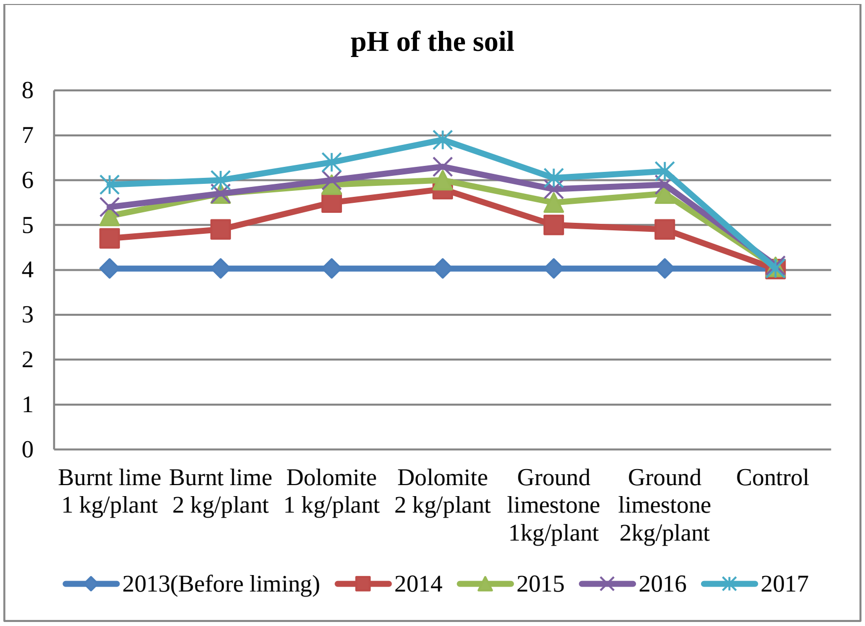

Figure 1. Effect of liming on soil pH

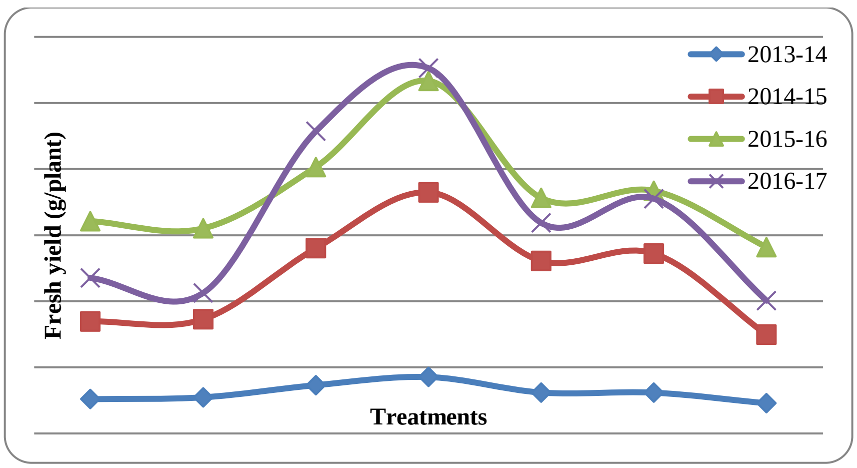

Figure 2. Effect of liming on fresh yield of cardamom variety PV 2

COMPETING INTERESTS

The authors declare that they have no competing interests

DATA AVAILABILITY STATEMENT

The raw data used to support the findings of this study are available from the corresponding author upon request.

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