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**M David Israel Mansingh**
Department of Soil Science and Agricultural Chemistry, Agricultural College and Research Institute (TNAU), Killikulam, Tamil Nadu, India

**S Suresh**
Department of Soil Science and Agricultural Chemistry, Agricultural College and Research Institute (TNAU), Killikulam, Tamil Nadu, India

**M Arun Raj**
Department of Soil Science and Agricultural Chemistry, Agricultural College and Research Institute (TNAU), Killikulam, Tamil Nadu, India

**S Vignesh**
Department of Soil Science and Agricultural Chemistry, Agricultural College and Research Institute (TNAU), Killikulam, Tamil Nadu, India

**Correspondence**
**M David Israel Mansingh**
Department of Soil Science and Agricultural Chemistry, Agricultural College and Research Institute (TNAU), Killikulam, Tamil Nadu, India

# Effect of liming on yield and nutrient uptake of rice in acidic soils

**M David Israel Mansingh, S Suresh, M Arun Raj and S Vignesh**

**Abstract**
Soil acidity is an important agricultural problem while evaluating the production potential of most of the crops. A field experiment was conducted in two farmer fields during *Pishanam* (Oct-Feb) and *late Pishanam* (Nov–Mar) season of 2017-2018 respectively, in the high rainfall zone to study the effect of different source and levels of lime on yield and nutrient uptake of rice. Liming materials *viz.*, dolomite and calcite were tried at different levels along with RDF+$ZnSO_4$. The experiment was conducted in RBD. The results of the experiment revealed that significantly higher grain (7.09 and 7.40 t $ha^{-1}$) and straw (10.3 and 10.5 t $ha^{-1}$) yield of rice were recorded with the application of dolomite @ 0.75 LR ($T_7$) and @ 0.50 LR ($T_5$) respectively in the strongly and moderately acidic soils. Similarly, higher nutrient uptake was recorded in treatment $T_7$ and $T_5$ respectively both seasons as compared to other treatments.

**Keywords:** Liming, rice, nutrient uptake, yield

## Introduction
Soil acidity is an important constraint in agriculture production. Soil acidity is a natural occurring process due to heavy rainfall and removal of cations like calcium, potassium and magnesium by leaching. Acidic parent materials and decomposition of organic matter also leads to formation of acidic condition in soil. Acceleration of acidification is by acid forming fertilizers usage, disturbance of soil structure, cultivation of high yielding crops (Fageria and Baligar, 2008). Higher acidity in soils leads to reduction in crop productivity. In India, acidic soils occupy about 49 million ha area, of which 26 m ha has pH below 5.5 and 23 m ha has pH between 5.6 and 6.5 (Panda, 1979) [16]. In Tamil Nadu, acidic soils occupy about 2.6 m ha area. Rice *(Oryza sativa* L.*)* is one of the important cereal crops in India contributing about 45% to the total food grain production and staple food for more than 60% of world population (Singh *et al.*, 2011) [18]. Acidic condition of the soil is one of the major limiting factor for plant growth and development (Adams, 1986). Lime application in acid soil is beneficial for soil health and improves the crop yields. The soils of high rainfall zone *viz.* Kanyakumari district are light textured, low in organic matter and strongly acidic to moderately acidic in nature in most cases. Lime application, is best amelioration technology for improving the fertility status of an acid soil. In these regard, a study is highly imperative in acidic soil to optimize the source and level of liming material for sustaining the rice crop productivity. The application of lime is potential and cost effective in reducing soil acidity. The present investigation was carried out to study the amelioration capacity of dolomite and calcite in acid soil and its influence on yield and economics.

## Material and Methods
A field experiment was conducted in farmers field at Gananadhasapuram village of Thovalai taluk (strongly acidic soil) and Andarkulam village of Agastheswaram taluk (moderately acidic soil) during *Pishanam* (Oct-Feb) and *late Pishanam* (Nov–Mar) season of 2017-18 respectively, in the high rainfall zone of Tamil Nadu, to study the effect of different sources and levels of lime on soil fertility, yield and economics of rice cultivation. The field experiment was conducted in the strongly acidic soils of Gananadasapuram (location I) and moderately acidic soils of Andarkulam villages (location II) during pishanam (Oct-Feb) and Late pishanam (Nov-Mar) seasons respectively in the high rainfall zone. The rice crop varieties TPS 3 and TPS 5 were used as test crops during the different seasons, respectively.
The experiment was laid out in a randomized block design with ten treatments replicated thrice. The treatment combinations include, treatment $T_1$ is absolute control, the treatment $T_2$

was the application of recommended dose of fertilizers with $ZnSO_4$ @ 25 kg $ha^{-1}$, For the treatments from $T_3$, $T_5$, $T_7$ and $T_9$, lime as dolomite at different levels based on lime requirements 0.25 LR (2.12 and 0.8 t $ha^{-1}$) ($T_3$), 0.50 LR (4.24 and 1.6 t $ha^{-1}$) ($T_5$), 0.75 LR (6.36 and 2.4 t $ha^{-1}$) ($T_7$) and 1.0 LR (8.48 and 3.2 t $ha^{-1}$) ($T_9$) respectively for pishanam and late pishanam seasons along with recommended dose of fertilizers and $ZnSO_4$ was tested. For the treatments from $T_4$, $T_6$, $T_8$ and $T_{10}$, lime as calcite at different levels based on lime requirement 0.25 LR (2.32 and 0.88 t $ha^{-1}$) ($T_4$), 0.50 LR (4.63 and 1.76 t $ha^{-1}$) (T6), 0.75 LR (6.95 and 2.64t $ha^{-1}$) ($T_8$) and 1.0 LR (9.25 and 3.22t $ha^{-1}$) (T10) during pishanam and late pishanam seasons along with recommended dose of fertilizers and $ZnSO_4$ was tested. The 0.25, 0.50, 0.75 and 1.0 LR corresponds to 25%, 50%, 75% and 100% Lime requirement of soil. The fertilizer was applied to all the plots except absolute control plot based on RDF (pishanam 150:50:50 and late pishanam 120:40:40 kg $ha^{-1}$of $N:P_2O_5:K_2O$ respectively). Lime was applied to the soil one week prior to transplanting rice seedlings and mixed thoroughly, The Ca content of calcite is 40 per cent and the Ca and Mg content of dolomite is 22 per cent, and 13 per cent respectively. The dolomite requirement was calculated based on calcium carbonate equivalent and neutralizing value. Phosphorus was applied basally as mussoorie rock phosphate. Potash was applied by broadcasting in four equal splits as muriate of potash, during basal, tillering, active tillering and panicle initiation stages. The $ZnSO_4$ was applied at the time of planting. The crop was kept free of weeding by hand weeding. It was also protected from pest and disease by adopting the need based plant protection measures.

### Plant analysis

Plant samples collected at different growth stages of rice were analyzed for total N (Humphries, 1956) [6], phosphorus (Piper, 1966) [17], potassium (Jackson, 1973) [8], exchangeable Ca and Mg (Jackson, 1973) [8] and total micronutrients Fe, Mn, Cu and Zn (Lindsay and Norwell, 1978) by using standard procedures. The data were subjected to statistical analysis as prescribed by Gomez and Gomez, (2010) [5].

## Results and Discussion

### Effect of liming on yield attributes and yield

The yield contributing characters such as number of productive tillers $m^{-2}$, grain and straw yield were influenced significantly by the application of lime, NPK fertilizers and $ZnSO_4$ (Table 1).

In the present study, the application of lime had significantly exhibited its superiority to increase the number of productive tillers $m^{-2}$, grain and straw yield of rice. The highest productive tillers $m^{-2}$ (375), grain (7.09 t $ha^{-1}$) and straw yield (10.3 t $ha^{-1}$) of rice was recorded with RDF + 25 kg $ZnSO_4$ + Dolomite @ 0.75 LR ($T_7$) followed by $T_8$ (356, 6.85 and 8.53 t $ha^{-1}$ of productive tillers $m^{-2}$, grain and straw yield respectively), which received RDF + 25 kg $ZnSO_4$ + Calcite @ 0.75 LR in the pishanam season. In the late pishanam season highest productive tillers $m^{-2}$ (395), grain (7.40 t $ha^{-1}$) and straw (10.5 t $ha^{-1}$) yield was recorded by $T_5$ (RDF + 25 kg $ZnSO_4$ + dolomite @ 0.50 LR) followed by $T_6$ (362, 6.98 and 9.86 t $ha^{-1}$ of productive tillers $m^{-2}$, grain and straw yield, respectively) which received RDF + 25 kg $ZnSO_4$ + Calcite @ 0.50 LR.

The yield benefits can be ascribed to the increase in soil pH upon liming along with the associated improvement in nutrients availability, reduced Fe availability and many other attributes of soil fertility (Manoj-Kumar *et al.*, 2012) [12]. Attanandana and Vacharotayan (1986) [2] reported that liming with recommended fertilizer application resulted in the 37% additional increase of paddy yield compared to liming alone. The above results are in agreement with the findings of Osundwa *et al.* (2013) [15].

**Table 1:** Effect of liming on yield attributes, yield and B:C ratio

| Treatments | Pishanam season (strongly acidic soil) | | | | Late pishanam season (moderately acidic soil) | | | |
|---|---|---|---|---|---|---|---|---|
| | No. of Productiv tillers $m^{-2}$ | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) | B:C ratio | No. of Productive tillers $m^{-2}$ | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) | B:C ratio |
| $T_1$ - Control | 280 | 2.46 | 4.24 | 1.10 | 284 | 2.64 | 4.58 | 1.18 |
| $T_2$ - RDF + $ZnSO_4$ @ 25 kg $ha^{-1}$ | 318 | 4.59 | 7.79 | 1.76 | 335 | 4.18 | 8.46 | 1.67 |
| $T_3$ - $T_2$ + Dolomite (0.25 LR) | 332 | 5.25 | 8.03 | 1.74 | 348 | 5.05 | 8.60 | 1.88 |
| $T_4$ - $T_2$ + Calcite (0.25 LR) | 323 | 4.97 | 8.02 | 1.24 | 344 | 4.48 | 8.53 | 1.47 |
| $T_5$ - $T_2$ + Dolomite (0.50 LR) | 352 | 6.33 | 8.11 | 1.83 | 395 | 7.40 | 10.5 | 2.56 |
| $T_6$ - $T_2$ + Calcite (0.50 LR) | 337 | 5.66 | 8.10 | 1.03 | 362 | 6.98 | 9.86 | 1.90 |
| $T_7$ - $T_2$ + Dolomite (0.75 LR) | 375 | 7.09 | 10.3 | 1.86 | 358 | 6.59 | 9.73 | 2.18 |
| $T_8$ - $T_2$ + Calcite (0.75 LR) | 356 | 6.85 | 8.53 | 0.98 | 353 | 5.38 | 9.00 | 1.30 |
| $T_9$ - $T_2$ + Dolomite (1.0 LR) | 304 | 4.39 | 7.06 | 1.06 | 331 | 4.07 | 7.86 | 1.32 |
| $T_{10}$ - $T_2$ + Calcite (1.0 LR) | 295 | 3.85 | 6.45 | 0.47 | 326 | 3.61 | 6.80 | 0.78 |
| SEd | 11.2 | 0.19 | 0.07 | - | 6.92 | 0.11 | 0.73 | - |
| CD (0.05 %) | 23.5 | 0.4 | 0.2 | - | 14.5 | 0.2 | 1.5 | - |

LR-Lime Requirement, RDF- Recommended Dose of Fertilizer, $ZnSO_4$- Zinc Sulphate

### Effect of liming on uptake of nutrients

The nutrient uptake was increased with the crop growth. Significant impact on total N, P, K, Ca, Mg, Zn, Cu, Fe and Mn uptake was observed due to application of different sources and levels of lime (Tables 2 and 3). The nutrient uptake of the crop depicted a steep increase with the advancement of crop growth stage. Higher total uptake of nitrogen (39.8 and 43.8 kg $ha^{-1}$), phosphorus (11.8 and 19.8 kg $ha^{-1}$), potassium (106 and 102 kg $ha^{-1}$), calcium (14.6 and 18.9 kg $ha^{-1}$), magnesium (16.9 and 18.9 kg $ha^{-1}$), zinc (1162 and 1478 g $ha^{-1}$), copper (1005 and 1236 g $ha^{-1}$), iron (57.5 and 77.8 kg $ha^{-1}$) and manganese (19.6 and 26.2 kg $ha^{-1}$) after harvest was recorded in $T_7$ (RDF + 25 kg $ZnSO_4$ + dolomite @ 0.75 LR) and $T_5$ (RDF + 25 kg $ZnSO_4$ + dolomite @ 0.50 LR) respectively in strongly and moderately acidic soils.

Nutrient uptake is usually governed by the nutrient concentrations and dry matter yield. The absorption of nutrients depends on their ionic forms in the rhizosphere, which is influenced by soil acidity and the overall concentrations of nutrients in the soil. The reduction in soil acidity might have increased the pH and availability of N and ultimately its uptake by the crop (Kihanda *et al.*, 1999).

Liming increased root proliferation by reducing toxic effects of Al and thus enhanced the uptake of P and K (Chang and Sung, 2004) [4], which attributed in increase in the yield of rice.
The uptake of Ca and Mg were dependent on their availability in soil. The applied lime as calcite (or) dolomite on dissolution releases Ca and Mg, thus enhancing the available Ca and Mg content in soil. The Ca and Mg content of the plant increases subsequently resulting in higher uptake by paddy crop upto 0.75 LR. The Ca, and Mg concentrations decreased higher lime rates of 1.0 LR as calcite (or) dolomite. This may be associated with lower dry matter production with increasing lime rates (Moreira *et al.*, 2008) [13].

Plant micronutrient is greatly influenced by soil pH. The majority of micronutrients (Fe, Zn, Mn and Cu) are more available within a pH range of 5-7. Outside these optimal pH range, these micronutrients are available to plants in lesser amounts. In the present study, the pH of the soil that received ameliorants maintained the same pH range of 5-7. Hence, higher content and uptake of these micronutrients were recorded in these treatments upon liming, Similar, observations were made in different crops by many scientists like Muse and Mitchell (1995) [14] and Hunter and Yapa (1996) [7].

**Table 2:** Effect of liming on nutrient uptake of rice in strongly acidic soil (Pishanam season)

| Treatments | Total N | Total P | Total K | Total Ca | Total Mg | Total Zn | Total Cu | Total Fe | Total Mn |
|---|---|---|---|---|---|---|---|---|---|
| | (kg $ha^{-1}$) | | | (c mol ($p^+$) $kg^{-1}$) | | (g $ha^{-1}$) | | (kg $ha^{-1}$) | |
| $T_1$ - Control | 14.6 | 3.50 | 30.3 | 4.30 | 3.20 | 441 | 378 | 17.0 | 7.40 |
| $T_2$ - RDF + $ZnSO_4$ @ 25 kg $ha^{-1}$ | 25.6 | 7.40 | 70.6 | 8.50 | 6.30 | 813 | 655 | 39.0 | 14.9 |
| $T_3$ - $T_2$ + dolomite (0.25 LR) | 28.3 | 7.90 | 76.5 | 9.00 | 6.00 | 876 | 728 | 48.9 | 17.3 |
| $T_4$ - $T_2$ + calcite (0.25 LR) | 26.6 | 7.10 | 74.0 | 8.30 | 5.90 | 853 | 699 | 48.5 | 16.3 |
| $T_5$ - $T_2$ + dolomite (0.50 LR) | 34.2 | 9.90 | 94.2 | 11.7 | 13.1 | 1024 | 870 | 52.9 | 18.9 |
| $T_6$ - $T_2$ + calcite (0.50 LR) | 30.9 | 8.50 | 88.3 | 10.4 | 11.1 | 958 | 796 | 50.4 | 17.6 |
| $T_7$ - $T_2$ + dolomite (0.75 LR) | 39.8 | 11.8 | 106 | 14.6 | 16.9 | 1162 | 1005 | 57.5 | 19.6 |
| $T_8$ - $T_2$ + calcite (0.75 LR) | 36.6 | 10.4 | 101 | 12.6 | 14.8 | 1107 | 940 | 53.3 | 19.3 |
| $T_9$ - $T_2$ + dolomite (1.0 LR) | 24.2 | 7.40 | 69.2 | 7.90 | 6.20 | 796 | 596 | 36.9 | 10.7 |
| $T_{10}$ - $T_2$ + calcite (1.0 LR) | 21.6 | 6.20 | 57.0 | 6.70 | 5.10 | 672 | 534 | 23.6 | 10.0 |
| SEd | 0.56 | 0.16 | 1.06 | 0.19 | 0.16 | 20.40 | 17.92 | 1.00 | 0.30 |
| CD (0.05 %) | 1.2 | 0.3 | 2.2 | 0.4 | 0.3 | 43.0 | 38.0 | 2.1 | 0.6 |

LR-Lime Requirement, RDF- Recommended Dose of Fertilizer, $ZnSO_4$- Zinc Sulphate

**Table3:** Effect of liming on nutrient uptake of rice in moderately acidic soil (late pishanam season)

| Treatments | Total N | Total P | Total K | Total Ca | Total Mg | Total Zn | Total Cu | Total Fe | Total Mn |
|---|---|---|---|---|---|---|---|---|---|
| | (kg $ha^{-1}$) | | | (c mol ($p^+$) $kg^{-1}$) | | (g $ha^{-1}$) | | (kg $ha^{-1}$) | |
| $T_1$ - Control | 16.2 | 3.20 | 35.1 | 5.50 | 4.20 | 531 | 464 | 18.5 | 8.10 |
| $T_2$ - RDF + $ZnSO_4$ @ 25 kg $ha^{-1}$ | 25.5 | 10.0 | 59.8 | 8.10 | 7.50 | 902 | 744 | 49.5 | 16.0 |
| $T_3$ - $T_2$ + dolomite (0.25 LR) | 31.8 | 13.3 | 74.2 | 11.4 | 8.30 | 1125 | 951 | 64.0 | 21.7 |
| $T_4$ - $T_2$ + calcite (0.25 LR) | 30.1 | 12.5 | 71.2 | 16.2 | 8.10 | 1081 | 900 | 54.7 | 18.1 |
| $T_5$ - $T_2$ + dolomite (0.50 LR) | 43.8 | 19.8 | 102 | 18.9 | 18.9 | 1478 | 1236 | 77.8 | 26.2 |
| $T_6$ - $T_2$ + calcite (0.50 LR) | 39.4 | 16.3 | 93.1 | 16.6 | 15.7 | 1332 | 1104 | 77.4 | 24.6 |
| $T_7$ - $T_2$ + dolomite (0.75 LR) | 35.7 | 13.9 | 83.6 | 13.5 | 18.2 | 1197 | 1077 | 72.0 | 22.1 |
| $T_8$ - $T_2$ + calcite (0.75 LR) | 34.4 | 14.9 | 81.7 | 12.5 | 16.4 | 1171 | 1043 | 69.7 | 22.0 |
| $T_9$ - $T_2$ + dolomite (1.0 LR) | 23.6 | 9.40 | 56.1 | 7.70 | 7.10 | 838 | 658 | 40.4 | 12.7 |
| $T_{10}$ - $T_2$ + calcite (1.0 LR) | 20.3 | 4.90 | 51.0 | 6.60 | 6.00 | 734 | 595 | 24.1 | 10.7 |
| SEd | 0.79 | 0.31 | 1.92 | 0.22 | 0.22 | 19.3 | 17.5 | 0.9 | 0.5 |
| CD (0.05 %) | 1.7 | 0.7 | 4.0 | 0.50 | 0.50 | 41 | 37 | 1.8 | 0.9 |

LR-Lime Requirement, RDF- Recommended Dose of Fertilizer, $ZnSO_4$- Zinc Sulphate

## Economic analysis

Higher crop productivity with lesser cost of cultivation could result in better economic parameters like net returns and B:C ratio. The identified treatment should be economically viable so that farmers can sustain their higher income. The B:C ratio was worked out for the different treatments in terms of soil management and fertilizers application in acidic soil (Table 1). The maximum and economic yield with B:C ratio of 1.86 was recorded with application of dolomite @ 0.75 LR along with RDF and $ZnSO_4$ ($T_7$) in the strongly acidic soil (pH 5.1), (Pishanam season). In case of late pishanam season rice cultivated in moderately acidic soil (pH 5.9), (late pishanam season) the maximum and economic yield with B:C ratio of 2.56 was recorded with the application of dolomite @ 0.50 LR along with RDF and $ZnSO_4$. The high economic return could be realized if lime is applied in acidic soil was also reported by Kumar (2015) [10].

## Conclusion

From this study, it can be concluded that application of dolomite @ 0.75 LR (6.36 t $ha^{-1}$) (T7) and @ 0.50 LR (1.6 t $ha^{-1}$) (T5) along with recommended dose of fertilizers and ZnSO4, could be considered as a better option for achieving higher productivity of rice and profitability of strongly and moderately acidic soils, respectively in the high rainfall zone of kanyakumari district.

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