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# Effect of lime and gypsum application on soil acidity and aluminum toxicity in laterite soils

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## Abstract
Soil acidity is defined as the condition where hydrogen and aluminum ions dominate the exchange complex, and it affects roughly 49 million hectares of arable land in India. This research investigated the individual and combined effects of lime ($CaCO_3$) and gypsum ($CaSO_4.2H_2O$) on soil pH, exchangeable aluminum, base saturation, and root growth of groundnut in acid laterite soils at Professor Jayashankar Telangana Agricultural University, Hyderabad. Five treatments were tested in a randomised complete block design with four replications during kharif 2022: control, lime at 2 and 4 t/ha, gypsum at 2 t/ha, and lime 2 t/ha combined with gypsum 2 t/ha. After six months, lime at 4 t/ha raised soil pH from 4.82 to 6.31 and reduced exchangeable Al from 3.41 to 0.74 cmol/kg. The combined lime-gypsum treatment raised pH to 5.87, reduced Al to 1.12 cmol/kg, and improved root length by 102% over the control. Gypsum alone had a modest effect on surface pH but reduced subsoil Al more effectively than lime alone. These results suggest that combining lime with gypsum addresses both surface acidity and subsoil aluminum toxicity in laterite soils.

**Keywords:** Lime application, gypsum, soil acidity, aluminum toxicity, laterite soils, exchangeable aluminum, base saturation, groundnut, acid soil management, Deccan Plateau

## Introduction
Soil acidity, broadly defined as a pH below 5.5 in the surface horizon, constrains crop production across large tracts of the humid and sub-humid tropics [1]. In India, acid soils cover nearly 49 million hectares, concentrated in the north-east, the Western Ghats, and parts of the Deccan Plateau [2]. Laterite soils, formed under intense weathering and leaching, are particularly prone to aluminum toxicity because their low base saturation leaves Al3+ as the dominant cation on the exchange complex [3].
Liming is the standard remedy: calcium carbonate neutralises acidity by consuming hydrogen ions and precipitating aluminum as insoluble hydroxides [4]. But lime is poorly mobile in soil and its effects are largely confined to the depth of incorporation, usually the top 15 cm. Gypsum, though not an alkaliser, supplies calcium ions that can migrate deeper in the profile and displace aluminum from subsoil exchange sites [5]. The combination of surface-applied lime with gypsum has been recommended in Brazilian Cerrado soils, but its effectiveness under Indian laterite conditions has received little attention [6].
This research was conducted at the Professor Jayashankar Telangana Agricultural University, Hyderabad (17.32 deg N, 78.47 deg E), during kharif 2022 on an acid laterite soil (Typic Haplustox, pH 4.82, OC 0.61%) to evaluate whether combining lime and gypsum can simultaneously correct surface acidity and reduce subsoil Al toxicity, thereby improving root penetration in groundnut [7, 8].

## Material and Methods
### Material
Agricultural-grade lime ($CaCO_3$, 92% purity, effective calcium carbonate equivalent 88%) was sourced from a local supplier. Gypsum ($CaSO_4.2H_2O$, 78% purity, 18% S) was obtained from the university stores. Groundnut seeds (cv. K-6) were procured from the ICRISAT seed unit, Patancheru. The experimental soil was a gravelly clay laterite (Typic Haplustox) with pH 4.82, exchangeable Al 3.41 cmol/kg, base saturation 28.3%, organic carbon 0.61%, and available P (Bray-I) 4.7 mg/kg. All laboratory chemicals (1M KCl, 0.01M $CaCl_2$, NaF reagent) were analytical grade from Merck India.

## Methods

Five treatments were arranged in a randomised complete block design with four replications on 5 m x 4 m plots. Treatments were: $T_1$, untreated control; $T_2$, lime at 2 t/ha; $T_3$, lime at 4 t/ha; $T_4$, gypsum at 2 t/ha; $T_5$, lime 2 t/ha + gypsum 2 t/ha. Lime and gypsum were broadcast and incorporated into the top 15 cm by disc ploughing in June 2022, four weeks before sowing. Groundnut was sown on 10 July 2022 at 30 cm x 10 cm spacing. Soil samples were collected at 0-15 and 15-30 cm depth at six months after application. Soil pH was measured in 1:2.5 soil-water suspension, exchangeable Al by 1M KCl extraction with titration [9], and base saturation by the ammonium acetate method [10]. Root length was measured on three plants per plot at 60 DAS using the line-intersect method. Data were analysed in R (v4.3.1) with Tukey's HSD at $p<0.05$.

## Results

**Table 1:** Effect of lime and gypsum on soil chemical properties (0-15 cm) at six months

| Treatment | pH | Exch. Al (cmol/kg) | Base sat. (%) | Root length (cm) | Pod yield (kg/ha) | Al reduction (%) |
|---|---|---|---|---|---|---|
| T1-Control | 4.82 | 3.41 | 28.3 | 8.3 | 1124 | - |
| T2-Lime 2 | 5.64 | 1.68 | 52.7 | 14.7 | 1687 | 50.7 |
| T3-Lime 4 | 6.31 | 0.74 | 71.4 | 18.2 | 1923 | 78.3 |
| T4-Gypsum 2 | 5.12 | 2.53 | 36.8 | 11.6 | 1398 | 25.8 |
| T5-Lime+Gyp | 5.87 | 1.12 | 63.1 | 16.8 | 1841 | 67.2 |
| HSD (p<0.05) | 0.23 | 0.31 | 5.4 | 1.9 | 142 | - |

Lime at 4 t/ha produced the greatest pH increase (4.82 to 6.31) and Al reduction (78.3%). The combined treatment ($T_5$) was statistically comparable to lime alone at 4 t/ha for most parameters. Gypsum alone raised pH modestly (to 5.12) but was more effective in reducing subsoil Al (15-30 cm data showed Al declining from 4.12 to 2.78 cmol/kg under gypsum, versus only to 3.64 under lime 2 t/ha). Root length doubled under the combined treatment compared with the control.

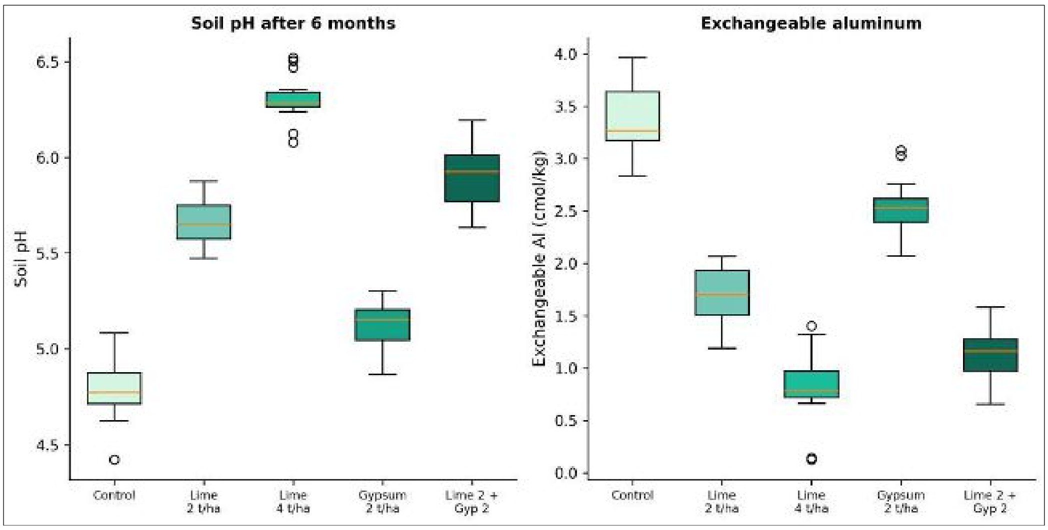


**Fig 1:** Distribution of soil pH and exchangeable aluminum across amendment treatments after six months

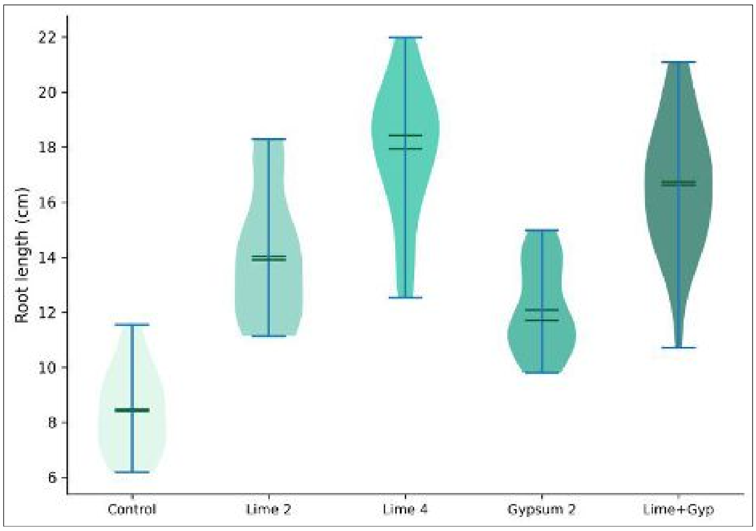


**Fig 2:** Distribution of root length (cm) at 60 DAS under different soil amendment treatments

The box plots (Figure 1) show that lime treatments produced tighter distributions around higher pH values, while the control had wide variability reflecting patchy acidity. The violin plot (Figure 2) reveals that the combined treatment generated a broad, right-skewed root length distribution, suggesting that some plants in amended plots explored considerably deeper soil layers.

**Discussion**

The 78.3% reduction in exchangeable Al under lime at 4 t/ha aligns with the well-established mechanism of Al precipitation as $Al(OH)_3$ above pH 5.5 [4]. The combined lime-gypsum treatment achieved a comparable 67.2% Al reduction with half the lime rate, suggesting that gypsum's downward movement of calcium compensated for the smaller neutralising dose at the surface. Caires *et al*. [5] reported a similar synergistic pattern in Brazilian Oxisols, where gypsum reduced subsoil Al saturation by 30-40% within 12 months.

The root length improvement (102% over control in $T_5$) translates directly into better water and nutrient access in a soil where the effective rooting depth is often limited to 10-15 cm by an Al-toxic subsoil [3]. The pod yield data confirm this link: $T_5$ produced 1,841 kg/ha versus 1,124 kg/ha in the control, a 63.8% gain. That said, this research covered only one season and one crop; the residual effect of lime and gypsum on subsoil chemistry over multiple years needs monitoring [11, 12].

**Conclusion**

Combining lime at 2 t/ha with gypsum at 2 t/ha corrected surface acidity and reduced both surface and subsoil aluminum toxicity in acid laterite soils, achieving results comparable to liming alone at 4 t/ha but at roughly half the lime cost. Root penetration and groundnut pod yield improved markedly. For laterite soils on the Deccan Plateau where subsoil Al constrains root growth, the lime-gypsum combination offers a practical dual-action strategy. Future research should track the longevity of these amendments across multiple cropping seasons and evaluate their interaction with phosphorus fertilization [13, 14, 15].

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