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Post-harvest soil nutrient availability in *Alfisols* under maize (*Zea mays* L.) cultivation with liming to counter fertilizer-induced acidity

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Abstract

Continuous use of acid-producing fertilizers promotes soil acidification, which may adversely affect nutrient availability in *Alfisols* under intensive maize production systems. Liming is widely adopted to neutralize fertilizer-induced acidity and improve soil chemical properties. A field investigation undertaken in the *Kharif* season of 2021-22 at the College of Agriculture, V.C. Farm, Mandya, examined the effects of lime and granulated dolomite application on post-harvest nutrient availability in *Alfisols*. The treatments included 100% and 50% fertilizer acidity neutralization using lime and granulated dolomite, lime (500 kg ha⁻¹) and dolomite (250 kg ha⁻¹) as standard checks and an untreated control. Post-harvest soil analysis showed that available nitrogen and potassium were highest under 100% RDF + FYM (T₂: 260.34 and 199.99 kg ha⁻¹, respectively), available phosphorus, sulphur and exchangeable calcium were highest under 500 kg lime ha⁻¹ along with RDF and FYM (T₃: 37.93 kg ha⁻¹ 8.67 mg kg⁻¹ and 8.43 cmol (p⁺) kg⁻¹, respectively), and significantly higher magnesium was recorded under 100% neutralization with granulated dolomite (T₇: 4.32 cmol (p⁺) kg⁻¹), indicating that liming improved post-harvest nutrient availability in *Alfisols*.

Keywords: Lime, granular dolomite, neutralization, fertilizer acidity, nutrient status

Introduction

Maize (*Zea mays* L.) is an important cereal crop, and its productivity under intensive production systems is strongly influenced by effective soil nutrient management. Sustaining high productivity of maize often requires repeated application of mineral fertilizers, particularly nitrogenous fertilizers such as urea and ammonium-based sources. While such fertilizers play a key role in enhancing crop productivity, their prolonged application can induce physiological acidity through nitrification processes and the release of hydrogen ions during plant nutrient absorption, even in soils with an initially neutral pH. (Havlin *et al.* 2014) ^[12].

Alfisols, which occupy a substantial area under maize cultivation, are generally characterized by moderate fertility and relatively low buffering capacity. Under intensive fertilizer use, these soils are prone to localized and gradual changes in soil chemical environment, especially in the rhizosphere, resulting in decreased availability of specific nutrients such as phosphorus, calcium, magnesium, sulphur (White, 2011) ^[29]. Physiological acidity induced by acid-forming fertilizers may not immediately lower bulk soil pH but can still influence nutrient transformations, base saturation, and nutrient balance, ultimately affecting soil fertility and crop performance (Brady and Weil, 2017) ^[3].

Beyond their traditional role in acidic soil correction, liming materials are gaining recognition for their effectiveness in alleviating fertilizer-induced soil acidity. Amendments such as agricultural lime and granulated dolomite neutralize excess hydrogen ions produced during fertilizer transformations, enrich the soil exchange complex with calcium and magnesium, and support the availability of macro- and secondary nutrients. When applied to neutral soils under high fertilizer inputs, liming helps stabilize the soil chemical environment without causing undesirable shifts in soil reaction, thereby contributing to sustained nutrient availability and overall soil health (Fageria and Baligar, 2008) ^[9].

Earlier research has primarily examined the role of liming in strongly acidic soils, whereas evidence on the use of lime and dolomite for managing physiological acidity arising from acid-forming fertilizers in neutral *Alfisols* under maize-based cropping systems is limited. In addition, information on the post-harvest availability of soil nutrients under such nutrient and acidity management strategies is not well documented. Accordingly, the present study aimed to evaluate the effect of liming materials applied to neutralize fertilizer-induced acidity on post-harvest nutrient status of maize-grown *Alfisols*.

Materials and Methods

Study site and initial soil properties

A field study conducted in the *Kharif* 2021-22 season at the

College of Agriculture, Vishweshwaraiah Canal Farm, Mandya, Karnataka, was located in Region III and Agro-Climatic Zone VI (Southern Dry Zone) of the state, positioned at 12°34' N latitude and 76°49' E longitude. The soil at the study location was red loamy sand in nature. Initial soil analysis indicated a neutral soil reaction (pH 7.19), low electrical conductivity (0.14 dS m⁻¹), and low organic carbon content (4.84 g kg⁻¹). Available nitrogen (241.60 kg ha⁻¹), phosphorus (25.56 kg P₂O₅ ha⁻¹), and potassium (182.45 K₂O kg ha⁻¹) in the medium fertility range. Details of the analytical procedures adopted for evaluating soil physico-chemical properties are provided in Table 1.

Table 1: Initial physicochemical properties of soil of the experimental site

Parameter	Value	Methods followed
Sand (%)	83.35	International Pipette method (Piper, 1966)
Silt (%)	6.32	
Clay (%)	10.33	
Textural class	Loamy sand	
pH (1:2.5)	7.19	Potentiometry (Jackson, 1973) ^[13]
EC (dS m ⁻¹)	0.14	Conductometry (Jackson, 1973) ^[13]
Organic carbon (g kg ⁻¹)	4.84	Wet oxidation (Walkley and Black, 1934) ^[28]
CEC (c mol (p ⁺) kg ⁻¹)	10.60	Ammonium acetate leaching method (Jackson, 1973) ^[13]
Available N (kg ha ⁻¹)	241.60	Alkaline permanganate method (Subbaiah and Asija, 1956) ^[27]
Available P ₂ O ₅ (kg ha ⁻¹)	25.56	Olsen's method using spectrophotometer (Jackson, 1973) ^[13]
Available K ₂ O (kg ha ⁻¹)	182.45	Flame photometry (Jackson, 1973) ^[13]
Exchangeable Ca (c mol (p ⁺) kg ⁻¹)	5.10	Turbidimetry extraction method (Black, 1965) ^[2]
Exchangeable Mg (c mol (p ⁺) kg ⁻¹)	1.80	Complexometric titration method (Jackson, 1973) ^[13]
Available S (mg kg ⁻¹)	9.02	Turbidimetry (Black, 1965) ^[2]
DTPA Fe (mg kg ⁻¹)	9.79	Atomic Absorption Spectrophotometry (Lindsay and Norwell, 1978) ^[16]
DTPA Zn (mg kg ⁻¹)	0.45	
DTPA Mn (mg kg ⁻¹)	7.23	
DTPA Cu (mg kg ⁻¹)	0.50	

Design of experiment and treatment description

The experimental setup followed a randomized complete block design with eight treatment combinations and three replications. The treatment structure included an untreated control (T₁), 100% recommended dose of fertilizers (RDF) with farmyard manure (FYM) (T₂), RDF + FYM along with lime at 500 kg ha⁻¹ (T₃), RDF + FYM with granulated dolomite at 250 kg ha⁻¹ (T₄), RDF + FYM with 100% neutralization of fertilizer acidity using lime (T₅), RDF + FYM with 50% neutralization using lime (T₆), RDF + FYM with 100% neutralization using granulated dolomite (T₇) and RDF + FYM with 50% neutralization using granulated dolomite (T₈).

Methods for measuring fertilizer acidity

Potential acidity of fertilizers is estimated using Pierre's method (PM) expressed in calcium carbonate equivalents (CCE) per unit weight of fertilizer. It refers to the CCE required to neutralize the acidity resulting from application of the fertilizer (Pierre, 1933) ^[22]. To calculate the acidity of the individual salts, the following equations were used:

$$\frac{\text{Molecular weight of element} \times \text{equivalent acidity for element} \times 1000 \text{ kg}}{\text{Molecular weight of salt}}$$

= kg of CaCO₃ acidity for element per 1000 kg metric tonne of fertilizer salt.

Liming materials and application

Liming treatments consisted of lime and granulated dolomite,

both containing calcium and magnesium constituents capable of ameliorating soil acidity. The lime used was calcium carbonate (CaCO₃) with a neutralizing value (Calcium Carbonate Equivalence, CCE) of 100%, whereas the granulated dolomite consisted of CaCO₃·MgCO₃ with a CCE of 108.7%. The designated liming materials were soil-incorporated two weeks before sowing in accordance with the treatment specifications. The quantities applied were 342 and 171 kg ha⁻¹ for 100% and 50% neutralization with lime, respectively, and 372 and 186 kg ha⁻¹ for 100% and 50% neutralization with granulated dolomite.

Crop management practices

The field was tilled using disc ploughing, followed by harrowing and two cultivator operations to achieve a fine tilth. The experimental plots had gross and net sizes of 5.1 m × 3.6 m and 3.9 m × 2.4 m, respectively, with a spacing of 0.5 m between plots and 0.6 m between replications. Bunds of 30 cm height were constructed between plots and replications. Farmyard manure at 10 t ha⁻¹ was incorporated uniformly into all treatments except the control, two weeks before sowing. Zinc sulphate was applied uniformly at 10 kg ha⁻¹.

The experiment utilized maize (*Zea mays* L.) variety MAH-14-05 as the test crop. Sowing was carried out in furrows spaced 60 cm apart by dibbling two seeds per hill at 30 cm intervals. The recommended fertilizer dose (150:75:40 kg N:P₂O₅:K₂O ha⁻¹) was supplied through urea, di-ammonium phosphate, and muriate of potash. Half of the nitrogen along with the full quantities of phosphorus and potassium was applied basally, whereas the remaining nitrogen was top-dressed in two equal splits at 30 and 45 DAS. Irrigation was given at sowing and subsequently

scheduled according to crop requirements using the ridge and furrow method. Intercultivation was carried out at 35 and 60 DAS and hand weeding was done to maintain weed-free conditions.

Soil sample collection and analytical procedure

Surface soil samples were collected from each plot at 30 and 60 days after sowing and at harvest. Following processing, the samples were analysed for available macro and micronutrients using standard analytical procedures outlined in Table 1.

Statistical Analysis

The data collected from the experiment were subjected to statistical analysis using analysis of variance (ANOVA) appropriate for a randomized complete block design (RCBD) as described by Gomez and Gomez (1984). Statistical analysis was performed using SPSS software (version 31.0; IBM Corp., Armonk, NY, USA). The significance of treatment effects was tested using the F-test at $P = 0.05$. When the F-test was found significant, treatment means were compared using the critical difference (CD) at the 5% level of significance. Standard error of mean (SEM) values was also computed to assess variability among treatments.

Results and Discussion

Soil chemical properties as influenced by liming for neutralization of fertilizer acidity

Soil pH

Application of lime and granulated dolomite for neutralizing fertilizer-induced acidity did not cause a statistically significant change in soil pH at 30 DAS, 60 DAS, or at harvest (Table 2). However, numerically higher pH values were consistently observed under limed treatments. The treatment comprising RDF + FYM with 100% lime-based neutralization (T_5) recorded the highest soil pH values of 7.34, 7.32, and 7.27 at 30 DAS, 60 DAS, and harvest, respectively, whereas the lowest pH was observed under RDF + FYM alone (T_2 : 7.20, 7.18, and 7.16).

The minimal variation in soil pH observed in the present study may be attributed to the initially neutral soil reaction (pH 7.19), which limited the extent of measurable pH changes during the experimental period. Although fertilizer application can induce localized acidification through nitrification and other processes, the magnitude of such changes under the field conditions appears to have been relatively small.

Red loamy sand soils are generally characterized by low buffering capacity due to their coarse texture and lower clay and organic matter content. Therefore, the limited change in pH observed in this study may be more closely associated with the initial neutral pH and the moderate rates of amendment application rather than inherent buffering capacity.

The marginal increase in soil pH following liming can be attributed to the dissolution of lime and the release of basic cations (Ca^{2+}), which neutralize hydrogen ions in the soil solution and increase base saturation. The slight rise in pH may also be associated with hydroxyl ion generation during lime hydrolysis (Shazana *et al.*, 2011) [26]. Conventional agricultural lime showed

relatively greater effectiveness than granulated forms, possibly due to its finer particle size and higher reactivity, as also reported by Fageria and Baligar (2008) [9].

Soil electrical conductivity (EC)

Soil electrical conductivity remained statistically unaffected by liming treatments throughout the crop growth period (Table 2). However, EC values were comparatively greater with 100% neutralization using granulated dolomite (T_7), showing 0.31, 0.29 and 0.26 $dS\ m^{-1}$ across 30 and 60 DAS and at harvest, whereas the absolute control (T_1) exhibited the minimum EC. The slight increase in EC under limed treatments may be due to the addition of soluble salts from liming materials and fertilizers, corroborating earlier reports by Khan *et al.* (2007) [15] and Shamim *et al.* (2008) [25].

Soil Organic Carbon (SOC)

The SOC content did not differ significantly among treatments at any growth stage (Table 2), though values declined slightly from the initial status. Among treatments, RDF + FYM combined with 50% neutralization using lime (T_6) recorded relatively higher organic carbon at harvest (4.71 $g\ kg^{-1}$), closely followed by 100% neutralization with lime (T_5 : 4.70 $g\ kg^{-1}$), whereas RDF + FYM alone (T_2) recorded the lowest values. The marginal improvement in organic carbon under limed treatments can be attributed to FYM addition, which enhances organic matter input and microbial activity, thereby improving carbon turnover and stabilization (Fan *et al.*, 2005; Wong and Yang, 2006) [11, 30].

Soil available nitrogen

Soil available nitrogen varied among treatments during crop growth (Table 3; Figure 1). Across stages, higher available N was observed under RDF + FYM (T_2), recording 282.14, 292.01, and 260.34 $kg\ ha^{-1}$ across 30 and 60 DAS and at harvest, relative to the absolute control. A decline in available N at harvest across treatments was evident, likely due to crop uptake and losses during later growth stages.

The relatively higher nitrogen availability under limed treatments may be attributed to improved microbial activity and enhanced mineralization of organic nitrogen under favourable soil chemical conditions. Application of $CaCO_3$ is known to stimulate nitrification and organic matter decomposition, thereby increasing mineral N availability (Ranjit *et al.*, 2007) [23]. Similar increases in soil mineral N following liming have been reported by Richard *et al.* (2010) [24] and Dixit and Sharma (2003) [8], supporting the present findings.

Soil available phosphorus

Soil available phosphorus was markedly lower in the absolute control and increased substantially with the lime application (Table 3). The highest available P was recorded under RDF + FYM + 500 $kg\ lime\ ha^{-1}$ (T_3), with values of 47.16, 41.57, and 37.93 $kg\ ha^{-1}$ across 30 and 60 DAS and at harvest, with T_4 and T_2 showing comparable values.

Table 2: Effect of liming material on pH, EC and organic carbon content of soil at different growth stages of maize

Treatments	pH (1:2.5)			EC ($dS\ m^{-1}$)			Organic carbon ($g\ kg^{-1}$)		
	30 DAS	60 DAS	At Harvest	30 DAS	60 DAS	At Harvest	30 DAS	60 DAS	At Harvest
T_1	7.18	7.18	7.17	0.17	0.15	0.12	4.57	4.59	4.64
T_2	7.20	7.18	7.16	0.20	0.18	0.15	4.53	4.56	4.60
T_3	7.23	7.21	7.18	0.22	0.20	0.17	4.54	4.58	4.66
T_4	7.29	7.25	7.22	0.28	0.24	0.21	4.53	4.55	4.64
T_5	7.34	7.32	7.27	0.29	0.27	0.24	4.56	4.59	4.70
T_6	7.21	7.19	7.14	0.24	0.22	0.19	4.56	4.59	4.71
T_7	7.32	7.30	7.23	0.31	0.29	0.26	4.55	4.57	4.68
T_8	7.22	7.20	7.18	0.29	0.27	0.24	4.55	4.57	4.69
S.Em $\pm$	0.32	0.32	0.32	0.03	0.03	0.03	0.20	0.20	0.20
CD @ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Effect of liming material on available nitrogen, phosphorous and potassium in soil at different growth stages of maize

Treatments	Available N			Available P ₂ O ₅			Available K ₂ O		
	kg ha ⁻¹								
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T ₁	233.21	228.47	221.45	21.49	18.34	16.32	172.41	166.28	163.89
T ₂	282.14	292.01	260.34	42.58	37.11	33.70	217.78	208.78	199.99
T ₃	279.19	289.83	256.79	47.16	41.57	37.93	199.56	190.90	179.67
T ₄	278.65	287.53	255.43	45.64	39.29	35.29	214.31	205.41	196.49
T ₅	261.04	273.64	245.38	32.41	26.32	24.48	203.12	194.38	183.58
T ₆	267.71	281.11	250.29	38.46	31.47	29.63	205.45	197.88	185.90
T ₇	272.24	283.40	253.13	40.12	34.68	31.47	210.64	201.52	189.76
T ₈	262.30	276.41	247.81	35.28	29.54	27.38	211.53	202.56	192.66
S.Em ±	11.46	11.77	10.72	1.57	1.34	1.23	8.74	8.39	8.03
CD @ 5%	34.76	35.71	32.52	4.75	4.07	3.72	26.51	25.45	24.35

Treatment details

T₁: Absolute control, T₅: T₂ + 100% neutralization with lime

T₂: 100% RDF (150:75:40 NPK kg ha⁻¹) + FYM, T₆: T₂ + 50% neutralization with lime

T₃: T₂ + 500 kg lime, T₇: T₂ + 100% neutralization with GD

T₄: T₂ + 250 kg GD, T₈: T₂ + 50% neutralization with GD

Enhanced phosphorus availability with liming may result from decreased fixation by iron and aluminium due to their precipitation at elevated pH, which improves phosphorus solubility. Liming has also been reported to convert insoluble Fe-Al phosphates into more plant-available calcium phosphates (Curtin and Syers, 2001) [17]. Similar enhancement in soil available P with lime application was documented by Nagaraja *et al.* (2012) [20], Melese *et al.* (2015) [17] Castro *et al.* (2010) [4].

Soil available potassium

Available potassium content was highest under RDF + FYM (T₂), recording 217.78, 208.78, and 199.99 kg ha⁻¹ across 30 and 60 DAS and at harvest, with minimum values in absolute control (Table 3; Figure 1). A gradual reduction in potassium availability was observed with increasing lime levels.

The decline in available K under limed treatments may be attributed to antagonistic interactions between calcium, magnesium, and potassium, where increased Ca and Mg concentrations reduce K availability and uptake. Similar reductions in potassium availability following lime application were noted by Fageria *et al.* (1995) [10]. These findings indicate that while liming improves overall soil fertility, excessive lime application may influence potassium dynamics through cationic

competition.

Exchangeable Calcium status in soil

The application of liming materials had a significant effect on the soil's exchangeable calcium levels (Table 4; Figure 2). Across growth stages, the highest exchangeable Ca was recorded under RDF + FYM + 500 kg lime ha⁻¹ (T₃), with values of 8.85, 8.63, and 8.43 cmol (p⁺) kg⁻¹ at 30, 60 DAS, and harvest, respectively, compared to the absolute control and RDF + FYM alone. Other limed treatments also showed elevated calcium levels and were comparable with T₃. The lower exchangeable Ca observed under T₂ (100% RDF + FYM) compared to the absolute control (T₁) may be attributed to increased nutrient interactions and cation dynamics following fertilizer and organic matter application. The addition of fertilizers, particularly nitrogenous sources, can enhance cation exchange reactions and may promote the displacement of Ca²⁺ from exchange sites by other cations such as NH₄⁺ and K⁺. Additionally, increased microbial activity and nutrient uptake under fertilized conditions could have contributed to a temporary reduction in exchangeable Ca levels. In contrast, the control treatment, with minimal external inputs, maintained relatively stable Ca levels due to the absence of such interactions.

Table 4: Effect of liming material on exchangeable Calcium, magnesium and sulphur in soil at different growth stages of maize

Treatments	Exchangeable Ca			Exchangeable Mg			Available S		
	[c mol (p+) kg ⁻¹]								
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T ₁	4.97	4.95	4.93	1.75	1.71	1.69	6.21	5.79	5.76
T ₂	4.65	4.63	4.60	1.61	1.54	1.52	6.12	6.09	6.03
T ₃	8.85	8.63	8.43	1.64	1.56	1.54	8.90	8.86	8.67
T ₄	7.99	7.75	7.56	4.19	4.12	4.01	8.73	8.56	8.45
T ₅	8.56	8.32	8.16	1.62	1.53	1.45	7.71	7.51	7.48
T ₆	8.39	8.23	8.01	1.69	1.58	1.50	8.25	8.01	7.94
T ₇	8.11	8.01	7.84	4.39	4.36	4.32	8.43	8.21	8.04
T ₈	8.01	7.90	7.68	4.11	4.01	3.98	7.90	7.78	7.63
S.Em ±	0.31	0.30	0.29	0.12	0.12	0.12	0.33	0.32	0.31
CD @ 5%	0.93	0.91	0.89	0.36	0.36	0.35	0.99	0.96	0.95

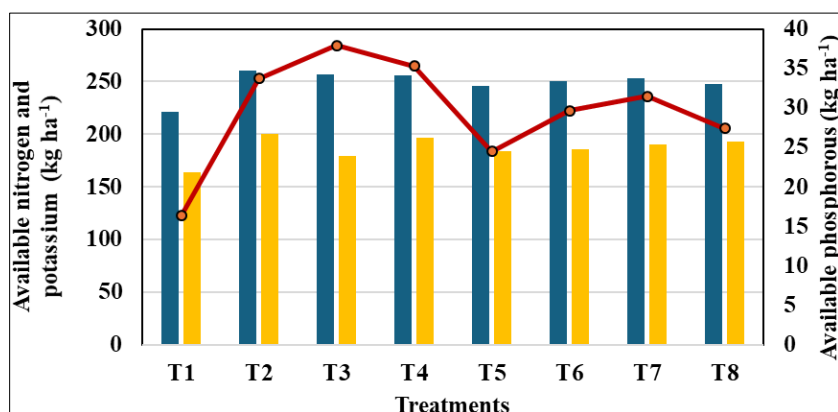


Fig 1: Influence of liming materials (lime and granulated dolomite) on available nitrogen, phosphorus and potassium in soil at harvest of maize. Values represent mean of three replications; error bars indicate standard error of mean (SEm) and differences were tested at $P = 0.05$

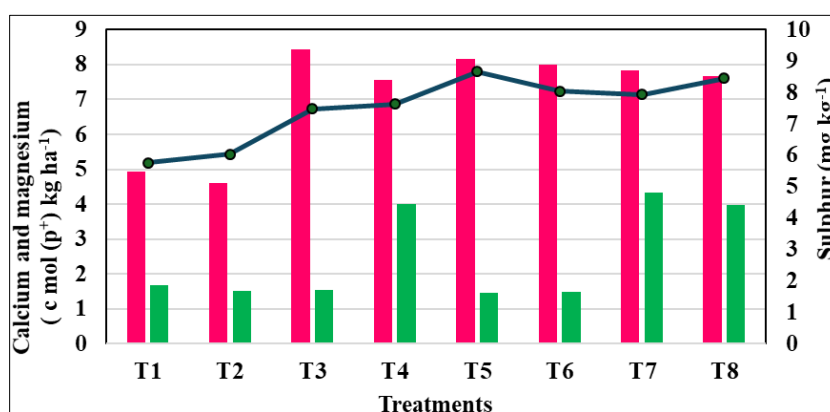


Fig 2: Influence of lime and granulated dolomite on exchangeable Calcium, Magnesium and Sulphur in soil at maize harvest. Data are expressed as mean $\pm$ SEM ($n = 3$) and treatment effects were significant at $P = 0.05$

Application of lime contributed directly to Ca levels in the soil, leading to higher base saturation and greater replacement of exchangeable sites with Ca^{2+} ions. Conventional agricultural lime has been reported to be more effective in increasing exchangeable calcium than granulated forms (Mullen *et al.* 2005) [19]. Nagaraja *et al.* (2012) [20] also observed comparable increases in exchangeable Ca after liming, which aligns with the results of the present study.

Exchangeable magnesium status in soil

Exchangeable magnesium content varied significantly among treatments (Table 4; Fig. 2). The highest magnesium content was observed in the RDF + FYM treatment with 100% neutralization using granulated dolomite (T₇), with values of 4.39, 4.36, and 4.32 cmol (p^+) kg^{-1} recorded on days 30 and 60 after sowing and at harvest, followed by lower rates of granulated dolomite (T₄ and T₈). The lowest magnesium content was observed in the absolute control.

The increase in exchangeable magnesium under dolomite application may be attributed to enhanced Mg^{2+} supply, increased base saturation, and reduced aluminium saturation on the exchange complex. Liming with dolomite improves soil charge density and promotes synergistic accumulation of magnesium on exchange sites (Paula *et al.*, 1997) [21]. Comparable improvements in soil magnesium status with dolomitic lime have been reported by Moreira and Fageria (2010) [18], and Castro *et al.*, (2010) [4].

Available sulphur status in soil

Soil sulphur availability was enhanced by the use of liming materials (Table 4; Figure 2). The highest sulphur availability was observed under RDF + FYM + 500 kg lime ha^{-1} (T₃), with values

of 8.90, 8.86, and 8.67 mg kg^{-1} at 30 DAS, 60 DAS, and harvest, respectively, followed by T₄, T₆, and T₇. The lowest sulphur content was recorded in the absolute control.

Enhanced soil sulphur levels under limed treatments may be due to reduced sulphate adsorption on soil exchange sites and enhanced mineralization of organic sulphur resulting from increased microbial activity. Hydroxyl ions released during lime hydrolysis may also displace sulphate ions into the soil solution, increasing sulphur availability (Kalluraya, 1990; Crusciol *et al.* 2010) [14, 6]. Consistent with the present findings, Churka *et al.* (2013) [5] recorded elevated sulphate concentrations in soil solution due to lime application.

Micronutrients availability in soil

Soil levels of DTPA-extractable Fe, Mn, Cu and Zn were not significantly influenced by liming treatments at any stage of maize growth (Tables 5 and 6). Although minor numerical variations were observed among treatments, these differences were not statistically significant and therefore do not indicate a definite treatment effect.

Relatively higher values were observed under treatments receiving lime along with RDF and FYM, particularly in T₃ recorded relatively higher DTPA-Fe (8.42, 8.27, and 8.08 mg kg^{-1}), Mn (7.19, 7.13, and 6.94 mg kg^{-1}), Cu (0.52, 0.49, and 0.47 mg kg^{-1}) and Zn (0.48, 0.47, and 0.39 mg kg^{-1}) corresponding to 30, 60 DAS and harvest. In contrast, the absolute control (T₁) exhibited the lowest values. However, these variations remained within the limits of experimental error. Any apparent reduction in micronutrient availability at higher liming levels may be associated with slight increases in soil pH, but such trends cannot be conclusively interpreted due to lack of statistical significance.

Similar findings have been reported in earlier studies, where liming had limited influence on micronutrient availability in neutral soils (Ayodele and Shittu, 2014)^[1].

Conclusion

The study demonstrated that the application of liming materials to neutralize physiological acidity in a neutral red loamy sand soil did not significantly alter soil pH or electrical conductivity, reflecting the inherent buffering capacity of the soil. However, the combined application of recommended fertilizers and farmyard manure, along with lime or granulated dolomite, favourably influenced soil nutrient availability during maize cultivation. Application of RDF + FYM improved soil available nitrogen and potassium, while supplementation with agricultural lime notably enhanced the availability of phosphorus, sulphur and exchangeable calcium. Granulated dolomite was particularly effective in increasing exchangeable magnesium levels. The availability of DTPA-extractable micronutrients remained within adequate ranges and was not significantly affected by liming, indicating no risk of micronutrient depletion under neutral soil conditions. Overall, the findings highlight that strategic use of liming materials can effectively mitigate fertilizer-induced acidity and improve soil nutrient balance, thereby supporting sustainable maize production in *Alfisols*.

Table 5: Effect of liming material on DTPA extractable iron and manganese in soil at different growth stages of maize

Treatments	Fe			Mn		
	(mg kg ⁻¹)					
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T ₁	6.89	6.81	6.74	7.01	6.99	6.48
T ₂	8.34	8.18	7.98	7.17	7.11	6.83
T ₃	8.42	8.27	8.08	7.19	7.13	6.94
T ₄	8.32	8.15	7.92	7.16	7.10	6.81
T ₅	8.10	7.90	7.79	7.10	7.06	6.58
T ₆	8.23	7.99	7.85	7.13	7.08	6.74
T ₇	8.29	8.06	7.90	7.15	7.09	6.79
T ₈	8.17	7.95	7.82	7.11	7.07	6.67
S.Em ±	0.35	0.34	0.33	0.31	0.31	0.29
CD @ 5%	NS	NS	NS	NS	NS	NS

Table 6: Effect of liming material on DTPA extractable Copper and Zinc in soil at different growth stages of maize

Treatments	Cu			Zn		
	(mg kg ⁻¹)					
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T ₁	0.45	0.43	0.41	0.40	0.38	0.29
T ₂	0.51	0.45	0.43	0.47	0.46	0.38
T ₃	0.52	0.49	0.47	0.48	0.47	0.39
T ₄	0.50	0.49	0.47	0.47	0.45	0.36
T ₅	0.46	0.44	0.42	0.44	0.42	0.30
T ₆	0.48	0.47	0.45	0.46	0.44	0.33
T ₇	0.49	0.48	0.46	0.46	0.45	0.35
T ₈	0.47	0.46	0.44	0.45	0.43	0.32
S.Em ±	0.02	0.02	0.02	0.02	0.02	0.02
CD @ 5%	NS	NS	NS	NS	NS	NS

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Declaration

The authors declare that they have no competing interests.

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