

Long-Term Effect Of Fertilizer And Manure Application On Different Fractions Of Calcium And Magnesium In Isothermic Kandic Paleustalfs.

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ABSTRACT

The soil samples collected after 31 cropping cycles (2017) from ongoing long-term fertilizer experiment under the finger millet-maize cropping system at GKVK, Bengaluru were studied for different fractions of calcium (Ca) and magnesium (Mg) and available nutrient status. The different fractions of Ca and Mg were in the order of mineral>acid soluble>exchangeable>organic complexed form. All forms of Ca and Mg were significantly higher in the treatments receiving 100 % NPK + FYM + lime (T₁₀). All fractions of Ca and Mg content were lower in the treatments receiving imbalanced nutrients. The correlation study revealed that pH, EC, OC, and nitrogen content are important parameters in influencing the status of Ca and Mg fractions. There was a positive correlation between grain yields (finger millet and maize) and fractions of Ca and Mg.

Keywords- Fertilizer, manure, exchangeable, organic complexed, acid-soluble, mineral, total Ca and Mg

Introduction

Enhancement and sustained crop production do play an important role in the improvement and soil fertility maintenance. The long-term fertilizer experiments act as repositories for valuable information regarding sustainability in agriculture and environmental quality. Long-term fertilizer experiments are widely recognized with continuous cropping on soil fertility and sustenance of crop production.

Calcium (Ca) is the fifth most abundant element constituting 3.63% of the earth crust. Magnesium (Mg) is in eighth position it's abundance, comprising of 2.5%. Despite the abundance of secondary nutrients in the earth crust, they are often present in suboptimal quantities in soil. In Karnataka, the deficiencies of Ca and Mg have been reported from Dakshina Kannada, Uttar Kannada and hilly areas [3] and Malaprabha command areas [5]. Ca do provide structural support to cell walls, it acts as a counteraction for organic and inorganic anions in the vacuole. Ca also involved in the maintenance of the configuration of specific enzymes. Mg is the central atom that constitutes 2.7 percent in the chlorophyll molecule. Mg acts as a phosphate carrier and therefore it accumulates to a considerable extent in the seeds, especially in plants rich in oils, plays a vital role in several plant physiological processes through its key function in phloem loading, being a co-factor and allosteric modulator for >300 enzymes (including Calvin cycle, kinases, RNA polymerases, and ATPases) and in chelation to nucleotide phosphate forms. Secondary nutrients in soils do present in different forms. Ca and mg exist as exchangeable forms, organically complexed form, acid-soluble forms, mineral forms and total Ca and Mg. Under intensive cultivation, Ca and Mg are removed by crops as they are available readily. This is followed by further release of exchangeable Ca and Mg from non-exchangeable forms. Intensive cultivation of high-yielding varieties of crops with the application of high rates of nitrogen (N), phosphorous (P), potassium (K) fertilizers tend to deplete the secondary nutrient reserve of soil at faster rate.

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It is necessary to determine not only the available amounts of nutrients but also the different fractions of it in the soil in order to obtain a clearer idea about its availability and the problems encountered by plants in its absorption from a particular type of soil. Hence the present study is carried out to study the changes in different fractions of soil Ca and Mg as influenced by continuous manuring with organic and inorganic fertilizers with the following objectives: 1. To study the different fractions of Ca and Mg in soils of long-term fertilizer experiment. 2. To study the correlation between different fractions of Ca and Mg with crop yield and soil physico-chemical properties.

Material and Methods

Location of the study area: A field study was conducted at Long Term Fertilizer Experiment (LTFE) field in "E- 18" block of Gandhi Krishi Vigyana Kendra (GKVK) with finger millet – hybrid maize cropping sequence having eleven treatments four replications with RCBD design initiated during May 1986-87, UAS, Bengaluru located in Eastern Dry Zone of Karnataka at 13° 4' 37" N latitude, 77° 34' 13" E longitude with an altitude of 930 meters above mean sea level (MSL). Initial soil properties is indicated in Table 1.

Collection of soil sample: The soil is classified as fine, mixed Isothermic Kandic Paleustalfs of Vijayapura series. A composite soil sample was taken from each plot from the study area by at 0-15 cm depth after harvest of the maize crop (2017). The soil was processed and analyzed for pH, EC, N, P, K, S and all fractions of calcium and magnesium by following standard procedures. Treatment details

The treatment details of on long-term fertilizer experiment are given in Table 2. In all the treatments except in treatment T₄ (100% NPK + Hand weeding),

chemical weed control is practiced using appropriate weedicides. Lime was applied based on lime requirement following the method given by Shoemaker [24] during the *kharif* season. If the pH is more than 6.00 then lime is applied @ 200 kg ha⁻¹. Well-decomposed farmyard manure (FYM) at the rate of 15 t ha⁻¹ is incorporated into the soil 10-15 days prior to sowing of the *kharif* crop.

Estimation of calcium and magnesium fractions

Different fractions of calcium and magnesium were extracted sequentially as shown in Fig.1. One gram of soil has been crushed and passed through a 35- mesh sieve (0.417mm) and was subjected to the following successive treatment.

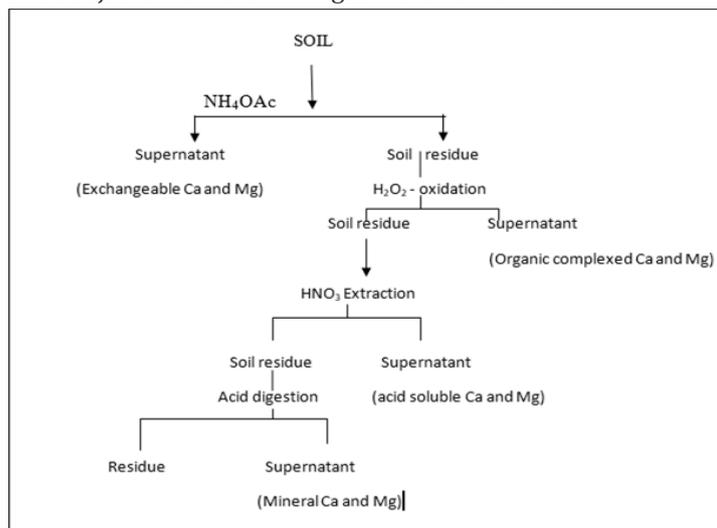


Fig. 1: Fractionation of soil for different forms of calcium and magnesium (Uzo and Melsted, 1972)

Total calcium and magnesium

Total calcium and magnesium were determined on a separate sample by digesting with 70% HClO₄ [14]. Calcium and magnesium in the extract was determined by versanate titration [21].

Results and Discussion

Effect of long term manuring and fertilizer application on different fractions of calcium in soil after 31 cropping cycles

The data pertaining to different fractions of Ca in soil as influenced by various long-term fertilizer experiment treatments after 31 cropping cycles are presented in Tables 3 and Fig. 2. The amount of calcium is generally much higher than those of other cations in soil solution, the values ranged from 1.7 to 19.4 mill molar in soil solution and the exchangeable form of calcium constituted 80-86 per cent of the exchange complex [1].

Exchangeable calcium [c mol (P⁺) kg⁻¹]

There was a significant difference among treatments with respect to the exchangeable Ca content of soil. Significantly higher exchangeable Ca content was observed in treatment received 100% NPK + FYM + lime (T₁₀: 5.58 c mol(p⁺) kg⁻¹) followed by 100% NPK + lime (T₅: 5.43 c mol(p⁺) kg⁻¹). However lower value of exchangeable Ca was recorded in treatment that received 100% NPK [Ca free P fertilizer (T₉: 3.55 c mol(p⁺) kg⁻¹)] followed by control (T₁₁: 3.70 c mol(p⁺) kg⁻¹). Exchangeable Ca contributed 9.20 to 10.67% to the total Ca content in the soil with an average of 9.91%. Exchangeable form of Ca was found to be higher in the treatments receiving lime as a source of Ca along with SSP as P fertilizer followed by treatments received FYM with 100% NPK fertilizers due to replenishment of Ca to soil.

Lower exchangeable Ca was observed due to removal of native calcium content present in soil without adding any calcium sources. The similar results were reported in the long term fertilizer experiment field at Bengaluru [22].

Organic complexed calcium [c mol (P⁺) kg⁻¹]

Significantly higher organic complexed Ca was observed in FYM applied treatment 100% NPK + FYM + lime (T₁₀: 1.75 c mol(p⁺) kg⁻¹) followed by 100% NPK+ FYM (T₈: 1.65 c mol (p⁺) kg⁻¹). However lower value of organic complexed Ca was recorded in T₁₁: 1.22 c mol (p⁺) kg⁻¹ followed by T₇: 100% N (1.25 c mol (p⁺) kg⁻¹) which is on par with treatment T₉: 100% NPK (1.27 c mol (p⁺) kg⁻¹). Organic complexed Ca contributed 2.72 to 3.56% to the total Ca content in the soil with an average of 3.52%. The treatment received lime and FYM along with 100% NPK has comparatively higher organic complexed Ca than others due to plant root biomass addition. This form of Ca was lower in the treatments that received Ca-free P fertilizers, imbalanced supply of fertilizers and in control due to reduced plant growth in turn decreases in plant root biomass addition.

Acid soluble calcium [c mol (P⁺) kg⁻¹]

Significantly higher acid-soluble calcium content was observed in lime applied treatment 100% NPK + FYM + lime (T₁₀: 16.30 c mol(p⁺) kg⁻¹) followed by 100% NPK+ lime (T₅: 16.20 c mol(p⁺) kg⁻¹). However, lower value of organic acid-soluble Ca was recorded in treatment receiving 100% N (T₇: 10.17 c mol(p⁺) kg⁻¹) followed by T₉: 10.73 c mol(p⁺) kg⁻¹ which received Ca free P fertilizer. Acid soluble Ca contributed 24.96 to 30.08% to the total Ca content in the soil with an average of 28.84%. Acid soluble form of Ca content in soil was significantly higher in the treatments received lime along with NPK fertilizers due to the maintenance of soil pH and the decrease in soil pH results is the solubility of Ca content in the soil, which might be in plant-available form in turn results in lower acid soluble calcium content.

Mineral calcium [c mol (P⁺) kg⁻¹]

Mineral Ca content was significantly higher in lime applied treatments *i.e.*, T₁₀: 27.00c mol(p⁺) kg⁻¹) followed by T₅: 26.75 c mol(p⁺) kg⁻¹. However, mineral Ca was recorded lower value (16.25 c mol (p⁺) kg⁻¹) in treatment that received Ca free P fertilizer, T₉: 100% NPK followed by treatment which received only 100% N (T₇: 19.08 c mol(p⁺) kg⁻¹). Mineral Ca contributed 44.63 to 54.14% to the total Ca content in the soil with an average of 50.05%. Lower values of mineral Ca were recorded in the treatments which have not received any calcium source due to continuous removal by the crops [7].

Total calcium [c mol (P⁺) kg⁻¹]

Significant difference noticed among treatments with respect to total calcium content of soil. Significantly higher total Ca content was observed in lime applied treatments 100% NPK + FYM + lime (T₁₀: 55.42 c mol(p⁺) kg⁻¹) followed by 100% NPK+ lime (T₅: 54.08 c mol(p⁺) kg⁻¹). However lower value of total Ca was recorded in T₉: 35.67 c mol(p⁺) kg⁻¹ followed by control (T₁₁: 37.92 c mol(p⁺) kg⁻¹). Total calcium was significantly lower in the treatments which have not received any Ca containing fertilizer, organic source due to continuous removal by the crops, release of Ca from non exchangeable forms. Significantly higher total Ca content in the soil was recorded in treatments receiving lime, Ca containing phosphatic fertilizer with inorganic fertilizers. The results were in conformity with the observations recorded in soils of Mandya and Chamarajanagar [4].

Effect of long term manuring and fertilizer application on different fractions of magnesium in soil after 31 cropping cycles

The data pertaining to different fractions of Mg in soil as influenced by various long term fertilizer experiment treatments after 31 cropping cycles are presented in Tables 4 and Fig. 3. The different fractions of magnesium in the soil were in the order of mineral > acid soluble > exchangeable > organic form. Similar results were obtained in the study of magnesium status in *Ustisols* and *Alfisols*. *Alfisols* had a higher average Mg(t) content which is in line with their lower weathering status [20].

Exchangeable magnesium [c mol (P⁺) kg⁻¹]

There was a significant difference noticed among treatments with respect to the exchangeable magnesium content of soil. Significantly higher exchangeable Mg content was observed in lime applied treatment receiving 100% NPK + FYM + lime (T₁₀: 2.78 c mol(p⁺) kg⁻¹) and 100% NPK+ lime (T₅: 2.62 c mol(p⁺) kg⁻¹). However lower value of exchangeable Mg was observed in treatment T₉: 100% NPK, S-P fertilizer (1.58 c mol (p⁺) kg⁻¹) followed by T₇: 100% N (1.73 c mol(p⁺) kg⁻¹). Exchangeable Mg contributed 6.57 to 9.89% to the total Mg content in the soil with an average of 8.33%. The exchangeable form of Mg was significantly higher in the treatments receiving lime and FYM which contains Mg to some extent, as a source of Mg along with NPK fertilizers. Manure has a positive effect on the content of available magnesium [25]. Exchangeable Mg content recorded a significantly lower value in the treatment that received no magnesium source. Similar results were in the long term fertilizer experiment field at Bengaluru [22]. Exchangeable magnesium was significantly lower in treatments T₉, T₇, and control may due to removal of native magnesium content present in soil without replenishment.

Organic complexed magnesium [c mol (P⁺) kg⁻¹]

Organic complexed Mg contributed 2.21 to 2.82% to the total Mg content in the soil with an average of 2.53%. Significantly higher organic complexed Mg content was observed in T₁₀: 100% NPK + FYM + lime (0.78 c mol(p⁺) kg⁻¹) and T₈: 100% NPK+ FYM (0.73 c mol(p⁺) kg⁻¹). Organic complexed Mg was significantly lower in treatment T₁₁ (0.58 c mol(p⁺) kg⁻¹) followed by 100% N (T₇: 0.60 c mol(p⁺) kg⁻¹). The treatment received lime and FYM in combination with 100% NPK has comparatively higher organic Mg than others due to plant root biomass addition. Imbalanced supply of fertilizers without Mg source reduced plant growth in turn decrease in plant root biomass addition. Similar results were reported in surface soils of Central Southern Nigeria the organic complexed magnesium varied from 0.12 - 0.63 c mol (p⁺) kg⁻¹ with mean of 0.33c mol (p⁺) kg⁻¹, respectively [20].

Acid-soluble magnesium [c mol (P⁺) kg⁻¹]

Acid-soluble magnesium constitute next to the mineral form to total magnesium present in soil [18]. The amount of acid-soluble magnesium was generally higher than that of the exchangeable magnesium. This confirms with the results obtained from crystalline basement complex soils of igneous and metamorphic rocks [20].

Significantly higher acid soluble Mg was observed in T₁₀: 100% NPK + FYM + lime (7.30 c mol(p⁺) kg⁻¹) followed by T₅: 100% NPK+ lime (7.30 c mol(p⁺) kg⁻¹). However lower value of acid-soluble Mg was recorded in treatment received 100% N (T₇: 4.33 c mol (p⁺) kg⁻¹) and 100% NP (T₆: 4.43 c mol (p⁺) kg⁻¹). Acid-soluble Mg contributed 16.30 to 25.39 % to the total Mg content in the soil with an average of 20.22%.

The higher value of acid-soluble form is due to the addition of lime and by addition, only nitrogenous fertilizers leads to a decrease in soil pH which in turn reduction in acid soluble form of magnesium content in soil. Shashikanth reported similar results in acid soils of Karnataka about acid soluble fraction of magnesium [23].

Mineral magnesium [c mol (P⁺) kg⁻¹]

There was a significant difference among the treatments with respect to the mineral magnesium content of soil. Mineral Mg content was significantly higher in lime and FYM applied treatment 100% NPK + FYM + lime (T₁₀: 18.33 c mol(p⁺) kg⁻¹). Mineral Mg was recorded lower value in treatment receiving 100% NPK, Ca-free P fertilizer (T₉: 12.08 c mol(p⁺) kg⁻¹). Mineral Mg contributed 52.77 to 67.71% to the total Mg content in the soil with an average of 59.49%. Significantly higher mineral Mg content in the soil is recorded in treatments receiving lime and FYM with inorganic fertilizers. Significantly lower value was recorded in the treatments neither received any Mg source, this is due to continuous removal by the crops and by weathering leads to release of Mg into the exchangeable pool [7]. Mineral Mg formed a major portion of the total Mg and majority accounting about 71% of the total Mg was present in the mineral pool [19].

Total magnesium [c mol (P⁺) kg⁻¹]

Markable differences noticed among treatments with respect to total magnesium content of soil. Total Mg was significantly recorded higher value in lime applied treatments 100% NPK + FYM + lime (T₁₀: 32.00 c mol(p⁺) kg⁻¹) followed by 100% NPK+ lime (T₅: 28.75 c mol(p⁺) kg⁻¹). However lower value of total Mg was recorded in treatment T₉ (100% NPK, Ca-free P fertilizer) 22.17 c mol(p⁺) kg⁻¹. Total Mg was significantly lower in the treatments which have not received any Mg fertilizer or organic source and due to continuous removal of Mg by the crops, release of Mg from nonexchangeable forms. The results were in conformity with the observations recorded with respect total magnesium content in the surface layer in long term experiment of Bengaluru [22] and by in soils of the Mediterranean coastal area of Motril (southeastern Spain) [15].

Correlation between different fractions of calcium, magnesium with soil physicochemical properties and grain yield of finger millet and maize

The correlation between different fractions of calcium and magnesium with soil physico-chemical properties and grain yield of finger millet and maize is presented in Table 5.

Exchangeable calcium has a significant positive correlation with EC (r=0.940**), OC (r=0.724*), available nitrogen (r=0.685*), potassium (r=0.624*), available sulfur (r=0.653*) and in soil. Exchangeable magnesium has a significant positive correlation with pH (r=0.832**), EC (r=0.760**) in soil. Soil pH was positively correlated with exchangeable Ca and Mg [6]. Exchangeable magnesium was positively and significantly correlated with pH (r=0.517**). Organic complexed Ca and Mg has a significant positive correlation with pH, EC, OC, available nitrogen and potassium in soil [17]. All forms of Ca and Mg showed a negative correlation with sand and silt content in soil. Clay content in soil has a positive correlation with all forms of Ca, Mg and organic complexed Ca has a significant positive correlation with clay content (r=0.078**). This might be due to the association of soil calcium with organic matter and clay content of soil [2]. Similarly, High correlation was reported between non-exchangeable magnesium released during 4 years of cropping and magnesium extracted from soils, or from their clay fractions and even total soil magnesium [13].

Exchangeable Ca and Mg has a positive correlation with grain yield of maize ($r=0.499$ and $r=0.224$, respectively) and finger millet ($r=0.523$ and $r=0.293$, respectively) however, it was nonsignificant. Organic complexed Ca and Mg has a significant and positive correlation with yield of maize ($r=0.649^*$ and $r=0.731^*$, respectively) and finger millet ($r=0.674^*$ and $r=0.755^{**}$, respectively). Acid soluble, total Ca and Mg has a positive but not significant correlation with yield of maize and finger millet. Similarly, wheat grain yield was positively correlated to the level of Ca ($r=0.50$) and Ca/Mg ratio ($r=0.52$) in the leaves [8]. An exchangeable and organic form of Ca and Mg has a positive correlation with grain yield, as plant available form increases in soil, the yield of crop increases due to crop uptake. The results were similar with the correlation between exchangeable magnesium and yield of wheat crop [10] and the concentration of calcium in soil is positively correlated with plant height, number of stems per plant, and yield [11]. Supplementary calcium enhances plant growth and fruit yield [9, 16]. Similar results with nutrient uptake and yield responses of peanuts and rice to lime and fused magnesium phosphate in an acid soil [12].

Conclusion

Liming and application of Ca-containing fertilizers (SSP) along with FYM increased the exchangeable form of calcium and magnesium over the years. Intensive cultivation of crops without the addition of Ca and Mg containing fertilizer sources results in depletion of soil reserve Ca and Mg. The correlation studies revealed that pH, EC, OC, and available nitrogen content influence the status of Ca and Mg fractions. A positive correlation exists between grain yields and fractions of Ca and Mg. The application of organic manure is important in maintaining, and improving soil fertility and productivity, in turn, crop yield.

Table 1: Initial physico-chemical properties of soil sample of study site (1986)

| Sl. No. | Soil property | Value |
|---------|--|-----------------|
| 1 | 1. Particle size analysis | |
| | a. Sand (%) | 62.00 |
| | b. Silt (%) | 8.60 |
| | c. Clay (%) | 29.40 |
| | Soil textural class | Sandy clay loam |
| 2 | pH (1:2.5 soil:water suspension) | 6.17 |
| 3 | Electrical conductivity ($dS\ m^{-1}$) | 0.059 |
| 4 | Organic carbon (%) | 0.60 |
| 5 | Available nitrogen ($kg\ N\ ha^{-1}$) | 256.70 |
| 6 | Available phosphorus ($kg\ P_2O_5\ ha^{-1}$) | 34.30 |
| 7 | Available potassium ($kg\ K_2O\ ha^{-1}$) | 123.10 |
| 8 | Available sulphur ($mg\ kg^{-1}$) | 20.34 |

Table 2: Treatments details of long term fertilizer experiment

| Treatments | NPK dosage ($kg\ ha^{-1}$) | | Fertilizer source |
|---|------------------------------|----------------|----------------------|
| | Finger millet | Hybrid maize | |
| T ₁ : 50 % NPK | 50 – 11 – 21 | 50 – 16 – 41 | Urea, SSP, MOP |
| T ₂ : 100% NPK | 100 – 22 – 42 | 100 – 32 – 82 | Urea, SSP, MOP |
| T ₃ : 150 % NPK | 150 – 33 – 63 | 150 – 48 – 123 | Urea, SSP, MOP |
| T ₄ : 100% NPK + HW | 100 – 22 – 42 | 100 – 32 – 82 | Urea, SSP, MOP |
| T ₅ : 100% NPK + lime | 100 – 22 – 42 | 100 – 32 – 82 | Urea, SSP, MOP, lime |
| T ₆ : 100% NP | 100 – 22 – 00 | 100 – 32 – 00 | Urea, SSP |
| T ₇ : 100% N | 100 – 00 – 00 | 100 – 00 – 00 | Urea |
| T ₈ : 100% NPK + FYM | 100 – 22 – 42 | 100 – 32 – 82 | Urea, SSP, MOP |
| T ₉ : 100% NPK (S-free) | 100 – 22 – 42 | 100 – 32 – 82 | Urea, DAP, MOP |
| T ₁₀ : 100% NPK + FYM + lime | 100 – 22 – 42 | 100 – 32 – 82 | Urea, SSP, MOP, lime |
| T ₁₁ : Control | 00 – 00 – 00 | 00 – 00 – 00 | |

Table 3: Effect of long term manuring on different fractions of calcium ($c \text{ mol } (p^+) \text{ kg}^{-1}$) in soil after 31 cropping cycles (after maize harvest, 2017)

| Treatments | Exch. Ca | Organic Ca | Acid soluble Ca | Mineral Ca | Total Ca |
|-----------------------------------|-----------------|----------------|------------------|------------------|--------------|
| T ₁ : 50% NPK | 4.08 (9.91) | 1.35 (3.20) | 12.30 (29.17) | 21.25 (50.39) | 42.17 |
| T ₂ : 100%NPK | 4.22 (10.27) | 1.40 (3.41) | 11.93 (29.04) | 21.83 (53.14) | 41.08 |
| T ₃ : 150%NPK | 4.58 (10.67) | 1.42 (3.31) | 12.27 (28.59) | 21.92 (51.07) | 42.92 |
| T ₄ : 100%NPK+HW | 4.12 (10.50) | 1.38 (3.52) | 11.70 (29.81) | 21.25 (54.14) | 39.25 |
| T ₅ : 100%NPK+lime | 5.43 (10.04) | 1.47 (2.72) | 16.20 (29.96) | 26.75 (49.46) | 54.08 |
| T ₆ : 100%NP | 4.48 (9.79) | 1.40 (3.06) | 13.10 (28.63) | 20.42 (44.63) | 45.75 |
| T ₇ : 100%N | 3.75 (9.20) | 1.25 (3.07) | 10.17 (24.96) | 19.08 (46.82) | 40.75 |
| T ₈ : 100%NPK+FYM | 4.52 (9.53) | 1.65 (3.48) | 13.30 (28.08) | 25.33 (53.42) | 47.42 |
| T ₉ : 100%NPK(S-free) | 3.55 (9.95) | 1.27 (3.56) | 10.73 (30.08) | 16.25 (45.56) | 35.67 |
| T ₁₀ :100%NPK+FYM+lime | 5.58 (10.07) | 1.75 (3.16) | 16.30 (29.41) | 27.00 (48.72) | 55.42 |
| T ₁₁ : Control | 3.70 (9.76) | 1.22 (3.22) | 11.17 (29.46) | 20.17 (53.19) | 37.92 |
| SEm± | 0.040 | 0.026 | 0.204 | 0.253 | 0.305 |
| CD @ 5 % | 0.12 | 0.08 | 0.60 | 0.75 | 0.90 |

Figures in parenthesis indicates per cent contribution towards total calcium

Table 4: Effect of long term manuring on different fractions of magnesium ($c \text{ mol } (p^+) \text{ kg}^{-1}$) in soil after 31 cropping cycles (after maize harvest, 2017)

| Treatments | Exch. Mg | Organic Mg | Acid soluble Mg | Mineral Mg | Total Mg |
|-----------------------------------|----------------|----------------|-----------------|------------------|--------------|
| T ₁ : 50% NPK | 2.35 (9.89) | 0.58 (2.44) | 4.63 (19.49) | 15.17 (63.87) | 23.75 |
| T ₂ : 100%NPK | 1.92 (8.08) | 0.67 (2.82) | 4.60 (19.37) | 16.08 (67.71) | 23.75 |
| T ₃ : 150%NPK | 1.90 (7.97) | 0.67 (2.81) | 4.67 (19.60) | 14.00 (58.75) | 23.83 |
| T ₄ : 100%NPK+HW | 1.97 (7.73) | 0.63 (2.47) | 5.57 (21.84) | 15.00 (58.82) | 25.50 |
| T ₅ : 100%NPK+lime | 2.62 (9.11) | 0.70 (2.43) | 7.30 (25.39) | 15.17 (52.77) | 28.75 |
| T ₆ : 100%NP | 2.12 (7.80) | 0.60 (2.21) | 4.43 (16.30) | 16.25 (59.81) | 27.17 |
| T ₇ : 100%N | 1.73 (6.57) | 0.60 (2.28) | 4.33 (16.45) | 14.83 (56.32) | 26.33 |
| T ₈ : 100%NPK+FYM | 2.38 (9.07) | 0.73 (2.78) | 4.77 (18.17) | 15.25 (58.10) | 26.25 |
| T ₉ : 100%NPK(S-free) | 1.58 (7.13) | 0.62 (2.80) | 5.10 (23.00) | 12.08 (54.49) | 22.17 |
| T ₁₀ :100%NPK+FYM+lime | 2.78 (8.69) | 0.78 (2.44) | 7.30 (22.81) | 18.33 (57.28) | 32.00 |
| T ₁₁ : Control | 2.33 (9.58) | 0.58 (2.38) | 4.87 (20.02) | 16.17 (66.46) | 24.33 |
| SEm± | 0.070 | 0.034 | 0.082 | 0.272 | 0.312 |
| CD @ 5 % | 0.21 | 0.10 | 0.24 | 0.80 | 0.92 |

Figures in parenthesis indicates per cent contribution towards total magnesium

Table 5: Correlation between different fractions of calcium and magnesium with soil electro-chemical properties and yield of finger millet and maize (2017)

| | Exc. Ca | Org. Ca | Acid Sol. Ca | Mineral Ca | Total Ca | Exc. Mg | Org. Mg | Acid Sol. Mg | Mineral Mg | Total Mg |
|---------------------|---------|---------|--------------|------------|----------|---------|---------|--------------|------------|----------|
| pH | 0.549 | 0.634* | 0.697* | 0.678* | 0.608* | 0.832** | 0.575 | 0.662* | 0.506 | 0.508 |
| EC | 0.940** | 0.815** | 0.903** | 0.907** | 0.866** | 0.760** | 0.855** | 0.763** | 0.588 | 0.709* |
| OC | 0.724* | 0.910** | 0.645* | 0.732* | 0.642* | 0.478 | 0.865** | 0.480 | 0.466 | 0.535 |
| N | 0.685* | 0.836** | 0.590 | 0.623* | 0.696* | 0.418 | 0.832** | 0.509 | 0.465 | 0.768** |
| P | 0.397 | 0.579 | 0.334 | 0.209 | 0.310 | 0.003 | 0.500 | 0.059 | -0.040 | 0.170 |
| K | 0.624* | 0.719* | 0.553 | 0.633* | 0.474 | 0.359 | 0.795** | 0.513 | 0.101 | 0.250 |
| S | 0.653* | 0.546 | 0.563 | 0.592 | 0.566 | 0.370 | 0.499 | 0.256 | 0.404 | 0.476 |
| Sand | -0.017 | -0.143 | -0.026 | -0.325 | -0.042 | -0.107 | -0.355 | -0.128 | -0.111 | -0.046 |
| Silt | -0.163 | -0.430 | -0.213 | -0.285 | -0.125 | 0.479 | 0.014 | 0.386 | 0.437 | 0.506* |
| Clay | 0.477 | 0.078** | 0.443 | 0.314 | 0.438 | 0.479 | 0.014 | 0.386 | 0.437 | 0.506* |
| Finger millet yield | 0.523 | 0.674* | 0.497 | 0.545 | 0.406 | 0.293 | 0.755** | 0.491 | -0.063 | 0.086 |
| Maize yield | 0.499 | 0.649* | 0.499 | 0.492 | 0.364 | 0.224 | 0.731* | 0.495 | -0.104 | 0.072 |

*. Correlation is significant at the 0.05 level (2-tailed)

** . Correlation is significant at the 0.01 level (2-tailed)

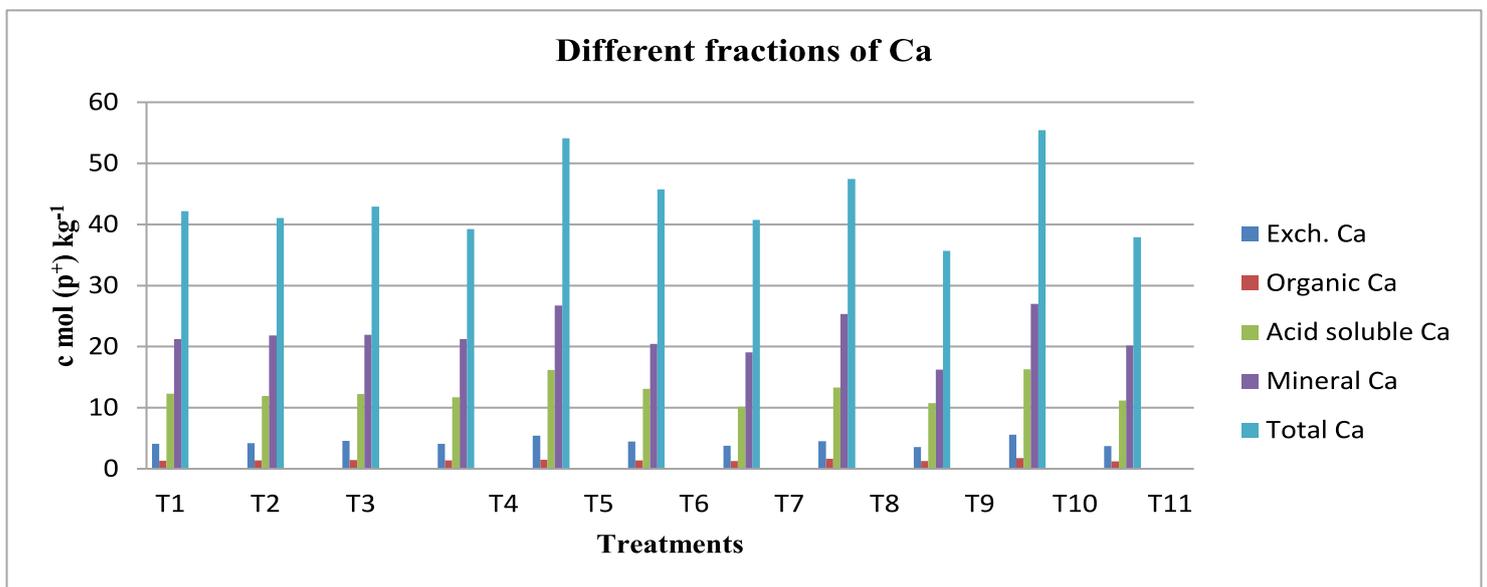


Fig. 2: Effect of long term manuring on different fractions of calcium and magnesium in soil after 31 cropping cycles (after maize harvest, 2017)

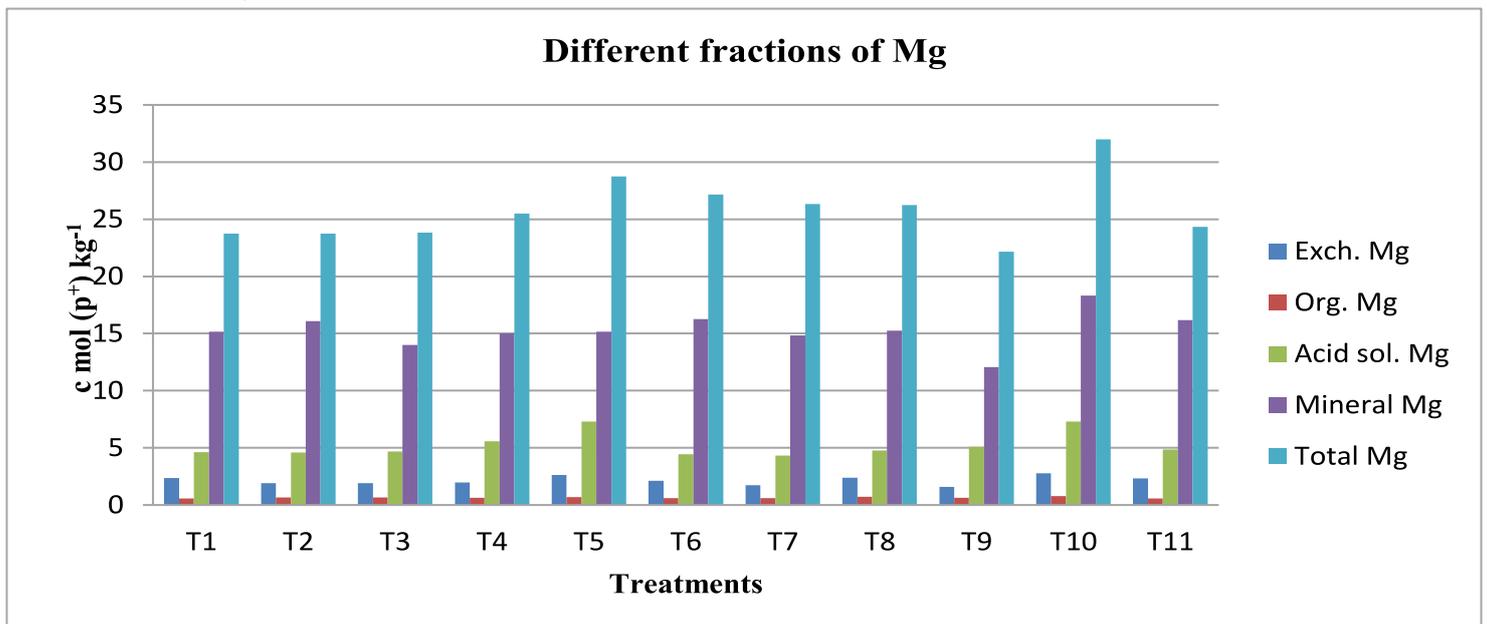


Fig. 3: Effect of long term manuring on different fractions of calcium and magnesium in soil after 31 cropping cycles (after maize harvest, 2017)

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