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FRACTIONATION OF LOWLAND PADDY SOILS FOR SECONDARY NUTRIENTS IN HILLY ZONE OF KARNATAKA INDIA

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ABSTRACT

Hilly zone of Karnataka receives high rainfall leading to acidic soil and becoming problematic for crop production. To overcome this, farmers are applying liming material in uplands. Due to high rainfall leaching of secondary nutrients takes place from uplands, which gets accumulated in low land paddy fields. An investigation was carried out to study the secondary nutrient status of soil and their ralationship with soil properties in lowland acid soil of Kodagu and Chikkamagaluru, Total 200 surface soil samples (0-15) were collected from lowland paddy fields in central parts of western ghats. Results revealed that soils were moderately acidic to neutral in soil reaction, ranged from 5.16 to 6.97. Available Calcium in soil was high, ranged 4.30 to 16.00 cmol (p^+) kg^{-1}, Water soluble calcium ranged from 1.50 to 4.90 cmol (p^+) kg^{-1}, Exchangeable calcium ranged from 2.60 to 12.70 cmol (p^+) kg^{-1}, Total calcium ranged from 10.40 to 39.40 cmol (p^+) kg^{-1}. Available magnesium in soil was ranged from 2.00 to 9.80 cmol (p^+) kg^{-1}, Water soluble magnesium ranged from 0.70 to 3.70 cmol (p^+) kg^{-1}, Exchangeable magnesium ranged from 0.80 to 8.70 cmol (p^+) kg^{-1}, Total magnesium ranged from 6.20 to 27.80 cmol (p^+) kg^{-1}. Available sulphur in soil was medium to high, ranged from 9.40 to 22.90 mg kg^{-1}, Water soluble sulphur ranged from 1.05 to 6.92 mg kg^{-1}, Exchangeable sulphur ranged from 4.39 to 21.35 mg kg^{-1}, Organic sulphur was 116.30 to 356.47 mg kg^{-1}, Total sulphur ranged from 190.47 to 433.37 mg kg^{-1}.

***Keywords*:** Lowland paddy fields, Secondary nutrients, Central parts of Western Ghats, Acid soil

Introduction

Enhancing and maintaining agricultural yield is crucial for raising soil fertility. In India, fertiliser application has never kept up with the crop's nutrient requirements. Secondary and basic nutrients are in short supply as a result of intensive farming practises

Calcium (Ca), magnesium (Mg), and sulphur (S), three essential plant nutrients, are essential for the growth and development of plants. Because plants require less of them than they do of nitrogen, phosphorus, and potassium, they are referred to as "Secondary" nutrients. These nutrients are needed by plants in greater quantities than micronutrients.

The Earth's crust contains around 3.64 per cent of calcium, the fifth most prevalent element. It is found in limestone, feldspar, amphiboles, and apatite minerals. The amount of calcium in soils varies significantly depending on the type of soil; for example, sandy soils in wet places have much lower calcium levels than calcareous soils in dry and semi-arid areas. High weathering soils in the humid tropics, however, may only contain 0.1 to 0.3 per cent calcium. Magnesium makes up 1.93 per cent of the Earth's crust, just like calcium does. Depending on the region, the amount of magnesium in the soil ranges from 0.1 per cent in coarse sandy soils in moist areas to 4 per cent in fine-grained desert or soils with a high magnesium content that are semi-arid. Magnesium is released into the soil as a result of the disintegration of rocks containing the major minerals biotite, dolomite, hornblende, olivine, and Sulfur is one of the seventeen essential elements and, after nitrogen, phosphorus, and potassium, is the fourth most important nutrient for crop productivity. The Earth's crust contains sulphur in amounts ranging from 0.03 to 0.1 per cent.

The productivity of acid soil is low because of issues associated with soil acidities, such as leaching loss of bases, a high concentration of exchangeable aluminum and a low CEC. Soils with low pH contain relatively high amounts of exchangeable H^+ and Al^{+3}, considered acid soil (Haynes and Ludecke 1981). Acid soils occur in those areas where rainfall is higher, *i.e*., precipitation > evapotranspiration.

About 48-49 million hectares of the total geographical area of our country is under acid soil; out of it, nearly 25 million hectares of land have a pH of 5.5 and 23 million hectares of land fall under the pH range of 5.5-5.6 The primary cropping system in these areas is coffee-based agroforestry in sloppy regions, followed by lowland paddy. The other crops cultivated in these areas include pepper, rubber, tea, cashew, arecanut, cocoa and spices.

Liming is a fundamental management strategy to deal with acid soil problems and boost productivity and it is always suggested for the acidic soils found in the hilly zone. There hasn't been much research done in the hilly region of Karnataka on calcium, magnesium, or sulphur. Because less research has been done in the low-lying areas of hilly regions, their nutritional status will be different from that of upland places.

In light of the circumstances above, there is no systematic information available regarding soil acidity and Ca, Mg and Sulphur dynamics in low land acid soils of Karnataka's hilly zone.

Material and Methods

The study area covered in Madikeri, Virajpet and Somvarpet taluks of Kodagu district and Chikkamagaluru, Koppa, Mudigere, Narasimharajapur and Sringeri taluks of Chikkamagaluru district in Karnataka. Kodagu and Chikkamagaluru districts are situated in the South-West part of the state; Kodagu district lies between the latitudes 11˚56'00" to 12˚50'00" N and longitudes 75˚22'00" to 76˚11'00" E and Chikkamagaluru districts lies in between latitudes 12˚54'42" to 13˚53'53" N and longitudes 75˚04'46" to 76˚21'15" E. The Temperature of Kodagu district begins to increase from March till April, which is the hottest month, with the mean daily maximum temperature at 28.6˚C. The average annual rainfall of the Kodagu district is about 2729 mm. The climate of the Chikkamagaluru district is very pleasant and cool. April is generally the hottest month, with the mean daily maximum temperature at 30.7˚C. The average annual rainfall of the taluks coming under the hilly zone in the Chikkamagaluru district is 2807 mm.

The study area was undertaken to know the status of secondary nutrients under lowland paddy areas of two districts, i.e., the Kodagu and Chikkamagaluru districts. The 200 representative soil samples were collected randomly from 0 to 20 cm depth at different locations under lowland paddy areas. Collected soil samples were processed and used for further physical and chemical analysis.

Particle size distribution

The relative proportion of clay present in soil samples was determined by international pipette method by using sodium hexametaphosphate as dispersing agent (Piper, 1966), then soil texture was identified based on relative proportion of sand, silt and clay present in these soils using the textural diagram given by IUSS and USDA (Ghildhayal and Tripathi, 1987).

Soil pH

Soil pH was determined in 1:2.5 soils by Potentiometric method: water suspensionby dipping the combined electrode (glass electrode plus calomel electrode) of digital pH meter as outlined by Jackson (1973).

Electrical Conductivity (EC)

Electrical Conductivity (EC) in soil samples were measured in 1:2 soil : water extract using Conductivity Bridge as outlined by Jackson (1973). The results were expressed as dS m^{-1} at 25 ^{0}C.

Organic carbon

Organic carbon content in the soil samples was determined by treating a known weight of finely powered soil (0.50 g) with known excess quantity of chromic acid (sulphuric acid and potassium dichromate) to oxidize the organic carbon present in the soil to carbon dioxide. After oxidation, the untreated potassium dichromate left in the contents was back titrated against standard ferrous ammonium sulphate by using diphenylamine indicator (Walkely and Black, 1934).

Different forms of calcium and magnesium in soil

Water soluble calcium and magnesium

Water soluble forms of calcium and magnesium were determined by treating the soil with distilled water for 5 minutes and estimation of the elements in the extract by versanate titration method (Page *et al*. 1982).

Total calcium and magnesium

One gram soil was taken in polypropylene bottle and 2 ml of aquaregia ($HNO_3 + HCl$) was added to this for decomposition of the carbonates present and it disperses the sample. Then 20 mL of HF was added to the bottle and the bottle was capped immediately. The contents of the bottle were shaken for 8 to 10 hrs. After this, about 50 mL of saturated H_3BO_3 was added. Further, it was shaken for 2 hours and kept for a week for dissolution of the sample completely. Finally, the volume of the digested sample was made up to 100 mL as described by Sridhar and Jackson (1994) and the contents of calcium and magnesium were determined by versenate titration method (Jackson, 1973).

Exchangeable calcium and magnesium

Exchangeable calcium and magnesium was obtained by taking the difference between available calcium and magnesium and water soluble calcium and magnesium (Exchangeable calcium and magnesium = Available calcium and magnesium-Water soluble calcium and magnesium).

Different forms of sulphur in soil

Water soluble sulphur

Water soluble form of sulphur in the soil were determined by adding distilled water to the sample and shaking for 15 minutes. After centrifuging the suspension, Sulphur was estimated by turbidimetric method using Spectrophotometer method (Williams & Steinbergs,1959).

Total sulphur

Two grams of soil was digested with 3 mL of 69 per cent HNO_3 on a water bath for one hour followed by 3 mL of 60 per cent $HClO_4$ and 7 mL of H_3PO4 on a sand bath till white fumes appeared. The heating was continued for another 30 minutes and then the contents were allowed to cool. The samples were again digested with 37 per cent HCl till white fumes appeared. The digested material was quantitatively transferred with 1N HCl and volume made up to 100 mL. Sulphur was estimated turbidimetrically. (Tabatabai 1982).

Exchangeable sulphur

Exchangeable sulphur was obtained by taking the difference between available sulphur and water soluble sulphur (Exchangeable sulphur = Available sulphur - Water soluble sulphur).

Organic sulphur

The soil was oxidized by treating with hydrogen peroxide and keeping it overnight. It was leached with 1 per cent NaCl and then made it chloride free. Then it was filtered and S in the filtrate was estimated turbidimetrically (Evans and Rost, 1945).

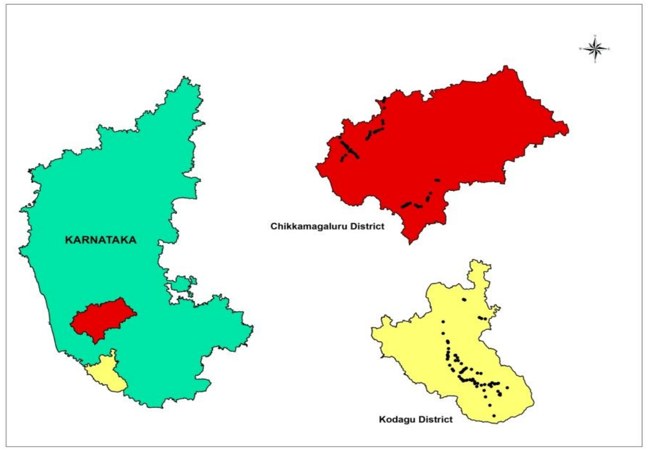

Fig. 1: Location map of the study area

Results and Discussion

The results presented in the Table 2 revealed that the pH of low land paddy cover in the Kodagu and Chikkamagaluru districts was in the range of 5.16 to 6.97. It shows that soils were moderately acidic to neutral in soil reaction. About 62.00 per cent of samples were moderately acidic this might be due to the predominance of igneous and metamorphic rock parent material and heavy rainfall which may leach out basic cations from the soil solum and the similar results have been reported by Asha (2016).

About 38.00 per cent of samples of were found to be neutral in soil reaction this might be due to an increase in pH of the soil upon submergence to a stable value (Meetei *et al*., 2020).

Electrical conductivity (EC) of soils in low land paddy cover of hilly zone, Kodagu and Chikkamagaluru districts, EC values were normal in soil ranged from 0.02 to 0.59 (dSm^{-1}). Shows that soil was non saline in nature. The normal electrical conductivity might be attributed to leaching of salts due to high rainfall. Devi *et al*. (2015).

Organic carbon status of soils under low land paddy cover in hilly zone of Karnataka, Kodagu and Chikkamagaluru districts Table 2 recorded in the range of 4.12 to 22.90 ($g\ kg^{-1}$). shows that soil was low to high in organic carbon status. Only 1.00 per cent of samples were having low organic carbon status, about 10.00 per cent of samples were having medium organic carbon status and remaining 89.00 per cent of samples were having high organic carbon status. The low biotic activity in these soils caused by the acidic pH which increases the accumulation of organic matter in soil may be responsible for their medium to high organic carbon status, which led to the buildup of organic matter in these soils. Same results were reported by Karthika *et al.* (2022), Marathe *et al.* (2003)

Cation exchange capacity of soil under low land paddy cover in hilly zone of Karnataka, Kodagu and Chikkamagaluru districts obtained in the range of 10.60 to 26.90 (cmol (p^+) kg^{-1}). It shows that cation exchange capacity of soil was medium to high. After the few days' submergence the pH of soil get increases and soluble exchangeable cations will increases in the soil leads to increase in soil CEC of soil. Fine texture of soil have greater CEC compare to the coarse texture soil Mulugeta *et al.* (2019).

As per textural diagram given by USDA (Black 1965), Table 2 shows that distribution of sand, silt and clay content under low land paddy cover in both Kodagu and Chikkamagaluru districts. The texture of study area was sandy clay loam to clay this might be attributed to soils derived from acidic granite and gneiss parent rock and due to heavy rainfall transportation and deposition of finer particles from upland to low land through runoff, leaching process and illuviation in subsurface horizons. (Pulakeshi *et al.*, 2014), (Geetha and Naidu 2013).

Table 1: Different forms of secondary nutrients status of soils under low land paddy cover in hilly zone of Karnataka. (Kodagu and Chikkamagaluru districts)

Parameters	Range	Mean	SD
pH	5.16 to 6.97	5.90	0.42
EC (dS m^{-1})	0.02 to 0.59	0.28	0.11
OC (g kg^{-1})	4.12 to 22.90	10.20	2.60
CEC (cmol (p^+) kg^{-1})	10.60 to 26.90	20.15	3.53
Sand (%)	69.25 to 22.65	45.35	9.47
Silt (%)	62.72 to 3.84	28.78	10.94
Clay (%)	46.90 to 7.20	25.83	8.98
Water soluble calcium (cmol (p^+) kg^{-1})	1.50 to 4.90	2.52	0.57
Exchangeable calcium (cmol (p^+) kg^{-1})	2.60 to 12.70	7.54	2.30
Total calcium (cmol (p^+) kg^{-1})	10.40 to 39.40	25.27	5.76
Water soluble magnesium (cmol (p^+) kg^{-1})	0.70 to 3.70	1.43	0.46
Exchangeable magneisum (cmol (p^+) kg^{-1})	0.80 to 8.70	4.95	1.86
Total magnesium (cmol (p^+) kg^{-1})	6.20 to 27.80	14.82	4.63
Water soluble sulphur (mg kg^{-1})	1.05 to 6.92	3.16	1.31
Exchangeable sulphur (mg kg^{-1})	4.39 to 21.35	13.04	3.51
Organic sulphur (mg kg^{-1})	116.30 to 356.47	213.50	43.00
Total sulphur (mg kg^{-1})	190.47 to 433.37	290.11	42.04

The Total calcium in low land paddy soil of hilly zone of Karnataka covering Kodagu and Chikkamagaluru districts (Table 1) obtained in the range of 10.40 to 39.40 cmol (p^+) kg^{-1}. It shows that Total calcium content in soil was higher this might be due to deposition and accumulation of free calcium carbonate in low land paddy area from the coffee based agro forestry. The water soluble calcium in low land paddy soil of hilly zone of Karnataka covering Kodagu and Chikkamagaluru districts (Table1) obtained in the range of 1.50 to 4.90 cmol (p^+) kg^{-1}. But water soluble calcium content in soil was lower than exchangeable calcium which was ranged from 2.60 to 12.70 cmol (p^+) kg^{-1} (Table 1). This might be due to the amount of adsorbed and exchangeable Ca^{2+} ions in the soil is accounted for by exchangeable calcium. In most soil, its content is typically substantially higher than that of other cations. As a result, its composition is largely determined by the kind, quantity, and humus content of the soil clay minerals and calcium was a dominant cation over the magnesium. Similar results were reported by Bhindhu *et al.* (2021).

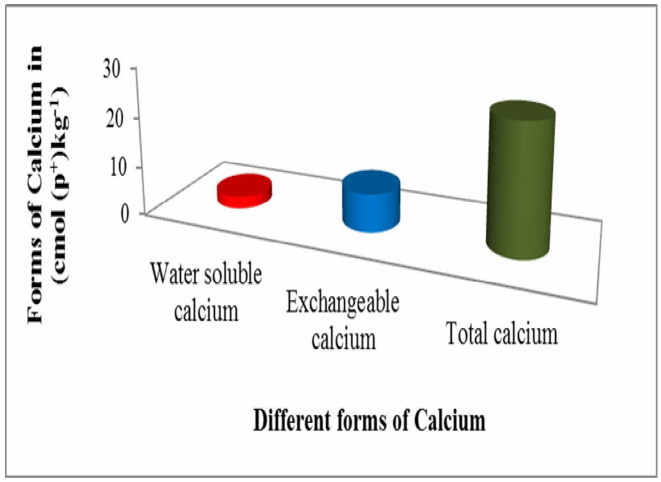

Fig. 1: Distribution of different forms of Calcium

The Total magnesium content in low land paddy soil of hilly zone of Karnataka covering Kodagu and Chikkamagaluru districts (Table 1) obtained in the range of 6.20 to 27.80 cmol (p^+) kg^{-1}. It shows that total magnesium content in soil was higher this due to the deposition and accumulation and deposition of liming material i.e., dolomite from the coffee based agroforestry and total magnesium content was relatively lower that of total calcium this is due to higher mobility of magnesium in soil and also due to higher rate of solubilisation of magnesium in soil. Water soluble magnesium in Kodagu and Chikkamagaluru district was ranged 0.70 to 3.70 cmol (p^+) kg^{-1} in Chikkamagaluru district (Table 1). But the water soluble magnesium content is soil was lower compared to the Exchangeable magnesium in soils of Kodagu and Chikkamagaluru district which was ranged from 0.80 to 8.70 cmol (p^+) kg^{-1} (Table 1). Regarding their distribution in soils, water soluble magnesium, exchangeable magnesium, and total magnesium showed a similar pattern to three types of calcium.

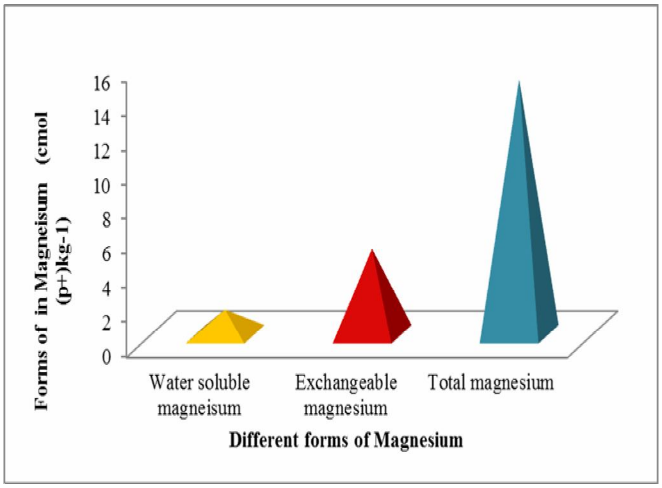

Fig. 2: Distribution of different forms of Magnesium

The Total sulphur content of soils varied widely in soils of Kodagu and Chikkamagaluru districts which was ranged from 190.47 to 433.37 mg kg^{-1} (Table 1). It shows that total sulphur content in soil was higher this might be attributed to presence of high organic matter content in soil and organic sulphur in soil was ranged from 116.30 to 356.47 mg kg^{-1} (Table 1). It shows that organic sulphur content was higher higher in soil this might be due to organic matter condition of the soils, the proportion of organic S in the total sulphur of the surface soils ranged from 5 to 98 per cent. Same results were reported by Singh *et al*. (2021), Azmi *et al*. (2018).

Water soluble sulphur content in soil was ranged from 1.05 to 6.92 mg kg^{-1} in (Table1). It shows that the water soluble sulphur content is soil lower this might be due to leaching, sulphate has been lost from the soils, showing that it is weakly attached to exchangeable sites and is readily dissolved by distilled water. Srinivasamurthy *et al*. (2009). Exchangeable sulphur content in soil was ranged from 4.39 to to 21.35 mg kg^{-1} (Table 1). It shows the exchangeable sulphur content was higher in soil this might be due to behaviour of the soil solids with regard to sulphate sorption and the rate at which organic sulphur compounds are mineralized. Similar results have been reported by Roshini *et al*. (2021).

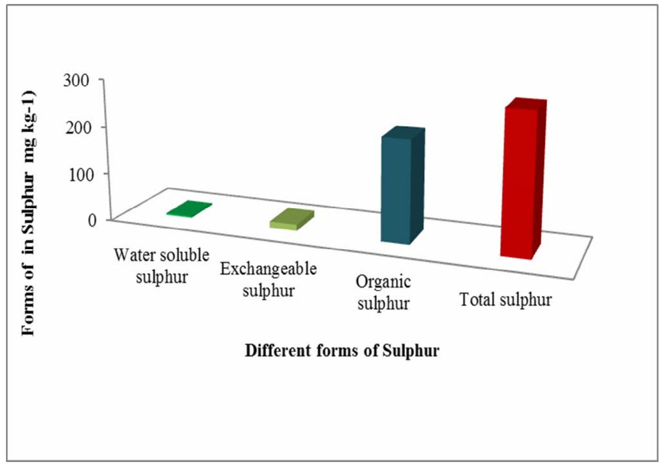

Fig. 3: Distribution of different forms of Sulphur

Table 2: Correlation between different forms of secondary nutrients with soil properties.

Parameters	pH	EC	OC	CEC	Clay
Avail - Ca	0.233**	0.167**	-0.374 NS	0.875**	0.321**
WS - Ca	-0.014 NS	-0.084 NS	-0.046 NS	0.133 NS	-0.257*
Exch - Ca	0.731**	0.135*	-0.063 NS	0.383**	0.236**
Total - Ca	0.203**	0.094**	-0.026 NS	0.388**	0.487**
Avail - Mg	0.131**	0.367*	-0.148*	0.911**	0.135**
WS - Mg	0.022 NS	-0.091 NS	-0.011 NS	0.117 NS	0.082 NS
Exch - Mg	0.548**	0.033 NS	-0.110 NS	0.487**	0.298**
Total - Mg	0.084**	0.179**	-0.059 NS	0.519**	0.354**
Avail - S	0.453**	0.384*	0.532**	0.233**	0.521**
WS - S	0.092 NS	-0.122 NS	-0.053**	0.073 NS	0.147 NS
Exch - S	0.268**	0.053 NS	0.235*	0.112*	0.219*
Organic - S	0.015**	0.042**	0.696**	0.116**	0.626**
Total - S	0.256**	0.458**	0.534**	0.123**	0.544**

Results indicated that available calcium was positive and significantly correlated with pH, EC, CEC and clay content. Available Mg was positively and significantly correlated with pH, EC, CEC and clay content of soil, it showed negative significant correlation with the OC. Available sulphur was positively significantly correlated with pH, OC, clay content soil.

Water soluble calcium was negatively non significantly correlated with pH, OC and positively significantly correlated with CEC. Water soluble magnesium was positively non significantly correlated with pH, CEC. Water soluble sulphur was positively non significantly correlated with pH, CEC, positive significant correlation with OC. Behera *et al.* 2023.

Exchangeable calcium and magnesium showed a positive significant correlation with pH, CEC. Exchangeable sulphur was positively significantly correlated with OC, CEC.

Total calcium was negatively non significantly correlated with OC, it showed a positive significant correlation with CEC, pH. Total magnesium was positive and significantly correlated with CEC, pH. Total sulphur was positively significantly correlated with OC, CEC. Organic sulphur was positively significantly correlated with pH, OC, CEC.

Conclusion

Soils coming under low land paddy cover of hilly zone of Kodagu and Chikkamagaluru districts moderately acidic to neutral in soil reaction with normal electrical conductivity shows that soils were non saline. Organic carbon status was medium to high. Cation exchange capacity was also medium to high in soil. Texture of soil in the study area was sandy clay loam to loam. Different forms of secondary nutrients in soil was also high. This suggests that appropriate management practices are very much essential for sustainable crop production.

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