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Sulphate Releasing Pattern of Soils under Acidic Conditions of Forest Soils of Nagaland

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Abstract
A research investigation was undertaken to study the sulphate releasing pattern of forest soils under acidic conditions covering three districts of Nagaland during 2014. The investigation results revealed that the amount of SO_4^{2-}-S released was highest in the first extraction followed gradual decrease till the seventh extraction after which no sulphate was detected from the samples by the three extractant used. The average total amount of SO_4^{2-}-S released by $CaCl_2$, KCl and KH_2PO_4 was 27.73 μg g^{-1}, 28.33 μg g^{-1} and 32.17 μg g^{-1} respectively. The amount of SO_4^{2-}-S released was highest using KH_2PO_4 compared to $CaCl_2$ and KCl extractant. KH_2PO_4 extractant has higher sulphate releasing power than $CaCl_2$ and KCl due to higher sulphate releasing power of phosphate than the chloride. The total $CaCl_2$ extractable SO_4^{2-}-S shows negative correlation with available K (-0.600*).

Keywords: Correlation, extractant, forest, sulphate

Introduction
Sulphur deficiency has become widespread over the past several decades in most of the agricultural areas of the world, becoming a limiting factor to higher yields and fertilizer efficiency. Intensification of agriculture with high yielding crop varieties and multiple cropping, coupled with use of high analysis S-free fertilizers and restricted use of organic manures, has accelerated the depletion of soil reserves. The reasons behind the deficiency of sulphate in soils are not well defined.

Adsorption/desorption are the key processes that govern the sulphur release and availability in the soils. Sulphate adsorption takes place below pH 6.5 in acid soils, Inceptisols (Dolui and Jana 1997), Alfisols and Vertisols (Patil *et al.* 1997) *etc.* Sulphate sorption by soils is reported to be influenced mostly by pH, organic carbon, nature of clay, sulphate concentration and cations and anions (Patil *et al.* 1997). Organic matter can influence sulphate adsorption through competition for adsorption sites between organic anions and sulphate.

Since S release characteristics studies are meagre, and no further work has been done in this field in Nagaland. Therefore an attempt was made to investigate the physico-chemical properties of soils and releasing pattern of extractable sulphate in soil using three different extractants, KCl, KH_2PO_4 and $CaCl_2$.

Materials and Methods
Surface soils (0-15cm) of forest land use system were collected from twelve villages of three selected districts of Nagaland namely, Rusoma, Kohima, Meriema and Kidima under Kohima district; Kangching, Tamlu town, Tamlu and Namsang under Tuensang district; and Wansoi, Maksha, Panso and Keshai under Longleng district. Soil were crushed and passed through 2 mm sieve.

The soil pH was determined in 1:2 soil: water suspension using glass electrode pH meter (Richards, 1954). Electrical conductivity was determined in 1:2 soil: water suspension using Conductivity Bridge and expressed as dSm^{-1} (Richards, 1954). The sand, silt and clay fractions of soil samples were determined by the International Pipette method using 1N sodium hydroxide (NaOH) as a dispersing agent (Piper, 1966). The organic carbon of the soil sample was determined by rapid titration method advocated by Walkely and Black method and expressed in percentage as described by Jackson (1973). The cation exchange capacity (CEC) of the soil was determined by leaching the soil with neutral normal ammonium acetate solution (1 N NH_4OAc) at pH 7.0 (Chapman, 1965).

The available nitrogen was determined by using alkaline potassium permanganate method (Subbiah and Asija, 1956). The available phosphorous was determined by Bray and Kurtz No-1 method (Bray and Kurtz, 1945) as described by Baruah and Barthakur (1997).

The available potassium was determined flame photometrically after extracting the soil with neutral normal Ammonium acetate (NH_4OAc) at pH 7.0 (Jackson, 1973). The available sulphur was extracted from the soil using 0.15% $CaCl_2$ as extractants in a ratio of 1:5 soil: extractant (Chesnin and Yien, 1950). The sulphur in the extract was determined by Turbidimetric method and the intensity of the turbidity formed was measured using UV spectrophotometer at a wavelength of 440 nm. The soluble and adsorbed sulphate S from the soil were extracted by 0.01M $Ca(H_2PO_4)_2$ and determined turbidimetrically by using spectrophotometer at wavelength 420µm (Chesnin and Yien, 1950). Exchangeable Ca and Mg were determined in 1N ammonium acetate extracts of soil by titration against EDTA (Black 1965).

Soil samples were added with solutions containing 200 μg SO_4^{2-}-S mL^{-1} in 1:2 soil: solution ratio for analysing the sulphate (SO_4^{2-}) releasing power. The contents were shaken continuously for 2 hours in a reciprocating shaker and equilibrated at with intermittent shaking for 96 hours. The soil suspensions were then filtered and the soil were air-dried and ground to pass through 2 mm sieve. The SO_4^{2-} saturated soils, thus prepared were used for analysis (Das *et al.* 2008).

KCl extractable SO_4^{2-}-S

Twenty-five ml of 0.016 M KCl was added to 2.5g SO_4^{2-} saturated soils samples and shaken continuously end-over-end for one hour and centrifuged. The supernatant was filtered using Whatman no. 42 filter paper. Concentration of SO_4^{2-}-S in the extract was determined turbidimetrically (Chesnin and Yien 1950). The same soil was extracted repeatedly for ten times following the same steps (Das *et al.* 2008).

KH_2PO_4 extractable SO_4^{2-}-S

Duplicate samples of 2.5g SO_4^{2-} saturated soils were extracted by 0.016 M KH_2PO_4 successively for ten times following the same procedure as adopted for extraction by 0.016 M KCl.

$CaCl_2$ extractable SO_4^{2-}-S

Duplicate samples of 2.5g of the SO_4^{2-} saturated soil were extracted with 0.15% $CaCl_2$. The SO_4^{2-} -S in soil extract was determined by turbidimetric method (Chesnin and Yien, 1950). The SO_4^{2-}-S in the soil were extracted successively for ten times.

Results and Discussion

The forest soils from twelve different location covering three districts, Kohima, Longleng and Tuensang of Nagaland comes under two textural class, sandy clay and sandy clay loam. The soils are strongly acidic to moderately acidic in reaction, high in soil organic carbon, medium to high in available N, deficient in available P, low to medium in available K. The CEC of the soils was found to be low.

Sulphate releasing pattern of forest soils

SO_4^{2-}-S released by 0.15 % CaCl2: The amount of SO_4^{2-}-S extracted by 0.15% $CaCl_2$ was highest in the 1st extraction with a slow decrease after the 2nd extraction till the 7th extraction after which no SO_4^{2-} was detected from the soil of uphill and foothill conditions also. Similar finding has been reported by Das *et al.* (2008). The average total SO_4^{2-}-S extracted by 0.15% $CaCl_2$ was 27.73 μg g^{-1}. On an average, the percentage of SO_4^{2-}-S retention in the form of adsorbed sulphate was 86.22% (Ghosh *et al.* 2012). This may be due to the fact that soil pH plays a dominant role in the adsorption-desorption and extractability of SO_4^{2-}-S in soils (Sahrawat *et al.* 2009) and sulphate sorption decreased with increasing pH (Guadalix *et al.* 1991). The total $CaCl_2$ SO_4^{2-}-S showed negative correlation with available K (r= -0.600*) which might be due to formation of potassium sulphate.

SO_4^{2-}-S released by 0.016 M KCl: The amount of SO_4^{2-}-S extracted by 0.016 M KCl was highest in the 1st extraction with a slow decrease after the 2nd extraction. It slowly decreases till the 7th extraction after which no SO_4^{2-} was detected, similar findings has been reported by Das *et al.* (2008). Since the removal of soluble SO_4^{2-} causes the release of adsorbed SO_4^{2-} to the soil solution to maintain the equilibrium, SO_4^{2-}-S released in the 2nd to 7th extraction may consists of adsorbed SO_4^{2-} released to the soil solution. The average percentage of sulphate released was (14.17%). This may be due to the fact that SO_4 adsorption increased with decreasing pH (Xue *et al.* 1991). The average percentage of sulphate retention was 85.81% which can be attributed to the fact that the retention of sulfate was dependent mainly on FeO and AlO (Alves *et al.* 2004).

SO_4^{2-}-S released by 0.016 M KH_2PO_4: The amount of SO_4^{2-}-S extracted by 0.016 M KH_2PO_4 was highest in the 1st extraction with a slow decrease after the 2nd extraction. It slowly decreases till the 7th extraction thereafter no SO_4^{2-} was detected, similar findings has been reported by Das *et al.* (2008). Since the removal of soluble SO_4^{2-} causes the release of adsorbed SO_4^{2-} to the soil solution to maintain the equilibrium, SO_4^{2-}-S released in the 2nd to 7th extraction may consists of adsorbed SO_4^{2-} released to the soil solution. The average percentage of sulphate released was 16.06% while sulphate adsorbed was 84.01%.

Comparison between SO_4^{2-}-S released by 0.15 % $CaCl_2$, 0.016 M KCl and 0.016 M KH_2PO_4

Total KH_2PO_4-SO_4^{2-} was higher than total $CaCl_2$-SO_4^{2-} and KCl-SO_4^{2-} since both soluble and adsorbed SO_4^{2-} were released in the case of the former, whereas only soluble SO_4^{2-} was released in case of the latter. Schnabel *et al.* (1991) also reported that addition of phosphate decreased the sulphate rentention. The SO_4^{2-}-S released was highest in the 1st extraction followed by slow decrease after the 2nd extraction by all the three extractants (Das *et al.* 2008). The higher amount of total SO_4^{2-} released by KH_2PO_4 can be attributed to the higher releasing power of phosphate than chloride.KH_2PO_4 was found to be a better extractant than $CaCl_2$ and KCl under acidic range.

Conclusion

The investigation results revealed that pH plays a dominant role in the sulphate adsorption and sulphate are mostly present in adsorbed form in forest soils of Nagaland which are in acidic condition. KH_2PO_4 extractant was found to be a better extractant for SO_4^{2-} sulphur than $CaCl_2$ and KCl under acidic range. Sulphate releasing pattern studies are scarce in Nagaland conditions, which necessitate further investigations to better understand the releasing pattern and factors affecting its availability to plants and to give confirmation to the present findings.

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