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Availability of Sulphur in *Alfisol* soil from the different land use systems on application of silicon and organic manure

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Abstract

The laboratory investigation was undertaken during 2016-17 in BCKV, Nadia West-Bengal to study the effect of Silica and organic manure on sulphur availability in *Alfisols* soil collected from the Jhargram W.B. Five land use systems [Fallow, Forest, Upland growing vegetables, medium land growing rice-vegetables and lowland growing rice-rice,] were selected for the study. Soil samples were processed and kept in non-corrosive plastic containers and incubated for 120 days. Release of available sulphur in these soils was evaluated under application of silicon (0 and 50 kg ha^{-1}) and organic manure (0 and 7.5 t ha^{-1}). Fertilizer S was applied uniformly to all the pots @ 30 kg ha^{-1} at the beginning of the study. The experiment was laid out in completely Randomized Design (CRD) with three replication and twenty treatments involving 60 pots in total. Treatments combinations for each of the Land use systems viz. T_0 (control), T_1-FYM 7.5 tha^{-1}, T_2-Si 50 kg ha^{-1} and T_3-Si 50 kg ha^{-1} + FYM 7.5 tha^{-1}. The result showed that the sharply increase the available sulphur content in the soils was observed during the first 30 days, it declined in the next 30 days (60 DAI) which increased again during the next 30 days (90 DAI) and then again decreased (120 DAI). The interaction effect among the land use system (LUS), silicon and FYM application throughout the period of incubation for 120 days. The lowest values of available sulphur content of the soil was recorded without application of either silicon or FYM in lowland soil and the values were 9.03, 8.60, 11.39, and 9.93 on the 30th, 60th, 90th and 120th DAI, respectively. It was interesting to note that excepting on the 30th DAI, during the rest of the incubation period, the highest available sulphur content of soils was recorded with application of silicon without FYM in upland soil. The corresponding values of available sulphur were 35.25, 32.42, 48.63 and 33.00 on the 30th, 60th, 90th and 120th DAI. Available sulphur content of the soil pooled over 120 days of incubation ranged from 9.23 in lowland without application of silicon and FYM to 31.55 in upland soil with application of silicon and without FYM.

Keywords: land use system, sulphur, silica and effect

Introduction

The success in soil management to maintain soil quality depends on an understanding of how soils respond to agricultural practices over time. For this reason, recent interest in evaluating the quality of our soil resources has been stimulated by increasing awareness that soil is a critically important component of the earth's biosphere, functioning not only in the production of food and fiber but also in the maintenance of local, regional and worldwide environmental quality (Doran and Parkin, 1994) [4]. The rate of soil quality degradation depends on land use systems, soil types, topography, and climatic conditions. Among these factors, inappropriate land use aggravates the degradation of soil physicochemical and biological properties (Singh *et al*., 1995; Saikhe *et al*., 1998a; He *et al*., 1999) [14, 13, 8]. In line with these, Maddonni *et al.* (1999) reported that land use affects basic processes such as erosion, soil structure and aggregate stability, nutrient cycling, leaching, carbon sequestration, and other similar physical and biochemical processes.

Sulphur recognized as fourth important plant nutrient after N, P and K and is gaining considerable importance in quality crop production in context of Indian agriculture, particularly when there is more and more use of non-S containing fertilizers as well as less use of organic manures. In India, nearly, 57 m ha of arable land suffers from various degree of sulphur deficiency (Tripathy, 2003). The availability of sulphur is largely dependent on its fractions. Sulphur exists in the soil as free and adsorbed sulphate and in diverse organic and inorganic compounds. In humid region, sulphur is largely present in organic form, while in arid soils, the sulphate salts of calcium, magnesium, sodium and even potash predominant (Kanwar, 1976) [9].

The terrestrial Si cycle has received increased attention in the past two decades (Struyf and Conley, 2012) [16]. Lithology controls the primary source of Si through the weathering of silicate minerals of the bedrock (Drever, 1994). This process provides Si to the soil solution in the form of mono-silicic acid (H_4SiO_4,) also referred to as dissolved silicon (DSi). This Dsi is taken up by plants and is resupplied to the soil in the form of relatively soluble biogenic silicates (BSi) upon plant die-off, usually in the form of phytoliths (plant silica bodies) (Piperno, 2006). Biogenic silica is one of the most soluble forms of Si in soils (Van Cappellen, 2003). Dissolution of soil BSi increases immediately after deforestation (Conley *et al*., 2008) [], increasing DSi fluxes out of the soil and the ecosystem. However, in the long term, Struyf *et al*. (2010) showed a decrease in overall DSi fluxes from cultivated land. The conversion from forest to croplands decreases the soil biogenic Si stock, the most important contributor to the easily available Si pool for plants. The decrease in soil biogenic Si stock has been related to two important factors. The first factor is the harvesting of crops (Guntzer *et al*., 2012; Meunier *et al*., 1999; Vandevenne *et al*., 2012) [21] The second factor affecting BSi losses is erosion. In cultivated catchments, preferential BSi mobilization is associated with erosion during strong rainfall events (Clymans biogenic Si can represent up *et al*., 2015) [1]. During such events, biogenic Si can represent up to 40% of the easily soluble Si inputs to rivers (Smis *et al*., 2011) [15]. Clymans *et al*. (2015) [1] found that Si mobilization did not depend on tillage technique or crop type but solely on soil loss rate due to erosion.

Application of organic manure (farmyard manure FYM) improved soil physical properties through increased soil aggregation, improved aggregate stability, and decrease in the volume of micro-pores while increasing macro-pores, increased saturated hydraulic conductivity and water infiltration rate, and improved soil water-holding capacity at both field capacity and wilting point. Several studies have reported that FYM plus inorganic fertilizer applications in irrigated systems resulted in reduced bulk density, higher soil organic carbon (SOC) and hydraulic conductivity and improved soil structure and microbial communities. Inorganic fertilizers are usually applied to soil for increasing or maintaining crop yields to meet the increasing demand of food (Haynes *et al*., 1998). Application of inorganic fertilizers results in higher soil organic matter (SOM) accumulation and biological activity due to increased plant biomass production and organic matter returns to soil in the form of decaying roots, litter and crop residues (Brar *et al*., 2015) [1].

Material and Methods

The Jhargram district of West-Bengal has a geographical area of 3037.64 km^2 and lies between 22.45° N latitude and 86.98° E longitude. The district is come under extremely humid and tropical hilly zone, with altitude ranging from 65 to 300 m above mean sea level (MSL). The monthly mean temperature ranges from 4 to 46°C with mean annual rainfall of 1400 mm. The Experiment was performed at the laboratory of the department of Agricultural Chemistry and Soil Science, faculty of Agriculture BCKV, Nadia West-Bengal for a period of 120 days at room temperature (25 ^{0}C). These soil samples were collected from different land use systems viz., Fallow, Forest, Upland growing vegetables, medium land growing rice-vegetables and lowland growing rice-rice, from Jhargram. Soil samples were processed and kept in non-corrosive plastic containers of 500 ml capacity and incubated for 120 days. Release of available sulphur in these soils was evaluated under application of silicon (0 and 50 kg ha^{-1}) through calcium silicate and organic manure (0 and 7.5 t ha^{-1}) through farm yard manure (FYM). Fertilizer S was applied uniformly to all the pots @ 30 kg ha^{-1} at the beginning of the study. The experiment was laid out in completely Randomized Design (CRD) with three replication and twenty treatments involving 60 pots in total. Treatments combinations for each of the Land use systems viz. T_0 (control), T_1-FYM 7.5 tha^{-1}, T_2-Si 50 kg ha^{-1} and T_3-Si 50 kg ha^{-1} + FYM 7.5 tha^{-1}.Pots were irrigated with water as and when required. The initial properties of soil are given in the Table-1. Available S content of the soils were extracted with a suitable extractant and analyzed at 30 days interval, i.e. 0, 30, 60, 90 and 120 days of incubation. Available sulphur was analyzed by the 0.15 % $CaCl_2$ (Williams and Steinberg's, 1959).

Table 1: The initial characteristics of soils under different land use systems

LUS	pH	EC (dSm^{-1})	OC (%)	CEC (m eq)	Av N (kgha^{-1})	Av P (kgha^{-1})	Av K (kgha^{-1})	Av S (mgkg^{-1})
LL	5.46	0.07	0.38	8.67	234.00	10.54	110.00	7.22
ML	5.77	0.08	0.36	7.94	251.00	13.67	115.00	9.01
UL	5.84	0.07	0.35	8.29	265.00	29.79	116.00	9.83
Forest	5.29	0.06	0.48	15.78	427.00	14.32	121.00	12.32
Fallow	5.87	0.09	0.29	7.11	211.00	16.13	119.00	9.09

*LL = Low land, ML = Medium land, UL = upper land, EC = electrical conductivity, CEC = Cation exchange capacity and Av = available

Result and Discussion

1. Changes in the available sulphur content of soil (mg kg^1)

Changes in the available sulphur content of soils collected from different land use systems have been presented in the (Table-2). Appraisal of the presented data revealed irregular pattern in the available sulphur content (mg.kg^{-1}) of the soils during incubation period from 0 to 120 days after incubation (DAI). While a sharp increase in the available sulphur content in the soils was observed during the first 30 days, it declined in the next 30 days (60 DAI) which increased again during the next 30 days (90 DAI) and then again decreased (120 DAI). The highest available sulphur content was observed on the 90th day of incubation. Irrespective of land use, the percent change in mean available sulphur content during the first 30 days witnessed a whopping 111.10 % increase over the initial value. The rate of increase during the remaining period, with respect to initial value followed the order: 30DAI (111.10 %) > 60 DAI (82.51 %) > 90 DAI (179.67 %) >120 DAI (92.23%). Though forest soil had the initial highest available sulphur content, at later stages of incubation upland soil furnished the highest values of available sulphur. Although in individual soils collected from different land use systems showed inconsistency in pattern, the available sulphur content registered an increase on the 30th day of incubation followed by a decrease on the 60th day, an increase on the 90th day and again a decrease on the 120th day. The mean value of available sulphur content pooled over 120 days of incubation in different land use system varied from13.79 in lowland to 22.41 in upland. The available sulphur content under different land use system followed the order: UL (22.41) > Forest (20.59) > Fallow (20.38) > ML (14.50) > LL (13.79). Similar findings were also reported by David *et al.* (1982) in horizons of North American forest soils and by Hari Ram *et al*. (1993) [7] for Indian soils. The adsorbed S content decreased with depth, except under sub-tropical forest, upland agriculture and ginger-based cropping land uses, where surface and sub-surface adsorbed S content were almost similar. There was also reduction in available S content with depth except in sub-tropical forest where availability was higher in the sub surface layer.

Table 2: Changes in the available Sulphur content of soil (mg.kg^{-1}) collected from different land use systems during incubation over a period of 120 days

LUS	Incubation Period (Days)					Pooled Mean
	0	30	60	90	120	
Fallow	9.09	23.75	18.88	30.55	19.66	20.38
Forest	12.32	22.71	20.17	28.42	19.36	20.59
LL	7.22	14.24	12.58	21.47	13.42	13.79
ML	9.01	15.58	13.52	19.13	15.24	14.50
UL	9.83	23.93	21.50	33.20	23.58	22.41
Mean	9.49	20.04	17.33	26.55	18.25	18.33
SEm(±)	0.65	2.78	3.91	5.03	2.67	
CD(P=0.05)	1.87	7.95	11.18	14.39	7.63	

2. Effect of silicon on changes in the available Sulphur content of soil (mg.kg^{-1})

The Careful appraisal of the presented data (Table-3) revealed significant increase ($P < 0.05$) in the available sulphur content (mg.kg^{-1}) of the soils throughout the period of incubation under the influence of application of silicon. The rate of increase (%) in the available sulphur content of the soil due to application of silicon compared to control without application of silicon during different periods of incubation revealed a gradually increasing trend. While an increase to the tune of 28.8% in silicon treated soils compared to silicon untreated soil was observed on 30 DAI, the rate of increase during the rest of the incubation period were: 31.15% on 60 DAI; 32.28% on 90 DAI; 30.14% on 120 DAI. Irrespective of land use system, the available sulphur content of the soils pooled over different days of incubation under the influence of silicon application revealed 27.10% increase compared to control without application of silicon. This could be due to increased root activity and enhanced the soil nutrient availability. This is in accordance with the reports of Wani *et al.* (2000).

3. Effect of FYM on changes in the available Sulphur content of soil (mg.kg^{-1})

Irrespective of land use system, application of FYM effectuated increase in the available sulphur content (mg.kg^{-1}) of the soil (Table-4) throughout the period of incubation over a period of 120 days.The rate of increase (%) in the available sulphur content of the soil due to application of FYM compared to control without application of FYM during different periods of incubation revealed a trend of increase. While an increase to the tune of 16.70% in FYM treated soils compared to FYM untreated soil was observed on 30 DAI, the rate of increase during the rest of the incubation period were: 16.70% on 60 DAI; 14.88% on 90 DAI; and 13.33% on 120 DAI. Irrespective of land use system, the available sulphur content of the soils pooled over different days of incubation under the influence of FYM application revealed 12.83% increase compared to control without application of FYM.Same result was reported by Saiborne (2102**)** that the available S was higher might be due to addition of FYM by farmers and also due to soils getting pulverized during crop planting and intercultural operations. A greater degree of pulverization exposes a higher surface area resulting in higher adsorbed S and available S in the surface soils. This trend indicates a higher rate of mineralization under the particular land use due to better aeration and pulverization under the raised bed method of planting.

Table 3: Effect of silicon on changes in the available Sulphur content of soil (mg.kg^{-1}) during incubation for a period of 120 days

Silicon	Incubation Period (Days)					Pooled Mean
	0	30	60	90	120	
Si0	9.49	17.52	14.99	22.86	15.86	16.15
Si_1	9.49	22.57	19.66	30.24	20.64	20.52
Mean	9.49	20.04	17.33	26.55	18.25	18.33
SEm(±)	0.41	1.76	2.47	3.18	1.69	
CD(P=0.05)	1.18	5.02	7.07	9.10	4.83	

Table 4: Effect of FYM on changes in the available Sulphur content of soil (mg. kg^{-1}) during incubation for a period of 120 days

FYM	Incubation Period (Days)					
	0	30	60	90	120	Pooled
F0	9.49	18.50	16.13	24.90	17.11	17.23
F_1	9.49	21.59	18.53	28.20	19.39	19.44
Mean	9.49	20.04	17.33	26.55	18.25	18.33
SEm(±)	0.41	1.76	2.47	3.18	1.69	
CD(P=0.05)	1.18	5.02	7.07	9.10	4.83	

4. Interaction effect on the land use system (LUS), silicon and FYM on changes in the available Sulphur content of soil (mg.kg^{-1})

Appraisal of data presented in Table-5 revealed significant influence of interaction among the land use system, silicon and FYM application throughout the period of incubation for 120 days. Throughout the 120 days of incubation, the lowest values of available sulphur content of the soil was recorded without application of either silicon or FYM in lowland soil and the values were 9.03, 8.60, 11.39, and 9.93 on the 30th, 60th, 90th and 120th DAI, respectively. It was interesting to note that excepting on the 30th DAI, during the rest of the incubation period, the highest available sulphur content of soils was recorded with application of silicon without FYM in upland soil. The corresponding values of available sulphur were 35.25, 32.42, 48.63 and 33.00 on the 30th, 60th, 90th and 120th DAI. Available sulphur content of the soil pooled over 120 days of incubation ranged from 9.23 in lowland without application of silicon and FYM to 31.55 in upland soil with application of silicon and without FYM. The increase in available S content of different soils due to application of FYM was obviously due to release of sulphur on mineralization in course of time. Application of silicon to soil could have replaced more S from the exchange sites and thereby effectuated increase in the available S content of the experimental soils. From the presented data silicon seemed to have exerted dominating effect on increasing availability of sulphur in different soils used in this work by effectuating desorption of sulphur from the surfaces of iron and Aluminium oxides present in these lateritic soils.In this study, an application of Si fertilizer caused a higher Si uptake. The deficiency or sufficiency of Si in soil is primarily determined by the rate of its replenishment in soil solution and its uptake during plant growth. Diffusion and leaching are responsible for affecting dissolution products of silicate minerals produced during the weathering process in the soil solution (Tubana *et al*, 2016) [19].

Conclusion

Among the different land use studied show that the sharply increase the available sulphur content in the soils. It was observed during first 30 days, it declined in the next 30 days

(60 DAI) which increased again during the next 30 days (90 DAI) and then again decreased (120 DAI). The available sulphur content under different land use system followed the order: UL (22.41) > Forest (20.59) > Fallow (20.38) > ML (14.50) > LL (13.79). The sole effect of Si and FYM on the extent availability sulphur that the sulphur availability increased 28.8 % and 12.83 % with the effect of silica and FYM. The interaction effect among the land use system (LUS), silicon and FYM application throughout the period of incubation for 120 days. The lowest values of available sulphur content of the soil was recorded in the control with lowland soil and the values were 9.03, 8.60, 11.39, and 9.93 on the 30th, 60th, 90th and 120th DAI, respectively. It was interesting to note that excepting on the 30th DAI, during the rest of the incubation period, the highest available sulphur content of soils was recorded with application of silicon without FYM in upland soil. The corresponding values of available sulphur were 35.25, 32.42, 48.63 and 33.00 on the 30th, 60th, 90th and 120th DAI. Available sulphur content of the soil pooled over 120 days of incubation ranged from 9.23 in lowland without application of silicon and FYM to 31.55 in upland soil with application of silicon and without FYM.

Table 5: Effect of interaction among land use system, silicon and FYM on changes in the available Sulphur content of soil (mg.kg^{-1}) during incubation for a period of 120 days

LUS x Si x FYM	Incubation Period (Days)					Pooled mean
	0	30	60	90	120	
LLSi$_0$F$_0$	7.22	9.03	8.60	11.39	9.93	9.23
LLSi$_0$F$_1$	7.22	14.21	12.63	18.46	11.95	12.89
LLSi1F0	7.22	20.37	17.64	29.73	16.93	18.38
LLSi1F1	7.22	13.37	11.45	26.29	14.88	14.64
MLSi0F0	9.01	10.77	10.14	13.42	10.89	10.85
MLSi0F1	9.01	16.25	13.08	18.42	15.30	14.41
MLSi1F0	9.01	20.62	18.53	27.19	18.73	18.82
MLSi1F1	9.01	14.66	12.35	17.49	16.04	13.91
ULSi0F0	9.83	13.91	11.96	22.96	14.47	14.62
ULSi0F1	9.83	25.43	21.71	31.94	22.71	22.32
ULSi1F0	9.83	33.87	32.42	48.63	33.00	31.55
ULSi1F1	9.83	22.51	19.90	29.26	24.14	21.13
ForSi0F0	12.32	17.36	15.40	21.43	14.98	16.30
ForSi0F1	12.32	29.47	27.91	39.64	24.57	26.78
ForSi1F0	12.32	24.10	19.99	27.69	20.38	20.90
ForSi1F1	12.32	19.91	17.36	24.91	17.50	18.40
FallSi0F0	9.09	13.97	10.48	20.25	13.66	13.49
FallSi0F1	9.09	24.79	18.03	30.70	20.15	20.55
FallSi1F0	9.09	20.99	16.11	26.34	18.13	18.13
FallSi1F1	9.09	35.25	30.89	44.89	26.68	29.36
Mean	9.49	20.04	17.33	26.55	18.25	18.33
SEm(±)	1.31	5.56	7.82	10.07	5.34	
CD(P=0.05)	3.73	15.89	22.35	28.78	15.26	

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