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Studies on long term effect of INM approach on forms of sulphur under rice on a Vertisol

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Abstract

Effect of INM approach on Sulphur fractions in rice grown on a Vertisol was studied under long-term fertilizer experiment during kharif 2019 at research farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The experiment comprised of different levels or doses of NPK fertilizers alone and in combination with zinc sulphate, farmyard manure (FYM), blue green algae (BGA) and green manuring (GM) was laid out in randomized block design with four replications and ten treatments viz. Control, 50% NPK, 100% NPK, 150% NPK, 100% NPK + ZnSO₄@ 10kg ha⁻¹, 100% N, 100% N + FYM @ 5t ha⁻¹, 50% NPK+BGA @ 10kg ha⁻¹ and 50% NPK + GM @ 40kg ha⁻¹. Different S fractions were estimated in surface and sub-surface soil samples before the rice transplanting (2019). Application of 150% NPK significantly increased the sulphate sulphur (36.4 kg ha⁻¹), water soluble sulphur (35.0 kg ha⁻¹), organic sulphur (86 kg ha⁻¹) and heat soluble sulphur (80 kg ha⁻¹) as compared to other treatments. A decrease in S fractions was observed with increase in the depth of soil from 0-15 to 15-30 cm. The results of surface and sub surface soil samples (0-15 cm and 15-30 cm) collected before of rice showed that zero fertilization led to decline in the levels of all the S forms, while application of sulphur containing fertilizer (SSP and ZnSO₄) and organics increased it over omission of these nutrients and control. Organic sulphur was found to be the most dominant fraction (about 90%) followed by heat soluble sulphur. Integration of inorganic fertilizers with organics proved better as compared to application of inorganic fertilizers alone. Integrated use of inorganic fertilizers in conjunction with organics increased grain and straw yields over inorganically treated plots. Highest grain and straw yields of rice were recorded in 150% NPK 6970 and 8364 (kg ha⁻¹), respectively. The yield of rice had highest correlation with sulphate sulphur (r=0.810**) followed by water soluble (r=0.793**). The values of coefficients of correlation for sulphate S, water soluble S, heat soluble S and organic S with yield of rice were 0.810**, 0.793**, 0.737** and 0.790**, respectively. All the sulphur fractions positively correlated with each other amongst continuous application of inorganic fertilizers and organic manure.

Keywords: Sulphate sulphur, water soluble sulphur, organic sulphur, heat soluble sulphur, long-term, organic manure

Introduction

The basic concept underlying integrated nutrient management is the maintenance and possible improvement of fertility of the soil for sustained crop productivity on long-term basis and use fertilizer nutrient as supplement to nutrients supplied by different organic sources available at the farm to meet the nutrient requirement of the crops to achieve a defined yield goal.

Sulphur has been widely recognized as the fourth major plant nutrient after N, P and K for some year. Prasad (2004) [10] reported that sulphur is emerging as the third rather than the 4th most important nutrient in India. Sulphur occurs in soils in organic and inorganic forms, with the organic S accounting for >95% of the total S in most soils from humid and semihumid regions. The proportion of organic and inorganic s in a soil sample, however, varies widely according to soil type and depth of sampling. In soil solution, sulfate S is present in very less concentration (Balik *et al.* 2009) [1] and vary continuously depending upon at any time on the balance between S plant uptake, fertilizer input, mineralization and immobilization (McLaren and Cameron 2004).

Sulphur content of leaves of cereal plants is in the range of 0.15% - 0.22% S. while rice contained 0.17% S in the grain and 0.1% S in the straw. Sulphur content of less than 0.1% in rice grain and similar or even higher S concentrations in straw than in grain have also been

reported from the lateritic soils in Kerala (John *et al.* 2006) [8]. In India, the total removal of S by growing crops is estimated to be 1.8 million tones per year and the addition of S through fertilizers is 0.8 million tones resulting in an annual deficit of 1.0 million tones.

Among, the cereals, rice and wheat are the most important food-grain crops which account for about 60% of world's human food requirement. These crops contribute more than 70% of the total cereal production in India and thus form the backbone of food security. (Lathwal *et al.*, 2010). Continuous rice-wheat cropping without adequate and balanced nutrition has resulted in a widespread problem of multiple nutrient deficiencies. About 41% cultivated area in India is deficient in Sulphur (Singh, 2009) [14]. Removal of sulphur by crops in India is about 1.26 millions tones, whereas, its replenishment through fertilizers is only about 0.77 million tones (Tiwari and Gupta, 2006) [15].

Materials and Methods

Study Site Description

A long-term field experiment in rice during Kharif 2019 was conducted at the experimental farm of Indira Gandhi Krishi Vishwavidala, Raipur, located at 22° 33' N to 21° 14' N latitude and 82° 6' E to 81° 38' E Longitude with the altitude of 293m above Mean Sea Level. Raipur region is sub-humid, temperatures remain moderate throughout the year, except from March to June. It receives an about 1200 - 1300mm (51") of rain, mostly in the monsoon season from late June to early October. The soil of the experimental field was Vertisol, which was fine Montmorillonite, Hyperthermic, Chromustert, also locally called as Kanhar and identified as Arang II series, having pH (7.5), EC (0.23 dsm⁻¹) and OC (0.60%), available N, P, K and S were 212, 21, 386 and 26 kg ha⁻¹, respectively.

Experimental details

The field experiment was conducted in randomized block design with four replicates in rice as a test crop and supplementing a part of nitrogen through different organic sources viz., FYM, green manure (*Sesbania aculeata*) and blue green algae. A set of ten treatments was repeated in the permanent laid out plots with following treatment details: T1 - Control, T2 - 50% of the recommended optimum NPK dose, T3 - 100% of the rec. optimum NPK dose, T4 - 150% of the rec. optimum NPK dose, T5 - 100% of the rec. optimum NPK + ZnSO₄ @ 10 kg ha⁻¹ in kharif crop only, T6 - 100% NP of rec. optimum N and P dose, T7 - 100% N of rec. optimum N dose, T8 - 100% NPK + FYM (5 t ha⁻¹), T9 - 50% NPK + BGA (10 kg ha⁻¹), T10 - 50% NPK + Green manure. Use of 100% NPK corresponded to the state level recommended dose of N,P and K for respective rice variety (Rajeshwari R-1), which was 120:60:40 kg/ha for rice, respectively.

In rice, half of N and entire quantity of P and K were applied as basal dose through urea, SSP and MOP, respectively. *Sesbania aculeata* (Sunhamp) was grown as an in-situ green-manure during kharif (may to July) for a period of 45-60 days and was chopped into small pieces of 5-7 cm and incorporated

into the soil by a power operated rotavator at the time of puddling before transplanting of rice. Transplanting of rice variety IGKV R-1 (Rajeshwari) during kharif 2019 was done on 15th July.

Soil sampling and analysis

The surface (0-15cm) was taken before sowing of rice (May, 2019) and were analyzed for soil pH, Organic carbon and EC using standard methods of analysis and the pooled data have been presented here. However, the surface and subsurface (15-30cm) soil samples taken before sowing of rice were analyzed for different fractions of sulphur. For determining of sulphate sulphur and available sulphur, the soil was extracted with 0.15% CaCl₂ using soil:extractant ratio 1:5. The sulphate sulphate in soil extract was determined in Spectrophotometer by developing BaCl₂ turbidity in the presence of gum acacia (Turbidity method by Williams and Steinberg's, 1969). Water soluble sulphur was determined by turbidity method (Turbidity method by Jackson, 1973). For determining of heat soluble sulphur soil samples were hydrolyzed with the addition of distilled water and then evaporated to dryness on a gently water boiling bath. Thereafter, soils were dried in hot air oven at 102 °C for 1 hour before extraction by suitable reagent. The heat soluble sulphur was determined turbidimetrically (Turbidity method by Cottenie, 1973). For Organic sulphur soils were until free of chloride with addition of distilled water and then oxidized with H₂O₂. Thereafter, determined turbidimetrically using Spectrophotometer (Turbidity method by Evans and Roost, 1945). The data generated were statistically analyzed using analysis of variance technique (Gomez and Gomez, 1984) [7].

Results and Discussion

Sulphate sulphur

Data on sulphate sulphur (Table 1) was 12.60 and 7.25 kg ha⁻¹ at 0-15 and 15-30 cm depths, respectively in control. The sulphate S was 36.45 and 25.20 kg ha⁻¹ at 0-15 and 15-30 cm depths, respectively, in 150% NPK followed by 100% NPK + ZnSO₄, 150% NPK was the best treatment followed by 100% NPK + ZnSO₄. Amongst integrated treatments (100%NPK + FYM, 50% NPK + BGA, 50% NPK + GM), 100%NPK + FYM was significantly superior to rest of the treatments regarding the sulphate S content. Data revealed that 50% sublimation of N through any of the organics proved better than 25% sublimation, the differences, however, were significant only in case of FYM. Addition of 150% NPK increased sulphate sulphur content in soil significantly over control which might be due to the addition of sulphur through SSP along with phosphorous causing synergetic effect of N and S. Randhawa and Arora (2000) also reported that synergistic interaction between P x S. Significant increases sulphate sulphur in the treatment were applied along with NPK fertilizers might be due to addition of S through SSP and also due to its addition through continuous application of organics. Similar results were noted by Kumar *et al.* (2011) and Dutta *et al.* (2013) [5].

Table 1: Sulphate sulphur and water soluble sulphur fraction under different treatments of long term fertilizer experiment

S. no.	Treatment	Sulphate sulphur (kg ha ⁻¹)		Water soluble sulphur (kg ha ⁻¹)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁	Control	12.60	7.25	16.1	9.4
T ₂	50% N:P ₂ O ₅ :K ₂ O	23.10	15.00	23.4	16.8
T ₃	100% N:P ₂ O ₅ :K ₂ O	25.90	17.50	27.0	23.8
T ₄	150% N:P ₂ O ₅ :K ₂ O	36.45	25.20	35.0	26.2
T ₅	100% N:P ₂ O ₅ :K ₂ O + Zn @ 10 kg ha ⁻¹	35.00	23.02	33.4	27.6
T ₆	100% N:P ₂ O ₅	26.47	14.82	25.6	19.3
T ₇	100% N	18.05	13.30	20.7	12.4
T ₈	100% N:P ₂ O ₅ :K ₂ O + FYM @ 5 t ha ⁻¹	30.10	20.52	32.5	24.4
T ₉	50% N:P ₂ O ₅ :K ₂ O + BGA @ 10 kg ha ⁻¹	23.10	15.92	22.4	17.5
T ₁₀	50% N:P ₂ O ₅ :K ₂ O + Green Manure	23.80	16.82	26.0	19.1
	SEm (±)	1.70	0.78	1.8	1.03
	CD (p = 0.05)	4.94	2.26	5.0	3.00

Water soluble sulphur

Data on water soluble sulphur (Table 1) varied from 16.1 to 35.0 kg ha⁻¹ 9.4 to 26.2 kg ha⁻¹ at 0-15 and 15-30 cm depths, respectively, in 150% NPK followed by 100% NPK + ZnSO₄. Combined use of manures and inorganic fertilizers on an average recorded about 11-13% higher water soluble sulphur over treatments where only inorganic fertilizers were applied. The lowest content of water soluble sulphur was recorded in control which might be due to omission of any type of fertilizers or organic manure in this treatment. Application of P through super phosphate significantly increased water soluble sulphur in 100 and 150% NPK treatments which might be ascribed to the addition of sulphur through super phosphate that contained 14% S in addition to its phosphorus content (Setia and Sharma, 2005) [11]. Dutta *et al.* (2013) [5] also observed that water soluble sulphur was highest in plots receiving super optimum doses of NPK.

Heat soluble sulphur

Data in Table 2 reveal that the heat soluble S content varied from 51 to 80 kg ha⁻¹ and 38 to 55 kg ha⁻¹ at 0-15 and 15-30

cm depths, respectively. Graded doses of 50 and 100% NPK to both the crops registered 33 and 43% increase, respectively, in heat soluble sulphur over control. Among different sources of organics (100%NPK + FYM, 50% NPK + BGA and 50% NPK + GM), 100% N substitution through FYM with 77 and 52 kg ha⁻¹ at 0-15 and 15-30 cm depths, respectively. Heat soluble S was found superior over rest of the inorganically and organically amended treatments. Application of inorganic fertilizers alone or in combination with organics increased heat soluble sulphur fraction as compared to control which might be due to higher soil organic matter in these treatments, as this fraction of sulphur was associated with organic matter which was released with heat treatment during determination. Similar findings were reported by Dutta *et al.* (2013) [5]. With the increase in the fertilizer rates from 50 to 100% NPK, the heat soluble sulphur also increased significantly. Bediger *et al.* (1985) [2] also reported that the significant increase in heat soluble sulphur content of soil with the increase in sulphur application through single super phosphate.

Table 2: Heat soluble sulphur and organic sulphur fraction under different treatments of long term fertilizer experiment

S. no.	Treatment	Heat soluble sulphur (kg ha ⁻¹)		Organic sulphur (kg ha ⁻¹)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁	Control	51	38	66	50
T ₂	50% N:P ₂ O ₅ :K ₂ O	68	47	73	58
T ₃	100% N:P ₂ O ₅ :K ₂ O	73	49	80	20
T ₄	150% N:P ₂ O ₅ :K ₂ O	80	55	86	68
T ₅	100% N:P ₂ O ₅ :K ₂ O + Zn @ 10 kg ha ⁻¹	79	53	85	65
T ₆	100% N:P ₂ O ₅	67	49	74	61
T ₇	100% N	51	38	68	52
T ₈	100% N:P ₂ O ₅ :K ₂ O + FYM @ 5 t ha ⁻¹	77	52	82	65
T ₉	50% N:P ₂ O ₅ :K ₂ O + BGA @ 10 kg ha ⁻¹	73	50	79	61
T ₁₀	50% N:P ₂ O ₅ :K ₂ O + Green Manure	75	49	80	62
	SEm (±)	0.7	0.79	1.0	1.0
	CD (p = 0.05)	2.0	2.3	2.2	1.8

Organic sulphur

Organic sulphur was one of the dominant fractions of sulphur in soil. It varied from 66 to 86 kg ha⁻¹ and 50 to 68 kg ha⁻¹ in control and 150% NPK, respectively at 0-15 and 15-30 cm depth of soil (Table 2). The highest (31.15%) increase in organic S over control was recorded in 150% NPK application. On an average, organic sulphur accounted for about 96% of total sulphur forming a major fraction. The minimum amount of organic sulphur in control may be due to

its mining to meet out the crop requirements. Application of inorganic fertilizers alone or along with organics also showed significant increase in organic sulphur content of soil over control. This increase due to increased levels of NPK fertilizer application could be attributed to the sulphur addition through applied P fertilizer and through different sources of organics. These results are in conformity with the findings of Dutta *et al.* (2013) [5].

Rice yield

S. no.	Treatment	Yields (kg ha ⁻¹)	
		Grain	Straw
T ₁	Control	2430	3110
T ₂	50% N:P ₂ O ₅ :K ₂ O	4580	5496
T ₃	100% N:P ₂ O ₅ :K ₂ O	6625	7950
T ₄	150% N:P ₂ O ₅ :K ₂ O	6970	8364
T ₅	100% N:P ₂ O ₅ :K ₂ O + Zn @ 10 kg ha ⁻¹	6565	7878
T ₆	100% N:P ₂ O ₅	6500	7800
T ₇	100% N	3535	4596
T ₈	100% N:P ₂ O ₅ :K ₂ O + FYM @ 5 t ha ⁻¹	6890	8268
T ₉	50% N:P ₂ O ₅ :K ₂ O + BGA @ 10 kg ha ⁻¹	4600	5520
T ₁₀	50% N:P ₂ O ₅ :K ₂ O + Green Manure	4920	5904
	SEm (±)	173	208
	CD (p = 0.05)	503	603

The grain yield of rice ranged from 2430 to 6970 kg ha⁻¹ and straw yield of rice range from 3110 to 8364 kg ha⁻¹ amongst various treatments of LTFE. Highest grain yield of rice 6970 kg ha⁻¹ was obtained with application of 150% NPK which was significantly superior over all the treatments but at par with 100% NPK + FYM (6890 kg ha⁻¹), whereas lowest yield was obtained in control (2430 kg ha⁻¹). Similarly graded level of zinc in the form of zinc sulphate also increased the grain and straw yield with those of 100% NPK + Zn. The 100% NPK + FYM showed significantly higher yield as compared to control but on par with 150% NPK.

Katkar *et al.*, (2011) [9] resulted that “the highest productivity of sorghum and wheat was recorded with the application of at 100% NPK + FYM @ 5 tonne per hectare. This was

significantly higher than 150% NPK. Omission of potassium and phosphorus and potassium through mineral fertilizer showed reduction in the total productivity over 100% NPK. Sharma *et al.*, (2015) [13] observed that the application of fertilizers alone or in combination of organic manure increase the grain and straw yields of rice significantly over control. Conjoint use of fertilizers and organic manure significantly increased the grain and straw and of rice over control.” The result in line with similar findings reported by Shambhavi *et al.*, (2017) [12] that the grain and straw of maize and wheat was lowest in control and highest in 100% NPK + FYM.

Correlation amongst various sulphur fractions and rice yield

Table 3: Correlation of different forms of sulphur and rice grain yield

	Sulphate sulphur	Water soluble sulphur	Organic sulphur	Heat soluble sulphur	Yield
Sulphate sulphur	1				
Water soluble sulphur	0.780**	1			
Organic sulphur	0.837**	0.719**	1		
Heat soluble sulphur	0.786**	0.687**	0.945**	1	
Yield	0.810**	0.793**	0.790**	0.737**	1

** = 1% level of significance

The correlation between forms of sulphur after harvest of grain yield of rice was calculated and tabulated in table 3. The data revealed that the various forms of sulphur like sulphate sulphur ($r = 0.810^{**}$), water soluble sulphur ($r = 0.793^{**}$), organic sulphur ($r = 0.790^{**}$) and heat soluble sulphur ($r = 0.730^{**}$) were significantly and highly correlated with grain yield of rice amongst continuous application of inorganic fertilizers and manures. The highest correlation was observed in sulphate sulphur ($r = 0.810^{**}$) with yield of rice amongst various treatments. All sulphur fractions were positively correlated amongst them viz. sulphate sulphur was positive correlated with water soluble sulphur ($r = 0.780^{**}$), organic sulphur (0.837^{**}) and heat soluble sulphur (0.786^{**}). Water soluble sulphur was positive correlated with organic sulphur ($r = 0.719^{**}$) and heat soluble sulphur (0.687^{**}) and organic sulphur was positively correlated with heat soluble sulphur ($r = 0.945^{**}$) amongst various treatments of LTFE.

Conclusion

Results from the present study indicated that all the fractions of sulphur viz., sulphate S, water soluble S, heat soluble S and organic S were significantly affected by different treatments. Without fertilization i.e. controlled to decline in the levels of all the forms of sulphur as compared to rest of the treatments. Application of inorganic fertilizers increased all the fractions of sulphur. Integration of inorganic fertilizers with organics

proved better as compared to application of inorganic fertilizers alone. Organic sulphur was found to be the most dominant (about 96%) fraction of total sulphur. Application of graded doses of fertilizers significantly increased grain yield over control by 88.4, 172.6 and 186.8% where 50, 100 and 150% NPK were applied, respectively, to rice crop. Conjoint use of inorganic fertilizers and organic manures by substituting 50% N through any of the organic materials recorded higher rice yield in comparison to its 25% substitution rate. Among different organic sources tried, FYM and green manure, proved better sources of organic N over BGA.

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