Application of Different Organic Amendments Influences the Different Forms of Sulphur in the Soil of Pea – Onion – Cauliflower Cropping System

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A study was conducted in sandy clay loam soils in a subtropical zone of Bihar to evaluate the effect of frequent application of organic amendments on sulphur fractions. Different organic amendments, including farmyard manure (FYM), vermicompost, azotobacter, phosphate solubilizing bacteria (PSB), panchagawya, and neem cake, were applied through nine treatments that resulted in a significant increase of water-soluble S, available S, heat-soluble S, adsorbed S, and organic S in organic treatment compared to the recommended dose of fertilizer (RDF) and control treatment. The maximum increment was observed in the treatment where the recommended dose of nitrogen was replaced by 75% recommended dose of nitrogen substituted farmyard manure + 25% recommended dose of nitrogen (vermicompost) along with azotobacter + PSB + one foliar spray of panchagawya. The total S content varied widely from 382 to 736 mg kg^{-1}. Increment in all the forms of sulphur is observed as a result of the application of different organic nutrient sources. All the forms of sulphur share a mutual positive and significant correlation with each other. Regression analysis suggested that the availability of sulphur was dominated by organic sulphur, which alone can explain 97.8% of the variation in availability of available sulphur in soil.

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INTRODUCTION

In the current scenario, the importance of secondary nutrients, especially sulphur, is being recognized because of an increase in crop losses due to their deficiencies in both quantity and quality. Sulphur is now being recognized as the fourth major nutrient in addition to nitrogen, phosphorus, and potassium. The deficiency of sulphur in soils and plants is being reported by several parts of the India. A deficiency of sulphur in the soil makes the plant weak, stunted, and pale green to pale yellow in colour with weak stems, such that the plants do not attain maturity in time. Knowledge about S fractions will help one understand the potential of soil to supply S by controlling its release and dynamics in soils (Siddiqui *et al.* 2014). Sulphur can be found in soil in both organic and inorganic forms, and it can change between these forms by several different processes, including mobilization, mineralization, immobilization, oxidation, and reduction. In soil, 90% of the S is present in organic form, and 10% is present in inorganic form. Nearly 90% of the total sulphur in soil is in the form of organic S, which is the major S-binding form in soil. Sulphate S is present in very small concentrations in soil solutions, and these concentrations constantly change based on the equilibrium between S plant uptake, fertilizer input, and immobilization (McLaren and Cameron 2004).

Response of pulses to S is a well-known phenomenon (Tandon 2011). The S requirement for these protein-rich legumes is thought to be higher than for cereal crops. Pea is one of the important pulse crops grown throughout India. Proper management of nutrient status in soil is essential to improve pea productivity of crops. The deficiency of sulphur is increasing daily due to the increased use of fertilizers free of sulphur, the use of only high-analysis fertilizers, and the intensive cultivation of crops with high sulphur requirements, all of which have a negative impact on the soil health. Keeping in view, insufficient sulphur in soil as well as soil health being affected by the inorganic sources to which organic nutrient sources may be a solution. The available sulphur has been reported to increase in the soil with organic manure application, such as vermicompost and farmyard manure (FYM), in comparison to absolute control and recommended dose of fertilizers (Reddy *et al.* 2020). Adding organic inputs could be an alternative for producing chemical-free products, protecting agricultural lands from exploitation of soil resources, and maintaining soil fertility. Considering the above-mentioned points, the present study planned to investigate the effect of frequent application of organic amendments on sulphur fractions.

EXPERIMENTAL

A field study was conducted on the 8th (Pea), 9th (Onion), and 10th (Cauliflower) cropping seasons under the Pea-Onion-Cauliflower cropping system, where pea was grown during summer, onion in *Kharif*, and cauliflower during *Rabi* season at the farm of Bihar Agricultural University, Sabour, Bihar, India. The details of the experimentation along with the methodology adopted during the course of investigation are as follows.

Location of the Study

Twenty-seven surface (0 to 15 cm) soil samples were collected from the research farm of Bihar Agricultural University, Bihar, India, which comes under the Middle Gangetic plain region. The experimental area is situated in a sub-tropical climate and is characterized by a hot desiccating summer, cold winter, and moderate annual rainfall with latitude and longitude of 25° 14’1” N and 87° 2’51” E, respectively.

Experimental soils and their analysis procedures

The surface (0 to 15 cm) soil samples were collected after the harvest of each crop, processed, and passed through 2-mm brass sieve and stored in polythene bag for laboratory analysis of different sulphur fractions under investigation. Available S was estimated by the method of Williams and Steinbergs (Williams and Steinbergs 1959). Water soluble S, heat soluble S, adsorbed S, organic S, and total S were extracted using the methods of Spencer and Freney (1960), Williams and Steinbergs (1959), Fox *et al.* (1964), and Tabatabai (1982), respectively.

Experimental design and treatments

The experiment was laid out in randomized block design (RBD) with nine (9) treatments replicated thrice in sandy clay loam soil with plot dimensions of 4.5 x 4.5 m^2, which is surrounded by 0.5 m-wide bunds. The seed materials of pea *cv.* Azad Pea 3, Onion *cv.* Agrifound Light Red, and Cauliflower *cv.* Sabour Agrim, were collected from the department of Plant Breeding and Genetic, Bihar Agricultural University, Bihar, India. For this study, different organic nutrient sources were applied in 9 treatments: T1- control (no fertilization); T2 – Recommended dose of fertilizer (RDF); T3- 100% Recommended dose of nitrogen (RDN) substituted through FYM; T4- 75% Recommended dose of nitrogen substituted through FYM + 25% Recommended dose of nitrogen substituted through Vermicompost; T5- 75% Recommended dose of nitrogen substituted through FYM + 25% Recommended dose of nitrogen substituted through Vermicompost + Azotobacter; T6- 75% Recommended dose of nitrogen substituted through FYM + 25% Recommended dose of nitrogen substituted through Vermicompost + Azotobacter + PSB; T7- 75% Recommended dose of nitrogen substituted through FYM +25% Recommended dose of nitrogen substituted through Vermicompost + Azotobacter + PSB + 1 Spray of Panchagawya (45 days after sowing or transplanting); T8- 75% Recommended dose of nitrogen substituted through FYM + 25% Recommended dose of nitrogen substituted through FYM Vermicompost + 2 Spray of Panchagawya (30 and 45 days after sowing); T9- 1/3 Recommended dose of nitrogen substituted through FYM + 1/3 Recommended dose of nitrogen substituted through Vermicompost + 1/3 Recommended dose of nitrogen substituted through Neem cake.

Methods

After harvesting, the crops plots were ploughed, and residues of the previous crops were incorporated into the field. Then, treatments were incorporated according to the layout. These seedlings of onion and cauliflower were treated with azotobacter and pea was treated with rhizobium culture along with PSB @ 10 mL kg^{-1}. Irrigation was applied at 2 to 3 day intervals during the summer season and 7 day intervals during winter. Within a day after sowing, pre-herbicide pendimethalin @ 2 mL lit^{-1} was used. Two hand weeding was also implemented at 25 days after sowing (DAS) and 45 DAS. Panchagawya was sprayed according to the treatment schedule at 30 and 45 days after transplanting/sowing at the rate of 3% solution.

Data and their collection procedures

The collected soil sample was used in the laboratory for analysis of different forms of sulphur. The available sulphur from soil was done by using 0.15% $CaCl_2$ (Williams and Steinbergs 1959). According to Tabatabai (1982), wet oxidation was used to determine the total sulphur. Organic S was determined as per the method proposed by Williams and Steinbergs (1959). The value of adsorbed S was computed by subtracting the value obtained with $Ca(H_2PO_4)_2$ extractant from the value obtained with 0.15% $CaCl_2$ extractant (Fox *et al*. 1964). Heat soluble sulphur was measured by special heat treatment and with 0.1% NaCl solution (Williams and Steinbergs 1959). Water soluble S was calculated using the soil: solution ratio and a 30-minute shaking period (Spencer and Freney 1960). After gathering the raw data, they were processed to obtain precise metrics or values for every parameter. This stage is essential for turning the unprocessed observations into information that can be measured, interpreted, and further examined. The next stage was to organize or arrange the data in a structured fashion following data collection and calculation. Sorting the data according to various variables or parameters may fall under this category. After the data were properly organized, statistical analysis was performed on them. To find links, patterns, or trends in the dataset, statistical approaches were used.

Statistical analysis

All the statistical analysis was done in SPSS software version 16. The coefficient of correlation among different S fractions was calculated as per the procedure mentioned in Gomez and Gomez (1983). Regression equations were established by the method given by Karl Pearson, as described in Gomez and Gomez (1983).

RESULTS AND DISCUSSION

Water Soluble Sulphur

The water-soluble sulphur status of soils varied widely between 9.73 and 19.35 mg kg^{-1} and contributed 2.33 to 2.63% of the total sulphur (Table 1 and Fig. 1).

Table 1. Different Forms of Sulphur in Experimental Soil

Treatments	Water Soluble S (mg kg^{-1})	Available S (mg kg^{-1})	Heat Soluble S (mg kg^{-1})	Adsorbed S (mg kg^{-1})	Organic S (mg kg^{-1})	Total S (mg kg^{-1})
T1	9.73(2.54)*	14.01(3.67)	29.55(7.74)	29.11(7.62)	338.87(88.71)	381.99
T2	10.66(2.33)	16.71(3.66)	35.32(7.73)	32.58(7.13)	407.45(89.21)	456.74
T3	12.28(2.41)	18.18(3.57)	37.22(7.31)	33.99(6.67)	457.08(89.76)	509.24
T4	14.74(2.46)	19.90(3.32)	43.44(7.26)	42.16(7.04)	536.58(89.63)	598.64
T5	17.36(2.50)	21.86(3.15)	45.51(6.55)	45.35(6.53)	627.12(90.32)	694.33
T6	18.97(2.62)	23.89(3.30)	52.76(7.29)	46.26(6.39)	653.83(90.31)	723.97
T7	19.35(2.63)	24.28(3.30)	66.99(9.10)	47.40(6.44)	664.81(90.27)	736.49
T8	17.60(2.58)	23.16(3.40)	51.15(7.50)	46.21(6.77)	612.88(89.83)	682.25
T9	16.02(2.60)	20.74(3.36)	35.62(5.78)	43.52(7.06)	552.36(89.58)	616.62
CD (0.05)	0.40	0.41	0.69	0.87	19.86	19.79
S.Em.(±)	0.13	0.14	0.23	0.29	6.62	6.60
CV %	1.51	1.15	0.90	1.24	2.13	1.91

*Value in the parenthesis indicates percent contribution over total sulphur content

Available sulphur is recognized mostly as the component that is available for use by the plant. It has an important role with respect to plant growth and developments. As all forms remain in equilibrium condition in soil, the biggest proportion of organic sulphur indirectly is responsible for plant growth. A significant increase was observed in the organic treated plots as compared to the RDF and control and increased in the order of T7 > T6 > T8 > T5 > T9 > T4 > T3 > T2 > T1. The highest value of water-soluble sulphur was observed in treatment T7 (19.4 mg kg^{-1}), in which the recommended dose of nitrogen was replaced by 75% RDN (FYM) + 25% RDN (vermicompost) along with azotobacter + PSB + one foliar spray of panchagawya applied, whereas treatment T6 (19.0 mg kg^{-1}) was statistically at par with treatment T7, which was similar to treatment T7 except for one foliar spray of panchagawya. This might be due to the application of different organic nutrient sources such as FYM, vermicompost, azotobacter, PSB, panchagawya, and neem cake. Application of these organic sources increased the organic carbon content in the soil, which improved microbial activity. Muramkar *et al.* (2001) observed contradictory reports where they obtained the highest values of water-soluble sulphur in the treatment where 100% NPK + 10 kg FYM ha^{-1} was applied, although they had no organic treatments in the experiment.

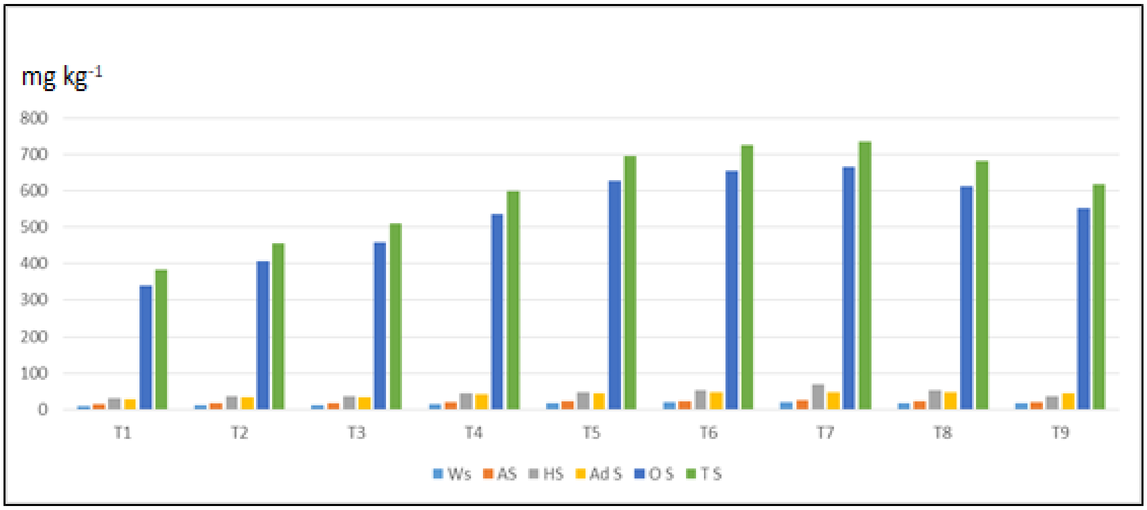

Fig. 1. Variation in sulphur forms in soil under different treatments after application of organic amendments. T1: Control (no fertilization); T2: RDF (Recommended dose of fertilizer); T3: 100% RDN substituted through FYM; T4: 75% RDN (FYM) + 25% RDN (Vermicompost); T5: 75% RDN (FYM) + 25% RDN (Vermicompost) + Azotobacter; T6: 75% RDN (FYM) + 25% RDN (Vermicompost) + Azotobacter + PSB; T7: 75% RDN (FYM) + 25% RDN (Vermicompost) + Azotobacter + PSB + 1 Spray of Panchagawya (45 days after sowing or transplanting); T8: 75% RDN (FYM) + 25% RDN (Vermicompost) + 2 Spray of Panchagawya (30 and 45 days after sowing); and T9: 1/3 RDN (FYM) + 1/3 RDN (Vermicompost) + 1/3 RND (Neem cake)

Microbial Activity and Organic Amendments' Role

Research highlighting the contribution of organic amendments to improving soil fertility is consistent with the observed rise in water-soluble sulphur in organic-treated plots. According to Marschner (2012), organic materials that contribute organic carbon, such as vermicompost and farmyard manure (FYM), foster microbial activity.

Influence of Azotobacter and PSB

The inclusion of phosphorus-solubilizing bacteria (PSB) and azotobacter in the treatments points to a complex influence on the dynamics of soil nutrients. The capacity of Azotobacter to fix nitrogen increases nitrogen availability, which in turn affects sulphur dynamics indirectly. According to Singh *et al.* (2017), PSB may increase the availability of all nutrients, including sulphur, by solubilizing phosphorus.

Microbial Activation and Carbon Content of Soil

The hypothesis that suggests a possible correlation between elevated levels of water-soluble sulphur and soil organic carbon content is consistent with the notion that sulphur mineralization is largely dependent on microbial activity bolstered by organic matter (Kizilkaya 2009).

Available Sulphur

The experimental result of available sulphur (Table 1) ranged from 14.0 to 24.3 mg kg^{-1} in the surface soil and contributed 3.15 to 3.67% of total sulphur. A significant increase in available sulphur was observed among the organic-treated plots as compared to chemical chemical-treated plot and the plot in which no fertilization was done. The increment was in the order: T7 > T6 > T8 > T5 > T9 > T4 > T3 > T2 > T1 and was significantly highest in treatment T7 (24.3 mg kg^{-1}) followed by treatment T6 (23.9 mg kg^{-1}), which was statistically at par with treatment T7. The value of available sulphur increased 43.0% at surface soil in T7 treatment over the 100% RDF after the harvest of the pea crop (Fig. 1). This might be due to the application of different organic nutrient sources for longer periods due to which the clay-humus complex becomes more active, opening additional sulphur exchange sites and increasing the access to sulphur. Another reason might be mineralization, which releases organically bound sulphur. These results are similar to the findings of Desai *et al.* (2018) and Vadiraj *et al.* (1993). The suggested processes for this improvement, which include the mineralization of sulphur bound to organic matter and the activation of the clay-humus complex, are in line with accepted theories in soil science (Marschner 2012; Singh *et al.* 2017). More sulphur access is thought to be due to the clay-humus complex's prolonged activity that generates more sulphur exchange sites. In addition, the process of mineralization may liberate sulphur from organic forms, expanding the sulphur pool that is accessible. These findings add to the understanding of the complex interactions between soil nutrient dynamics, microbial activity, and organic amendments, as well as offer useful implications for maximizing soil sulphur content.

Heat Soluble Sulphur

The experimental soils' heat-soluble sulphur content ranged from 29.6 to 67.0 mg kg^{-1}, indicating the significant effects of different treatments on this particular sulphur fraction. The heat-soluble sulphur content of treatment T7 was the highest (67.0 mg kg^{-1}), whereas the control plot has the lowest (29.6 mg kg^{-1}). The substantial rise in heat-soluble sulphur in organic-treated plots, particularly T7, accounting for 5.78% to 9.10% of the total sulphur, is probably due to the buildup of organic carbon in the soil. This enrichment was possible *via* the application of 75% of the recommended nitrogen dose through farmyard manure (FYM), 25% through vermicompost, and the addition of azotobacter, phosphorus-solubilizing bacteria (PSB), and a foliar spray of panchagawya. Increased microbial activity due to this increase in organic carbon content makes it easier for organically bound sulphur to break down into forms that are soluble in heat. The observed hierarchical increase on heat-soluble sulphur (T7 > T6 > T8 > T5 > T4 > T3 > T9 > T2 > T1) highlights the combined effect of organic treatments. These results are consistent with the body of literature on soil sulphur dynamics (Bolan *et al.* 2003; Smith and Smith 2011), which highlights the complex interactions between the availability of different sulphur fractions in soil and nutrient management strategies.

Adsorbed Sulphur

In the experimental soils, adsorbed sulphur content ranged from 29.1 to 47.4 mg kg^{-1}, accounting for 6.39% to 7.62% of total sulphur. This analysis reveals the complex reactions of this sulphur fraction to various treatments. Treatment T7 stands out in particular because it substituted 25% RDN (vermicompost) and 75% RDN (FYM) for the recommended nitrogen dose. Additionally, it included azotobacter, PSB, and one foliar spray of panchagawya. This resulted in the highest adsorbed sulphur content, measuring

47.4 mg kg^{-1}. Conversely, the unfertilized control plot had the lowest amount of adsorbed sulphur, measuring 29.1 mg kg^{-1}. The continuous application of organic nutrient sources is responsible for the elevation in adsorbed sulphur that has been observed. The increasing influence of continuous organic amendments on adsorbed sulphur is highlighted by the hierarchical progression (T7 > T6 > T8 > T5 > T9 > T4 > T3 > T2 > T1). Relevant recent research by Zheng *et al.* (2021) and Wang *et al.* (2022) highlights the critical role that organic amendments play in determining the dynamics of soil sulphur and offers more information about the mechanisms affecting sulphur availability and adsorption.

Organic Sulphur

Organic sulphur, which had the highest contribution (88.7 to 90.3%) to the total sulphur ranged from 339 to 665 mg kg^{-1} (Table 1). The value of organic sulphur was observed highest in treatment T7 (665 mg kg^{-1}) and the lowest value in the control plot (339 mg kg^{-1}). The increase in organic form was observed in the order of T7 > T6 > T5 > T8 > T9 > T4 > T3 > T2 > T1. This form of sulphur showed a significantly highest increment in treatment T7 due to the different organic nutrient sources, *i.e.*, FYM (75% RDN) + vermicompost (25% RDN) along with azotobacter + PSB+ one foliar spray of panchagawya. The FYM application results in an increment of organic carbon content in soil (Gupta *et al.* 1992). The idea that increased organic carbon from FYM application leads to elevated levels of organic sulphur in the soil is further supported by the observed relationship between soil organic carbon content and levels of organic sulphur (Gowrisankar and Shukla 1999).

Total Sulphur

The analysis of the soil's total sulphur content, ranging from 382 to 736 mgkg^{-1}, shows how different treatments have a complex impact on the dynamics of sulphur overall (Table 1). With azotobacter, PSB, and a foliar spray of panchagawya added, treatment T7, which replaced the recommended nitrogen dose with 75% RDN (FYM) + 25% RDN (vermicompost), showed the highest total sulphur content, measuring 736 mgkg^{-1}. With a statistically comparable total sulphur content of 724 mgkg^{-1}, treatment T6 closely resembled treatment T7. Plots treated organically showed a more marked increase than the control and chemically treated plots, in the following order: T7 > T6 > T5 > T8 > T9 > T4 > T3 > T2 > T1. This observed increase can be ascribed to the combined benefits of various organic nutrient sources in T7, which have improved soil sulphur accumulation. Interestingly, these results agree with research conducted in a maize-wheat cropping system by Setia and Sharma (2005), who found that applying FYM increased the amounts of different forms of sulphur in a comparable way. Similar results were reported by Reddy *et al.* (2009), which supports the current study and emphasizes the usefulness of organic amendments in affecting the overall sulphur content of soil. This thorough knowledge highlights the importance of customized organic nutrient management strategies for maximizing soil sulphur dynamics in agricultural ecosystems and emphasizes the contribution of various organic sources to raising total sulphur availability.

Relationship Among Different Forms of Sulphur

The relationship between different forms of sulphur in soil under the influence of organic management practices after the 11th (pea) crop season has been tabulated with the coefficient of correlation (Table 2).

Table 2. Relationship Amongst Different Forms of Sulphur in Experimental Soil

Forms of S	Water Soluble S	Available S	Heat Soluble S	Adsorbed S	Organic S
Available S	0.985**				
Heat soluble S	0.854**	0.871**			
Adsorbed S	0.980**	0.970**	0.798*		
Organic S	0.992**	0.989**	0.851**	0.982**	
Total S	0.992**	0.990**	0.850**	0.983**	0.999**

*Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level

A thorough examination of the data showed that a positive and highly significant correlation existed among all the fractions of sulphur. Water soluble sulphur showed a significant and positive correlation with available sulphur (r = 0.985**), heat soluble sulphur (r = 0.854**), adsorbed sulphur (r = 0.980**), organic sulphur (r = 0.992**), and total sulphur (r = 0.992**). Available sulphur showed a significant and positive correlation with water-soluble sulphur (r = 0.985**), heat-soluble sulphur (r = 0.871**), adsorbed sulphur (r = 0.970**), organic sulphur (r = 0.989**), and total sulphur (r = 0.990**). Heat soluble sulphur showed a significant and positive correlation with water-soluble sulphur (r = 0.854**), available sulphur (r = 0.871**), adsorbed sulphur (r = 0.798*), organic sulphur (r = 0.851**), and total sulphur (r = 0.850**). Adsorbed sulphur showed a significant and positive correlation with water-soluble sulphur (r = 0.980**), available sulphur (r = 0.970**), heat-soluble sulphur (r =0.798*), organic sulphur (r = 0.982**), and total sulphur (0.983**). Organic sulphur showed a significant and positive correlation with water-soluble sulphur (r =0.992**), available sulphur (r = 0.989**), heat-soluble sulphur (r = 0.851**), adsorbed sulphur (r = 0.982**), and total sulphur (r = 0.999**). Total sulphur showed a significant and positive correlation with water-soluble sulphur (r = 0.992**), available sulphur (r = 0.990**), heat-soluble sulphur (r = 0.850**), adsorbed sulphur (r = 0.983**), and organic sulphur (r =0.999**).

Table 3. Different Forms of Sulphur Predicting Sulphur Availability Using Regression Analysis

Equations	Cumulative Contribution (R^2 x 100)	Contribution of Individual Soil Characters (R^2 x 100)
$Y_1 = 4.242+0.030X_1$	97.8	97.8
$Y_2= 4.319 +0.021X_1 +0.165X_2 +0.032X_3 +0.022X_4$	98.2	0.4
When organic form of sulphur is excluded		
$Y_3= 5.722+0.960X_5$	97.1	97.1
$Y4= 4.145+0.602X_5+0.044X_6+0.124X_7$	97.6	0.5

Y= Available S, X_1= Organic S, X_2 = Water soluble, X_3 = Heat soluble S, X_4 = Adsorbed S, X_5 = Water soluble, X_6 = Heat soluble S, X_7 = Adsorbed S

Influence of Organic Amendments on the Variability of Available Forms of Sulphur

The findings showed that organic sulphur contributed significantly to the variation in soil available sulphur, explaining 97.8% of the variation that was observed (Table 3 and Fig. 2). It is interesting to note that the total contribution rose to 98.2% when all other forms of sulphur were taken into account, with each additional form contributing 0.4%. This suggests that various forms of sulphur work together to maintain an equilibrium, even though their individual contributions are not very significant. Moreover, water-soluble sulphur alone contributed significantly, making up 97.1% of the available sulphur, even after the organic form of sulphur was taken out of the analysis.

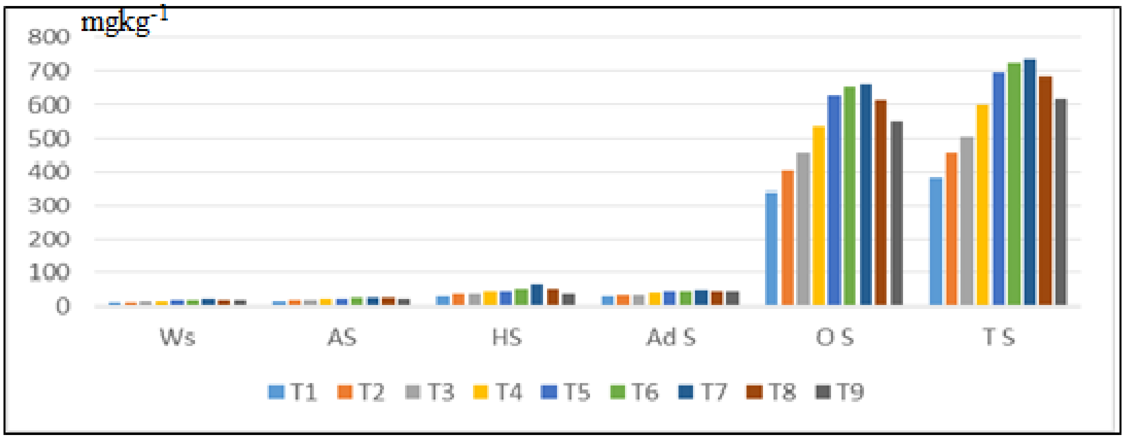

Fig. 2. Effect of different treatments on sulphur forms after frequent application of organic amendments. T1: Control (no fertilization); T2: RDF (Recommended dose of fertilizer); T3: 100% RDN substituted through FYM; T4: 75% RDN (FYM) + 25% RDN (Vermicompost); T5: 75% RDN (FYM) + 25% RDN (Vermicompost) + Azotobacter; T6: 75% RDN (FYM) + 25% RDN (Vermicompost) + Azotobacter + PSB; T7: 75% RDN (FYM) + 25% RDN (Vermicompost) + Azotobacter + PSB +1 Spray of Panchagawya (45 days after sowing or transplanting); T8: 75% RDN (FYM) + 25% RDN (Vermicompost) + 2 Spray of Panchagawya (30 and 45 days after sowing) and T9: 1/3 RDN (FYM) + 1/3 RDN (Vermicompost) + 1/3 RND (Neem cake).

These results highlight the critical role that organic sulphur plays in affecting the total amount of sulphur available in soil, with water-soluble sulphur emerging as another important factor. The findings are consistent with the intricate dynamics of soil sulphur transformations, highlighting the complex interactions between various forms of sulphur (McGrath and Zhao 1996). Water-soluble sulphur is frequently thought to be more easily accessible, even though organic sulphur has been acknowledged for its long-term availability and gradual release. This detailed knowledge advances our understanding of the cycling of sulphur in soil ecosystems.

CONCLUSIONS

1. The results of this study highlight the significant influence that regular organic amendments have on different types of sulphur and how they interact with one another on the soil's surface.
2. According to the results, the organic fraction of sulphur predominates and is a significant source of native sulphur in the soils under study.
3. One interesting finding is the steady rise in sulphur in all forms after applying various sources of organic nutrients, implying a direct relationship between increased soil sulphur concentration and organic amendments.
4. Moreover, synchronized behaviour is implied by the positive and substantial correlations found among all the forms of sulphur, which remains in an equilibrium condition in soil, suggesting a cohesive relationship among these many sulphur species.

5. This connectivity emphasizes how intricately and mutually dependent sulphur transformations in response to organic amendments are.
6. The data's regression analysis provides insightful information about the variables influencing the soil's availability of sulphur.
7. The findings highlight the importance of organic sulphur, which by itself can explain an astounding 97.8% of the variation in sulphur availability in the soil that has been observed, emphasizing its significance to the total amount of sulphur available.
8. Regression analysis shows a significant explanatory power even when the organic form is not considered, with the availability of sulphur being explained by 97.1%, indicating the influence of a variety of sulphur forms in addition to organic sulphur.
9. In summary, this study's findings provide insight into the complex dynamics of sulphur in soil, especially as it relates to organic amendments, with significance for sustainable farming practices seeking to maximize soil sulphur availability and offering insightful information about soil nutrient management.

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