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Effect of organic manure amended sulphur on transformation of different fractions in calcareous soil of Bihar

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Abstract
A laboratory investigation was conducted with seven levels of sulphur alone and along with organic manure to study changes in different fractions in the post-harvest soil after Mustard crop. The added Sulphur was dominantly transformed into organic-sulphur in soils and it constituted 40.5-53.1 per cent of the total sulphur present in post-harvest soils. Application of organic manures were able to restrict the leaching loss of S to a great extent. All the fractions of S were in a dynamic equilibrium as evident from correlation studies. All the forms of sulphur except non-sulphate-S were found to be significantly correlated with most of the plant parameters of mustard like S-concentration in seed and straw, S-uptake by seed and straw, total sulphur uptake and available S-content in post-harvest soil, the higher correlation coefficient values being in case of sulphate -S, total water soluble-S and heat soluble-S. Similar correlation was obtained in case of rice crop also. In addition, the rice grain and straw yields also significantly correlated with different S pools. The stepdown multiple regression indicated the importance of sulphate-S, total water soluble-S and organic-S in explaining the variation in mustard and rice yield and yield parameters satisfactorily.

Keywords: Sulphur fractions, organic manure, dynamic equilibrium, transformations

Introduction
The fertilizer needs of Indian agriculture have travelled beyond nitrogen, phosphorus potassium. Like NPK, Sulphur is an essential plant nutrient. It is increasingly being recognised as the 4th major plant nutrient after nitrogen, phosphorus and potassium (Parakhia et al., 2016) [9]. Sulphur occurs in soil as organic and inorganic forms. Organic-S, like organic-N becomes available through mineralization and the pathways of transformation of N and S are similar in many ways. Organic-S is dominant fraction in most Indian soil. In temperate countries more than 99 per cent S in soil occurs as organic forms, but in some soils, organic-S is as low as 20% of the total S (Ahmad and Jha, 1969) [1]. S supplying capacity is dependent on the status, forms and interrelationship with some important soil characteristics including organic matter content which affects its release and dynamics in soil (Das et al., 2012) [5]. The wide variation in the distribution of S among various fractions in Indian soil is reflection of diversity in parent materials, climatic condition, amount of organic matter etc. (Arora and Takkar, 1988) [2]. In soil, S can be broadly grouped into four forms viz. sulphate-S, organic-S, total-S and non-sulphate-S (Pasricha and Sarkar, 2012) [10]. Microbial oxidation of elemental S and mineralization of organic S were major sources of soil sulphate-S (Jaggy et al., 2005) [7]. Organic sulphur is the main S-binding form in soil (Scherer, 2009) [13] and contributes up to 95% of total soil S in cultivated soil. The present study was therefore, conducted to evaluate changes in different fraction of applied sulphur especially along with organic manure

Material and methods
Surface soil samples (0-15cm) from selected treated plots were collected to study the transformation in post-harvest soil of mustard and rice in experimental site of nursery jhilli of RAU, Pusa farm on calcareous soil under mustard-rice cropping system with the following treatment levels:
$OM_0S_0(T_1)$, OM_0S_{20} (T_2), OM_0S_{40} (T_3), $OM_0S_{60}(T_4)$, $OM_0S_{80}(T_5)$, OM_0S_{100} (T_6), $OM_0S_{120}(T_7)$, $FYMS_0(T_8)$, $FYMS_{20}(T_9)$, $FYMS_{40}(T_{10})$, $FYMS_{60}(T_{11})$, $FYMS_{80}(T_{12})$, $FYMS_{100}(T_{13})$, $FYMS_{120}(T_{14})$, $BGSS_0$ (T_{15}), $BGSS_{20}$ (T_{16}), $BGSS_{40}$ (T_{17}), $BGSS_{60}$ (T_{18}), $BGSS_{80}$ (T_{19}), $BGSS_{100}$ (T_{20}), $BGSS_{120}$ (T_{21}).O.M=Organic manure, BGS=Bio-Gas Slurry Source of Sulphur Phospho-zypsum (1%P_2O_5) and 14% S, Organic Manure (FYM/Biogas slurry) @ 5.0 t/ha. S-

levels alone and along with organic manures were replicated thrice in randomized block design. Organic manures were amended with different levels of S and incubated for one month before application in mustard. Different fractions of S were analysed by using standard procedure. The total S content in the soil was determined by acid digestion method of Tabatabai (1982) [17], the organic S content in soil was estimated by the procedure of Evans and Rost (1945) [6] as modified by Williams and Steinbergs (1959) [19]. Total water soluble Sulphur was determined by the procedure given by Williams and Steinbergs (1959) [19]. Also, heat soluble sulphur was estimated by the procedure given by Williams and Steinbergs (1959) [19]. Available sulphate sulphur was extracted by using 0.15% $CaCl_2$ solution and the concentration of sulphate sulphur in the extracts was determined by Turbidimetric method given by Chesnine and Yien (1951)[4]. Organic Carbon was estimated following the method Walkley and Black (1934) [18]. General properties of initial surface soil of experimental plot are Sandy loam in texture (Sand-76%, Silt-12% and Clay-12%), pH (1:2) 8.4, EC 0.35 ds/m, Organic Carbon 4.10 gkg^{-1}, Free calcium carbonate 334 gkg^{-1}, CEC 8.80 $Cmol(P^{+})kg^{-1}$, Available N 240.0 $kgha^{-1}$, P_2O_5 14.0 $kgha^{-1}$, K_2O 78.0 $kgha^{-1}$, Available Zn 0.57 mg kg^{-1}, Available Fe 20.55 mg kg^{-1}, Available Cu 3.62 mg kg^{-1}, Available Mn 9.92 mg kg^{-1}, Total S 349.8 mg kg^{-1} and Available S 8.26 mg kg^{-1}. Two test crops Mustard (var. Varuna) and Rice (Var. Rajshree) were grown successively to see the direct and residual effect of S alone and along with organic manure.

Result and Discussion

Soil sulphur in the post-harvest soil after mustard under different treatments were fractionated into different forms of S like total-S (T-S), organic-S (O-S), sulphate-S (S-S), total water soluble-S(TWS-S), heat soluble-S(HS-S) and non-sulphate-S(NS-S) to study the transformation of native as well as applied-S alone or along with organic manure. This form of S were analysed for different statistical parameters along with crops parameters to test the best utilization of these S-forms by crops.

Total Sulphur (T-S)

Total-S content in surface soil varied from 338.3 to 491.1 mg kg^{-1} due to different treatments .The addition of higher dose of sulphur leads to increase in total-S (Table-1). This values of total-S are similar to that observed in R.A.U. research farm, Pusa with different fertility levels (231.21 to 397.26 mg kg^{-1}) by Azmi *et al*. (2018) [3]. The addition of higher dose of sulphur leads to increase in total-S. The rate of increase was higher in organic manure treated soil as compared to inorganic-S treatments. This indicated that organic manure increased the S retaining power of soil. The sub-soil sulphur which moved upward was retained in the surface soil layer. The addition of higher dose of inorganic S leads to accumulate comparatively higher amount of total-S in soil (Table-1). The results of the present investigation was similar to that as reported by Saren *et.al.* (2016) [12]. The retaining power was more in case of organic manure and sulphur combination. Between organic manures, BGS was more effective than FYM in increasing total-S which might be due to higher built-up of organic carbon in soil as well as higher S content in BGS as compare to FYM. The increase in total sulphur with increase on organic -C contents was also reported Sharma and Gangwar (1997) [15].

Organic Sulphur (O-S)

The data in table 1 and 2 indicated that Organic-S was the major fraction of S in soil which varied from 146.6 to 260.8 mg kg^{-1} and constituted 40.5 to 53.1% of total-S. The highest quantity of this form of sulphur was found in BGS treated soils (174.2 - 260.8 mg kg^{-1}) followed by FYM treated soils 169.3 to 229.2 mg kg^{-1}) and the lowest in organic manure untreated soils (146.6 to 162.1 mg kg^{-1}). The percent contribution of organic-S to total-S was in the same sequence with respect to organic manure treatments. Although increasing rate of S application increased the organic-S content in soil but the percent contribution towards total-S remained almost similar. The distribution of organic-S in these soil is mainly influenced by the organic carbon contents of these soils as also referred by Singh *et al*. (2006) [16].

Sulphate Sulphur (S-S)

The sulphate sulphur varied from 18.1 to 91.2 mg kg^{-1}(Table1) in post-harvest surface soils after mustard which comes to 5.3 to 20.5% of total-S (Table 2). The highest amount of this fraction was present in BGS treated soil 29.6 to 91.2 mg kg^{-1} followed by FYM treated soils 29.5 to 86.4 mg kg^{-1} and organic manure untreated soils 18.1 to 82.0 mg kg^{-1}. Sulphate sulphur was increased apparently with S levels as well as addition of organic manure. Rate of increase was higher as compared to organic-S which indicated that S applied either through inorganic or organic form is being transferred into different forms and a part of that enrich the sulphate-S pool. The rate of increase was more in case of inorganic source than organic manure which shows the transformation of applied S into organic-S when applied along with organic manure. The sulphate fraction is most important form from the plant nutrition point of view and it may prove a suitable index in evaluating the amount of sulphur available to plants (Kher and Singh, 1993)[8].

Total water soluble Sulphur (TWS-S)

Like sulphate-S, total water soluble-S accounted very small fraction of total sulphur ranging from 6.6 to 21.2 per cent. Total water soluble-S almost showed similar pattern of its distribution to that of sulphate-S with a bit higher values ranging from 22.5 to 94.1 $mgkg^{-1}$. Such relative behaviour of these two forms of sulphur is expected because total water soluble-S contains the amount of sulphur oxidised with hydrogen peroxide from the organic matter and extracted with 1% NaCl used for leaching the soils to determine this form of sulphur in addition to sulphate-S (Sharma *et al*. 1986)[14].

Heat Soluble sulphur (HS-S)

Heat soluble sulphur ranged from 24.5 to 99.0 mg kg^{-1} which contributed 7.2 to 22.1 per cent towards total-S. The quantity of heat soluble –S was slightly higher over total water soluble-S and exhibited almost similar pattern of distribution as total water soluble-S (Table 1 and 2). This increase might be due to dissolution of sulphate covalently held by organic matter by heating the soil. Similar observations were also reported by Sahu *et al*. (1998) [11].

Non-sulphate Sulphur (NS-S)

Non-sulphate form of sulphur remains un-extractable after the removal of organic carbon (H_2O_2 extractable) and sulphate-S (0.15% $CaCl_2$ solution) and is mostly made up of insoluble compounds of Ba, Ca etc. occluded in and adsorbed on carbonates of soils (Evans and Rost, 1945) [6]. The results indicated that non-sulphate-S constituted 28.3 to 51.3 per cent

(139.1 to 174.9 mg kg^{-1}) of the total-S (Table 1 and 2). The soils without organic manure contained high amount of non-sulphate-S than organic manure treated-S. Non-sulphate-S decreased with increasing doses of S applied in the soils and were almost higher in the organic manure un-treated soils. The higher amount of non-sulphate-S might be due to presence of calcium carbonate, slightly alkaline condition and low organic matter as also evidenced by the findings of Kher and Singh (1993) [8] in mustard growing soils of north kashmir. Data in table 1 and 2 thus conclude that addition of organic matter decreased non-sulphate-S in soil due to the activities of S-oxidising organisms which not only releases sulphate-S from the added organic source but also from the native source present in the soil. The present results are in agreement with works of Saren *et al*. 2016 [12].

Correlation studies

Significant correlation among different sulphur pools of post-harvest soils after mustard revealed that all the fractions of S were in dynamic equilibrium with correlation coefficient values of -0.564 to 0.997. All the fractions were positively and significantly correlated among themselves except non-sulphate-S which produced negative and significant correlation with other sulphur fractions. This suggested that non-sulphate fraction is also important to raise the available fraction on utilisation by crops (Table 3). Positive and significant correlation of different forms of sulphur among themselves gave support to the findings of Sahu *et al.* (1998) [11].

Data presented in table 3 indicated that different plant parameter of mustard like S-concentration in seed and straw, S-uptake by seed and straw, total S uptake and available S were positively an significantly correlated with most of the S fractions. Non-sulphate-S failed to produce significant correlation with plant parameter except S-concentration in seed and available S in soil where it was negatively and significantly correlated. Sulphate-S, total water soluble-S and heat soluble-S show better correlation with S-concentration in straw, S-uptake by straw and total sulphur uptake compared to total and organic-S suggesting thereby plants derive soil-S from these pools to a greater extent which are by and large, the available form of sulphur. The other fractions was also made available to the plants on transformation into easily available form i.e. sulphate-S.

Correlation studies of different S fractions with parameters of rice crop have been presented in Table 4 which revealed that grain yield, straw yield, S concentration in grain, s concentration in straw, S-uptake by grain and straw, total-S uptake and available-s of rice were positively and significantly correlated with all the fraction of S except non-sulphate-S which produced negative and significant correlation with S-concentration and uptake by rice. Total water soluble sulphur was found to be most important in increasing all the parameters studied which was followed by sulphate-S and heat soluble-S with slightly lesser values.

Multiple regression studies

To evaluate the relative contribution of different S fractions on different plant parameters such as grain yield (Y_1), straw yield (Y_2), S-concentration in grain (Y_3), S-concentration in straw (Y_4), S-uptake by grain (Y_5), S-uptake by straw (Y_6) and total-S uptake (Y_7) step down multiple regression analysis was carried out (Table-5).The independent variable were total-S (X_1), organic –S (X_2), sulphate-S (X_3), non-sulphate-S (X_4), water soluble-S (X_5) and heat soluble-S(x_6)

It was observed that none of the S-pools have shown positive and significant contribution on seed yield (y_1) and straw yield (Y_2) of mustard. However, among fractions, organic-S appeared to be most important as evident from the highest regression coefficient.It was noticed that maximum adjusted R^2 (0.741) value in S-concentration in grain of mustard was obtained in case of equation where x_2, x_3 and x_6 factors were included which explained 78.0 per cent variation. Inclusion of other fractions in equation hardly explains 0.4 per cent additional variations in S-concentration in mustard seed. The standard regression coefficient indicated that x_6 is the most important factor followed by x_2

With regards to S-concentration in straw of mustard, the highest R^2 value was noted at equation where 84.3 per cent variation was explained through variations in X_3 and X_4 with significant effect of X_3. Further inclusion of other S-fractions in regression equation was able to explain additional 1 per cent variation. The importance of X_3 factor was evident from standard regression coefficient values.

Similarly, the regression equations for sulphur uptake by grain of mustard revealed that maximum adjusted R^2 (0.385) was obtained through combined effect of X_2 and X_6 which explained 44.7 per cent variation with comparatively more effectiveness of X_2 i.e. organic-S followed by X_6. Further inclusion of other factors increase the predictability by a small margin of 0.6 per cent.

It was observed that maximum adjusted R^2 value of 0.724 was obtained for equation by which 73.7 percent in S-uptake by mustard straw could be explained through variation in X_3 with significant effect. The extent of additional variation which could be explained through the variation in other S-fractions was found to be only 1.3 percent. Similarly, in case of total sulphur uptake by mustard SO_4-S(x_3) contributed significantly and was found to be lone important fraction which could explain 69.6 per cent variation in total S-uptake as evident by highest adjusted R^2 value of 0.680. The effect of other factors was marginal in explaining the variation in total S-uptake.

The overall view of stepdown multiple regression equation presented in table 5 along with the adjusted R^2 and standard regression coefficients which measure the relative contribution of different soil pools, revealed that sulphate –S emergedas the most important pool to describe the maximum variation in different parameters related to straw while organic-S emerged as most important for parameters related to mustard seed. Hence,it can be inferred that sulphate-S and organic-S are the most important sulphur fractions contributing to the S nutrition of mustard.

Similar stepdown multiple regression analysis were carried out to explain the variations in dependent variables of rice such as grain yield (y_1), straw yield (y_2), S-concentration in grain (y_3), S-concentration in straw(y_4), S-uptake by grain(y_5), S-uptake by straw (Y_6) and total S-uptake by rice (y_7) through the variations in different S-fractions in soil such as total-S(x_1), organic-S(x_2), sulphate-(x_3) non-sulphate- (x_4), total water soluble-S(x_5) and heat soluble-S(x_6) as independent variables. The regression equations obtained are presented in table 6. The highest adjusted R^2 value (0.500) was obtained for equation in case of grain yield of rice where 52.5 per cent variation in this parameter could be explained through the variation in x_5 of water soluble S. Further inclusion of other S-fractions in regression equation hardly explain about 3 per cent variation in yield. However, in all the equations the relative importance of x_5 was superior as evidenced from higher standard regression coefficient value. In case of straw yield of rice, 76.6 per cent variation was explained through the variations in x_2, x_3, x_4 and x_5 where the adjusted R^2 value was highest (0.708).The highest value of standard regression coefficient in case of x_5(2.348) explains its importance followed by x_4. Factors x_2 and x_3 were less important as their standard regression coefficient values were negative. Inclusion of x_1 and x_6 in regression equation did not explain remarkable additional variations in straw yield of rice. The S-concentration in grain can best be explained through equation having highest adjusted R^2 value and this equation explain 78.6 per cent variation through the variation in x_3 and x_5.The effect of x_5 was significant and its relative importance is higher as evidenced by higher standard regression coefficient. Inclusion of other factors in regression equations failed to explain even one per cent of additional variation in S-concentration in grain. In case of S-concentration in straw, 88.8 per cent variation could be explained through the variations in x_2,x_3 and x_5 as evidenced from its highest R^2 adjusted value.The effect of x_2 and x_3 was significant.The standard regression coefficient value suggested that x_3 relatively more important than x_2.The effect of x_5 was least important.Further inclusion of other S-fractions in regression equation was not able to explain much additional variations in S-content in straw.

The variations in S-uptake by rice grain could satisfactorily be explained through equation with 80 per cent determination as evidenced by its highest R^2 adjusted value. This parameter was mostly contributed by x_5 and x_3 where the effect of x_5 was significant with highest standard regression coefficient.Inclusion of x_6 in equation increased the determination level of 0.7 per cent but further inclusion of remaining factors hardly increased the level of determination up to 0.3 per cent. It was noticed that 93.2 per cent variations in S-uptake by straw could significantly be explained through variations in x_2 and x_3 with highest R^2 adjusted value of 0.925. The effect of both the factors was significant, however, the higher value of standard regression coefficient with respect to x_3 as compared to x_2 explained its comparatively more importance in explaining the variation in S-uptake by rice straw. As regards to total S-uptake by rice, the stepdown regression equation suggested the importance of equation through 93.5 per cent in its variations could significantly be explained through the variations in x_2, x_3 and x_4 as evidenced by the adjusted predicted value (0.923). Among these two fractions the effect of x_3 was proved to be superior over x_2. Inclusion of other fractions step by step in to regression equation did not changes the prediction value for explaining variations in total S-uptake by rice.

The overall view of regression studies with respect to rice and mustard indicated that different plant parameters could well be explained through variations in organic-S (x_2), and sulphate-S (x_3) and total water soluble -S (x_5) with relatively more significance of x_5 for grain production and x_3 for straw production where different plant parameters could be satisfactorily explained through a single but different multiple regression equation.

Table 1: Different forms of sulphur (mg kg^{-1}) in post-harvest surface soil of mustard

Soils	T-S	O-S	S-S	TWS-S	HS-S	NS-S
T_1	338.3	146.6	18.1	22.5	24.5	173.6
T_2	345.9	150.9	20.9	22.8	24.8	174.1
T_3	357.2	154.5	27.8	30.9	33.4	174.9
T_4	367.8	155.4	40.0	44.3	46.4	172.4
T_5	380.1	157.0	53.7	59.2	61.3	169.4
T_6	390.0	161.3	67.3	70.2	76.7	161.4
T_7	400.0	162.1	82.0	84.8	88.3	155.9
T_8	349.4	169.3	29.5	31.7	32.2	150.6
T_9	368.8	176.3	32.9	37.5	45.0	159.6
T_{10}	383.9	188.1	44.8	49.8	55.3	151.0
T_{11}	409.6	199.1	55.1	60.2	61.2	155.4
T_{12}	417.2	204.8	68.4	74.6	77.4	144.0
T_{13}	442.8	212.8	70.0	83.7	88.5	160.0
T_{14}	472.3	229.2	86.4	94.1	98.5	156.7
T_{15}	353.9	174.2	29.6	34.3	37.8	150.1
T_{16}	377.8	182.1	46.0	48.5	49.3	149.7
T_{17}	411.1	194.8	48.8	52.5	58.7	167.5
T_{18}	423.9	217.5	59.5	62.5	67.5	146.9
T_{19}	449.5	228.1	72.8	80.9	83.6	148.6
T_{20}	468.6	244.2	81.7	87.1	94.6	142.7
T_{21}	491.1	260.8	91.2	92.5	99.0	139.1

Table 2: Per cent of different forms of sulphur in respect of total-S in post-harvest surface soils of mustard

Soils	O-S	S-S	TWS-S	HS-S	NS-S
T_1	43.3	5.3	6.6	7.2	51.3
T_2	43.6	6.0	6.6	7.2	50.3
T_3	43.2	7.8	8.6	9.3	49.0
T_4	42.2	10.9	12.0	12.6	46.9
T_5	41.3	14.1	15.6	16.1	44.6
T_6	41.4	17.3	18.0	19.7	41.4
T_7	40.5	20.5	21.2	22.1	39.0
T_8	48.4	8.4	9.1	9.2	43.1
T_9	47.8	8.9	10.2	12.2	43.3
T_{10}	49.0	11.7	13.0	14.4	39.3
T_{11}	48.6	13.4	14.7	14.9	37.9
T_{12}	49.1	16.4	17.9	18.5	34.5
T_{13}	48.1	15.8	18.9	20.0	36.1
T_{14}	48.5	18.3	19.9	20.8	33.2
T_{15}	49.2	8.4	9.7	10.7	42.4
T_{16}	48.2	12.2	12.8	13.0	39.6
T_{17}	47.4	11.9	12.8	14.3	40.7
T_{18}	51.3	14.0	14.7	15.9	34.6
T_{19}	50.7	16.2	18.0	18.6	33.0
T_{20}	52.1	17.4	18.6	20.2	30.4
T_{21}	53.1	18.6	18.8	20.1	28.3

Table 3: Correlation coefficients among different sulphur pool and with plant parameters of Mustard

Parameters	Total sulphur	Organic Sulphur	Sulphate Sulphur	Non-sulphate sulphur	Water soluble sulphur	Heat soluble sulphur
Organic Sulphur	0.932**	-				
Sulphate Sulphur	0.914**	0.752**	-			
Non-sulphate Sulphur	-0.599**	-0.749**	-0.584**	-		
Water soluble sulphur	0.919**	0.757**	0.994**	-0.564**	-	
Heat soluble sulphur	0.926**	0.768**	0.991**	-0.565**	0.997**	-
Grain yield	0326	0.366	0.281	-0.346	0.274	0.277
Straw yield	0.300	0.370	0.200	-0.298	0.193	0.198
S-concentration in grain	0.841**	0.753**	0.837**	-0.559**	0.855**	0.863**
S-concentration in straw	0798**	0.600**	0.905**	-0.403	0.900**	0.904**

S-uptake by grain	0.648**	0.633**	0.613**	-0.519	0.616**	0.623**
S-uptake by straw	0.795**	0.644**	0.857**	-0.450	0.850**	0.854**
Total sulphur uptake	0.790	0.663	0.833	-0.478	0.828	0.833*
Protein content in grain	0.030	-0.040	0.016	0.208	0.024	0.006
Available S	0.914**	0.752**	-	-0.584**	0.994**	0.991*

Table 4: Correlation coefficients (r-values) between sulphur pools and rice parameters

Parameters	Total sulphur	Organic Sulphur	Sulphate Sulphur	Non-sulphate sulphur	Water soluble sulphur	Heat soluble sulphur
Grain yield	0.694**	0.588**	0.710**	-0.394**	0.725**	0.713**
Straw yield	0.580**	0.322**	0.715**	-0.069**	0.742**	0.736**
S-concentration in grain	0.776**	0.628**	0.850**	-0.467**	0.873**	0.869**
S-concentration in straw	0.921**	0.889**	0.857**	-0.674**	0.843**	0.854**
S-uptake by grain	0.782**	0.634**	0.859**	-0.475**	0.882**	0.871**
S-uptake by straw	0.952**	0.856**	0.937**	-0.617**	0.930**	0.938**
Total sulphur uptake	0.867**	0.817**	0.880**	-0.720**	0.871**	0.864**
Protein content in grain	0.078	0.004	0.120	0.059	0.147	0.137
Available S	0.951**	0.835**	0.978**	-0.636**	0.976**	0.975**

Level of Significance at P (0.05) = 0.4329
Level of Significance at P (0.01) = 0.5487

Table 5: Step down Multiple regression sowing the influence of sulphur pools on Plant Parameters of mustard

Dependent variable	Regression coefficient	R2	S.E	R2 (adj)
Sulphur concentration in seed (y3)	0.6598 +0.0003 X2 – 0.0021 X3 +0.0034 X6 (0.196) (-0.932) (1.636)	0.780**	0.026	0.741
Sulphur concentration in straw (y4)	0.0666 + 0.0041 X3** + 0.0015 X4 (1.014) (0.186)	0.843**	0.038	0.826
Sulphur uptake by seed (y5)	5.364 + 0.0114 X2 + 0.0137 X6 (0.377) (0.334)	0.447**	0.787	0.385
Sulphur uptake by straw (y6)	12.4891 + 0.1460** X3	0.737**	2.005	0.724
Total sulphur uptake (Y7)	19.3562 + 0.1739**X3 (0.834)	0.696**	2.642	0.680

Figures in parentheses indicated the Standard regression coefficient
Note: X1= Total-S, X2 = Organic –S, X3 = Sulphate –S, X4= Non – sulphate –S, X5= Total water soluble –S, X6= Heat soluble –S

Table 6: Step down Multiple regression sowing the influence of sulphur pools on Plant Parameters of rice

Dependent variable	Regression coefficient	R2	S.E	R2 (adj)
Grain Yield(Y1)	42.996 +0.091 ** X5 (0.725)	0.525 **	2.082	0.500
Straw Yield (Y2)	47.079 -0.051 X2 -0.273 X3 +0.149 X4 +0.518 X5 (-0.327) (-1.185) (0.319) (2.348)	0.766 **	2.795	0.708
Sulphur concentration in grain (Y3)	0.0673 -0.00071 X3 + 0.00110* X5 (1.364) (2.229)	0.786**	0.006	0.762
Sulphur concentration in straw(Y4)	0.0124 +0.00057 ** X2 +0.0022 *x3-0.0015 X5 (0.595) (1.550) (-1.148)	0.888 **	0.011	0.868
Sulphur uptake by grain (Y5)	2.867 -0.044 X3 +0.070* X5 (-1.313) (2.187)	0.800**	0.355	0.778
Sulphur uptake by straw (Y6)	1.152 + 0.030** X2 + 0.084* X3 (0.350) (0.675)	0.932	0.767	0.925
Total sulphur uptake (Y7)	-03731 + 0.035* X2 + 0.114** X3 + 0.024 X4 (0.335) (0.742) (0.079)	0.935**	0.958	0.923

Figures in parentheses indicated the Slandered Regression coefficient
Note: X1= Total-S, X2 = Organic –S, X3 = Sulphate –S, X4= Non – sulphate –S, X5= Total water soluble –S, X6= Heat soluble –S

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