

## **Suitability of Extractants for Available Sulfur and Relationship of Sulfur Fraction with some Soil Properties in Paddy Soils of Western UP**

VIRINDER SINGH, Y. K. SHARMA, VEER SINGH<sup>1</sup> AND PUNEET MAHAJAN

*Department of Agricultural Chemistry & Soil Science, Gochar Mahavidhyalaya, Rampur Maniharan, Saharanpur 247001, UP, India*

<sup>1</sup>*Department of Soil Science, G. B. Pant University of Agriculture & Technology Pantnagar 263145, Utrakhnad, India*  
*E-mail : veer1969\_singh@yahoo.co.in*

### **Abstract**

An investigation was undertaken to evaluate suitable extractants for available sulfur, different forms of sulfur (S) and their relationship with the some soil properties in paddy soils of Saharanpur district (UP). Soils were found to be neutral to alkaline in reaction (6.0 to 8.6), electrical conductivity and organic carbon content were in lower and medium in magnitude (0.17 to 0.45 ds/m and 4.1 to 8.8 g/kg, respectively), and calcium carbonate varied from 0.5 to 3.0%. The values of available N was found to be (43 to 174 mg/kg) while available P and K was optimum in range (7.5 to 19.6 and 50 to 380 mg/kg, respectively). The content of sand, silt and clay resulted loam texture. Total sulfur, organic sulfur, sodium dihydrogen phosphate extractable sulfur, heat soluble sulfur and calcium chloride extractable sulfur ranged between 261.0 to 670.0, 114.8 to 435.8, 14.7 to 50.7, 14.0 to 48.5 and 11.6 to 47.7 mg/kg, respectively, with corresponding average values of 434.4, 250.2, 30.5, 28.3 and 26.3 mg/kg. The 0.03 M sodium-dihydrogen extractant found to be more compatible to extract the available sulfur over other extractants while organic form of sulphur came out to be most dominant form of sulphur and least was with 0.15% calcium chloride extractable sulfur in all locations. Sulfur forms in the soils of study area were found above the critical limit for paddy crop. Forms of sulfur had significant and positive correlation with OC, available N and clay but not with available K, pH, EC, CaCO<sub>3</sub>, silt and sand. Clay was found to have greater impact on different forms of sulfur followed by available N and organic carbon. Except between total-S and NaH<sub>2</sub>PO<sub>4</sub> extractable-S, the observed correlations were positive among all forms of sulfur.

**Key words :** Paddy soil, Sulfur extraction methods, Forms of sulfur, Soil properties, Critical limit.

Sulfur in Indian agriculture is now gaining added importance because of recognition of its role in increasing crop production, not only of oil seeds, pulses, legumes and forages but also many cereals, plantation crops and forest vegetation. The reports of sulfur deficiency are wide spread being reported from different parts of country. Out of 142 million hectares arable land in India, about 40% suffers from various degrees of sulfur deficiency (1). The reduction of emission of sulfur containing gases as a result of national policies and use of high analysis of low S fertilizers, decline in S containing pesticides and intensive cropping with high yielding varieties as a good endeavour for boosting food production are causing marked depletion in sulfur. The problem is likely to become imminent in the future as the level of native

available sulfur gets depleted to below its critical concentration. Although total and organic sulfur are useful to indicate long-term supply of available sulfur but the content and forms of sulfur in soil are integrated index and their distribution in soil and interrelationship with some soil characteristics decide the sulfur supplying capacity of soil. Sulfur availability in soil system is known to depend upon soil reaction, particles size distribution, redox potential, physiographic through its influence on drainage, leaching, type, vegetation, profiles development. Different forms of sulfur and its availability have been reported in Indian soils (2, 3). Since, no satisfactory information is available for the different forms of sulfur in the study area, the present investigation was undertaken to evaluate the different forms of sulfur and their rela-

**Table 1.** The values of some soil properties of surface soil samples. Parentheses indicate mean values. L=Loam.

Block	pH	EC (dS/m)	CaCO <sub>2</sub> Eq (%)	OC (%)	Av. N (mg/kg)	Av. P (mg/kg)
Rampur	6.2—8.2	0.18—0.40	0.5—2.5	0.45—0.87	85—164	9.5—19.2
Maniharan	(7.0)*	(0.28)	(1.71)	(0.66)	(123.1)	(13.1)
Nanauta	6.2—8.2	0.20—0.40	0.5—2.2	0.45—0.85	85—170	7.5—17.3
	(7.2)	(0.28)	(1.55)	(0.63)	(119.6)	(13.1)
Deoband	6.3—7.8	0.18—0.40	0.5—2.5	0.58—0.85	109—170	9.1—17.6
	(7.0)	(0.27)	(1.50)	(0.71)	(137.3)	(12.9)
Nagal	6.2—8.6	0.19—0.45	0.5—2.5	0.49—0.73	90—135	8.9—17.6
	(7.1)	(0.28)	(1.60)	(0.60)	(112.4)	(13.2)
Balia	6.4—8.2	0.18—0.40	0.5—2.5	0.47—0.70	87—132	9.0—17.8
Kheri	(7.1)	(0.29)	(1.64)	(0.57)	(108.4)	(12.8)
Gangoh	6.0—8.2	0.17—0.43	0.5—2.5	0.50—0.88	93—174	9.3—17.6
	(7.0)	(0.27)	(1.57)	(0.75)	(141.5)	(21.3)
Nakur	6.5—8.2	0.17—0.44	1.0—3.0	0.43—0.70	77—128	8.2—17.3
	(7.2)	(0.29)	(1.85)	(0.57)	(107.2)	(18.3)
Sarsawa	6.2—8.6	0.17—0.45	0.5—2.5	0.44—0.86	80—159	9.5—18.2
	(7.2)	(0.29)	(1.62)	(0.63)	(118.0)	(13.3)
Punwarks	6.0—8.2	0.17—0.40	0.5—2.5	0.45—0.80	80—150	11.0—18.2
	(7.0)	(0.27)	(1.64)	(0.58)	(109.2)	(13.7)
Muzafarab ad	6.0—8.2	0.17—0.40	0.5—2.5	0.58—0.88	106—170	11.5—19.6
	(7.0)	(0.26)	(1.55)	(0.72)	(136.5)	(14.6)
Sadholi	6.4—8.2	0.18—0.40	0.5—2.6	0.41—0.78	43—144	11.3—19.0
Qadim	(7.1)	(0.28)	(1.77)	(0.61)	(110.8)	(14.0)

**Table 1.** Continued.

Block	Av. K (mg/kg)	Sand (%)	Silt (%)	Clay (%)	Class
Rampur	74—150	30.2—64.0	23.0—39.8	13.0—30.0	L
Maniharan	(105.8)	(45.9)	(31.8)	(21.8)	
Nanauta	70—170	32.0—52.0	32.0—42.0	16.0—28.0	L
	(106.8)	(41.1)	(37.5)	(21.2)	
Deoband	77—187	30.0—50.6	31.0—42.0	18.0—28.0	L
	(114.7)	(42.5)	(34.1)	(23.0)	
Nagal	78—212	30.0—55.0	28.0—43.0	17.0—28.0	L
	(111.8)	(43.1)	(34.1)	(22.7)	
Balia	70—125	30.0—55.0	25.0—42.0	15.0—28.0	L
Kheri	(98.6)	(43.4)	(33.1)	(22.6)	
Gangoh	72—214	28.0—54.0	28.0—42.0	18.0—28.0	L
	(124.3)	(40.6)	(35.0)	(23.6)	
Nakur	81—132	32.0—53.0	29.0—41.1	18.0—28.0	L
	(102.8)	(42.2)	(34.0)	(22.7)	
Sarsawa	89—200	30.0—58.1	28.0—42.0	15.0—28.0	L
	(123.6)	(46.2)	(33.8)	(20.0)	
Punwarka	50—163	27.8—60.2	25.0—49.2	14.8—23.0	L
	(97.3)	(44.6)	(37.4)	(17.9)	
Muzafarab ad	70—170	28.0—52.0	33.0—43.5	17.5—28.5	L
	(109.7)	(41.4)	(36.3)	(22.0)	
Sadholi	87—380	26.0—56.0	27.0—52.0	17.0—22.0	L
Qadim	(166.0)	(40.5)	(39.8)	(19.6)	

tionship with some soil properties and their inter-relationship.

### Methods

The study area (district Saharanpur) lies between

**Table 2.** Different form of sulfur in surface soil samples (mg/kg). \*Parentheses indicate mean values.

Block	Total-S	Organic-S	0.03 M NaH <sub>2</sub> PO <sub>4</sub> ext-S	Heat Soluble-S	0.15% CaCl <sub>2</sub> ext-S
Rampur	457.0—670.0	223.2—435.5	28.3—50.7	28.3—45.5	26.0—45.1
Maniharan	(580.2)*	(346.3)	(40.30)	(38.11)	(35.8)
Nanauta	331.0—470.0	191.9—338.1	22.0—42.3	20.1—38.0	16.7—37.7
	(407.9)	(257.5)	(29.9)	(27.9)	(26.3)
Deoband	500.0—600.9	277.1—377.3	30.2—49.5	29.0—48.5	23.2—46.6
	(568.1)	(334.2)	(39.9)	(36.2)	(33.9)
Nagal	520.2—631.0	274.0—435.2	30.0—49.8	27.0—47.6	23.2—47.4
	(578.0)	(358.3)	(40.1)	(37.6)	(34.9)
Balia Kheri	370.6—557.0	222.3—386.1	20.0—46.6	19.6—45.9	18.0—43.3
	(444.2)	(281.4)	(29.5)	(28.4)	(26.7)
Gangoh	300.0—451.7	180.3—293.0	18.6—36.6	15.0—36.1	13.8—35.2
	(366.5)	(249.4)	(39.7)	(25.0)	(23.1)
Nakur	375.0—510.0	227.8—350.5	22.0—39.9	20.0—39.8	20.0—38.4
	(443.4)	(296.2)	(45.5)	(27.8)	(26.6)
Sarsawa	350.0—420.2	205.2—294.9	21.7—28.8	18.0—27.6	17.2—27.3
	(370.9)	(220.0)	(25.5)	(22.9)	(21.7)
Punwarka	367.9—460.7	190.5—307.0	22.6—45.6	19.1—42.8	16.5—41.1
	(409.1)	(245.4)	(30.3)	(27.5)	(25.2)
Muzafarabad	261.0—334.0	114.8—216.6	16.5—25.4	15.3—25.4	11.6—21.7
	(298.6)	(181.8)	(20.3)	(19.2)	(17.0)
Sadholi	280.0—340.0	154.3—211.9	14.7—30.0	14.0—28.9	12.0—25.0
Qadim	(313.2)	(183.9)	(22.4)	(20.9)	(19.1)

77°15' and 76°0' E and 27°10' and 29°34' N latitude having an altitude of 275.05 m above mean sea level and situated below foot hills of North Himalaya. The winter season is fairly cold and the summer is appreciable hot and temperature touches 0C during winter to 40C during summer season. Showers are frequent during January.

Two hundreds randomly collected soil samples from eleven blocks (18 from ten and 20 samples from one block) from 0—30 cm depth of paddy soils were dried in shade after mixing it thoroughly and then grinded samples were passed through 2 mm sieve. The different physico-chemical, chemical and physical properties of the representative soil samples viz. soil reaction (pH), electrical conductivity (EC), calcium carbonate eq. (CaCO<sub>3</sub>) and oxidizable organic carbon (OC), N, P, K and particle size analysis were determined by following the standard methods as suggested by Jackson (4). The status the available S was determined separately by using the solutions of 0.15% calcium chloride and heat soluble S (5) and 0.03M sodium dihydrogen phosphate (6) as an extractants to find out their suitability. Total sulfur and organic sulfur contents were estimated following the meth-

ods given by Kalthoff (7), and Bradsley and Lancaster (8) respectively. Simple correlation coefficients among forms of sulfur extracted by different extractants and some soil properties and inter-correlation among forms of sulfur were computed by adopting standard statistical procedures.

## Results and Discussion

### *Physico-Chemical Soil Properties*

The values of soil physico-chemical, chemical and physical properties and different forms of sulfur with range and average in various locations are presented in Table 1. The soil pH, EC, CaCO<sub>3</sub> and OC values varied from 6.0 to 8.6, 0.17 to 0.45 dS/m, 0.5 to 3.0% and 4.1 to 8.8 g/kg, with mean values of 7.08, 0.27 dS/m, 1.63% and 6.3 g/kg, respectively. Data showed that soils of the entire study area did not vary much in their values resulting neutral to alkaline in reaction. The observed pH range was quite comparable to 6.0—8.1 with mean value of 6.8 (9). Electrical conductivity and CaCO<sub>3</sub> eq. were of lower magnitude which could be attributed to fact that the soils of the district are well drained and soluble salts which re-

**Table 3.** The values of correlation coefficients (*r*) between soil properties and forms of sulfur in surface soil. \*\*Significant at 1% level of significance, \*Significant at 5% level of significance.

Soil property	Total-S	Organic-2	0.03M NaH <sub>2</sub> PO <sub>4</sub> ext-S	Heat soluble	0.15% CaCl <sub>2</sub> ext-S
1. pH	-0.284**	-0.337**	0.115	-0.215**	-0.185**
2. EC	-0.257**	-0.302**	-0.092	-0.195**	-0.175*
3. Org. carbon	0.375**	0.081	0.421**	0.127	0.096
4. CaCO <sub>3</sub>	-0.281**	-0.309**	-0.072	-0.214**	-0.212**
5. Available N	0.205**	0.270**	0.129	0.181**	0.163*
6. Available P	-0.379**	0.228**	0.909**	-0.005	0.007
7. Available K	-0.108	-0.194**	-0.148*	-0.151*	-0.158*
8. Sand	-0.038	-0.309**	-0.401**	-0.125	-0.119
9. Silt	-0.129	-0.015	0.108	-0.058	-0.058
10. Clay	0.275**	0.480**	0.331**	0.246**	0.33**

sulted to EC are washed out by Ganga and Yamuna rivers and their tributaries to the plains of neighboring districts. The organic carbon content, in general, was observed medium in range, however, the Gangoh, Muzafarabad and Deoband blocks showed the slightly higher content of OC (Table 1) because of there areas are dense planted and undergo forestry system leading to rice in litter. The available N, P and K ranged from 43 to 174 (120.3 mg/kg), 7.5 to 19.6 (14.57) mg/kg, and 50 to 380 (117.0 mg/kg), respectively. The results revealed that available N was low but P and K were in optimum range. It might be due to intensively cultivation owing to higher exploitation of available N. The close variation in soil particles were observed in all locations. The content of sand, silt and clay varied from 26.0 to 64.0, 23.0 to 52.0, and 13.0 to 30.0% with the respective mean values of 45.8, 35.1 and 21.6% resulted loam texture in which more clay content contributes more OC (Table 1).

#### Forms of Sulfur

The data on the amount of different forms of sulfur are presented in Table 2.

**Total Sulfur.** Total sulfur ranged from 261.0 to 670.0 mg/kg in Muzafarabad and Rampur Maniharan, respectively, with mean value of 434.4 mg/kg. Since the total sulfur in agriculture soils normally ranged between 100.0—500.0 mg/kg (10), these soils, therefore, may be rated as medium to high. Data revealed that higher contents were found in Rampur maniharan, Deoband and Nagal as compared to other blocks which might be due to the variation in basic rocks

from which the soils had derived and the higher content of organic carbon.

**Organic Sulfur.** The amount of organic sulfur ranged from 114.8 to 435.8 mg/kg with mean values of 250.2 mg/kg. The higher organic sulfur contents were determined in soils of Rampur Maniharan and Nagal and least in Muzafarabad. The organic sulfur in some soils was found to be associated with higher contents of total sulfur and organic carbon but, in general, in other soils it did not bear relationship with total sulfur and organic carbon. This finding is corroborating with the finding of Pandey et al. (11).

**Available Sulfur Extracted by Different Extractants.** The extractable/available sulfur extracted by 0.03M sodium-dihydrogen, heat soluble and 0.15% calcium chloride extractants varied between 14.7 to 50.7, 14.0 to 48.5 and 11.6 to 47.7 mg/kg, respectively, with corresponding mean values of 30.5, 28.3 and 28.3 mg/kg. The amounts of available sulfur extracted by different extractants showed the wide variation in all locations but the differences in available sulfur among the locations were observed quite close. The available sulfur in all locations was found to be in the following decreasing order : 0.03M NaH<sub>2</sub>PO<sub>4</sub> > heat soluble > 0.15% CaCl<sub>2</sub>. The higher status of 0.03<sub>M</sub> NaH<sub>2</sub>PO<sub>4</sub> extractable sulfur as compared to other two extractants was might be due to the better extraction capacity of NaH<sub>2</sub>PO<sub>4</sub> which extract readily soluble sulfate plus part of adsorbed sulfate plus part of organic sulfur, whereas, heat soluble and calcium chloride extract readily soluble sulfur plus part of adsorbed sulfate and only readily soluble sulfur, respectively

**Table 4.** Inter-correlation coefficients ( $r$ ) among different forms of sulfur in surface soil. \*\*Significant at 1% level of significance.

	Organic-S	0.03M NaH <sub>2</sub> PO <sub>4</sub> ext-S	Heat soluble	0.15% CaCl <sub>2</sub> ext-S
Total-S	0.751**	-0.122	0.740**	0.706**
Organic-S		0.480**	0.744**	0.722**
0.03M NaH <sub>2</sub> PO <sub>4</sub> ext-S			0.311**	0.311**
Heat soluble				0.959**

(12). The higher availability of sulfur was noticed in soils of Deoband and Nagal with all extractants which may be because of higher organic matter and presence of soluble salts.

#### *Relationship between the Soil Properties and Forms of Sulfur*

Except the 0.03M NaH<sub>2</sub>PO<sub>4</sub> extractable sulfur, all other forms of sulfur were significantly and negatively correlated with soil pH, EC and CaCO<sub>3</sub> eq. (Table 3) indicated that increase in pH value would result decrease in the forms of sulfur. These findings are similar to that reported in many earlier studies (11, 13). Organic carbon was found to be positively and significantly correlated with total (0.375\*\*) and 0.03M NaH<sub>2</sub>PO<sub>4</sub> (0.421\*\*) extractable sulfur but positively with other forms of sulfur corroborating the findings of Bhatnagar and Bhadauria (14) and Pareek (15). It might be attributed to that most of sulfur present in soil is in organic matter and this enriches the soils with in organic sulfur (16). Positive and significant correlation of available N was obtained with all forms of sulfur except 0.03M NaH<sub>2</sub>PO<sub>4</sub> extractable sulfur. Available P showed significant correlation with total sulfur ( $r = -0.379$ \*\*), organic sulfur ( $r = 0.228$ \*\*) and 0.03M NaH<sub>2</sub>PO<sub>4</sub> extractable sulfur ( $r = 0.909$ \*\*) but non-significant with heat soluble sulfur ( $r = -0.005$ ) and 0.15% CaCl<sub>2</sub> extractable sulfur ( $r = 0.007$ ). The highly significant positive correlation ( $r = 0.909$ \*\*) may be due to the reason that better extraction capacity of the extractant to release phosphate bond sulfur from the total sulfur pool of the soil. All forms of sulfur were found to have significantly negative relationship with available K.

Particle size analysis indicated that sand content

was negatively and significantly correlated with organic (-0.309\*\*) and 0.03M NaH<sub>2</sub>PO<sub>4</sub> extractable (-0.401\*\*) sulfur but negative and non-significant with rest of the forms of sulfur. Silt also observed negative and non-significant relationship with all forms of sulfur except 0.03M NaH<sub>2</sub>PO<sub>4</sub> extractable sulfur. But positive and significant relationship was noticed between clay and all forms of sulfur, it might be due to increase in holding capacity of soils and formation of organic complex which is supposed a reserve pool for sulfur since sulfate sulfur and other forms of sulfur are in dynamic equilibrium and related significantly to each other. Similar correlations between clay and all form of sulfur were reported by Sharma and Gangwar (13) and Kumar (9).

#### *Interrelationship Among Different Soil Sulfur Fractions*

Negative and non-significant inter-correlation was observed between total and 0.03M NaH<sub>2</sub>PO<sub>4</sub> extractable sulfur while inter-correlations among different forms of sulfur were significant and positive at 1% level of significance (Table 4). Similar inter-correlations among different sulfur fraction were also reported by several workers (17, 18). Since sulfate sulfur and other forms of sulfur are in a dynamic equilibrium, therefore, related significantly to each other.

Among the different extractants used for estimating the available sulfur forms, CaCl<sub>2</sub> extractant was found most suitable over the other extractants. Considering the critical limits of 11, 10 for NaH<sub>2</sub>PO<sub>4</sub> ext-S, CaCl<sub>2</sub> ext-S (test crop-rice), respectively and 12.5 mg/kg for heat soluble sulfur (test-wheat), it was concluded that all the soils in the study area are above the critical limit for paddy crop. However, for a given soil crop situation, more than one extractant could be suitable but the critical limits used for delineating soils into deficient and non-deficient categories would vary with the method. Therefore, it must be emphasized that there is need to determine critical limits for different soil crop situation for proper delineation of sulfur deficient areas.

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