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Distribution of different forms of Sulphur and their relationship with properties of soils of Banaskantha district under groundnut cultivation

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Abstract
A study was undertaken to delineate the status of different forms of sulphur for which one hundred forty surface soil samples (0-15 cm) from various groundnut growing fields (Ten samples from each taluka) of Banaskantha were collected during May, 2018 by using multistage stratified random sampling. The groundnut growing soils of study area had the major part of their sulphur content in non sulphate sulphur (59.01 per cent) and followed by organic sulphur (34.16 per cent) and sulphate sulphur (6.84 per cent) of the total sulphur. The mean value of total sulphur, organic sulphur, sulphate sulphur, non sulphate sulphur, heat soluble sulphur and water soluble sulphur of the study area were to the tune of 145.72, 49.79, 9.98, 86.06, 12.32 and 7.35 mg kg^{-1}, respectively. All the forms of sulphur were positive correlated with EC, organic carbon, available phosphorous, available potassium, clay and silt content. But, it was negatively correlated with sand and pH except organic–S. Thus, indicating that these soil properties played a major role in availability of sulphur content. The different forms of sulphur were correlated positively with each other, except non sulphate sulphur which was negatively correlated with organic sulphur, sulphate sulphur and water soluble sulphur. On the basis of sulphate fraction, 69.3 per cent of the soil samples were found deficient. The present study indicates that groundnut growing soils in Banaskantha district of Gujarat are deficient in available sulphur and thus, calls for sound integrated fertility management programme for better groundnut production in the district.

Keywords: Sulphur fractions, Groundnut, Banaskantha

Introduction
India occupies the first position in the world both in area and production of groundnut and accounts for about 40 per cent of world's area and 30 per cent of the world's production. In India, groundnut is the principal oil seed crop has a vital role in Indian agriculture industry and export trade with the economy of country. It has a specific place in Indian agriculture because edible oil is next to food grain.

Groundnut is known by many other local names such as earthnuts, monkey nuts, gobber peas and pygmy nuts. Despite, its name and appearance the peanut is not a nut, but rather a legume. It is mainly cultivated in *kharif* and summer seasons. Groundnut is a rich source of energy as it contains about 50 per cent edible oil and the remaining fifty per cent in seed has high quality protein (22 to 30 per cent), carbohydrate (13 to 16 per cent), minerals like calcium, magnesium, iron and vitamins like B_1 and B_2 (Das, 1997) [5]. The chemical composition of groundnut compares favorably with the dry fruits. Some of the nutrients like protein and vitamins (Thiamine, Riboflavin and Niacin) are available in higher quantities in groundnut than dry fruits. One gram kernels supplies 5.8 calories. Groundnut oil is also considered as a stable and nutritive food as it contains the right proportion of oleic (40 to 50%) and linoleic (25 to 35%) acids (Mathur and Khan 1997) [16]. The groundnut cake is a good source of protein for milch animals. It also contains about 7 to 8 per cent nitrogen and considered as concentrated organic manure. Apart from oil and cake, the haulm is a better nutritious fodder for animals. Moreover, as a leguminous crop, it helps in improving soil fertility.

Sulphur is a constituent of protein and plays an important role in oil synthesis. Since groundnut is rich both in oil and protein, requirement of sulphur for this crop is substantial. Application of sulphur also regulates the pH and increases the availability of other nutrients. It improves nodulation, pod yield and reduces the incidence of diseases. Sulphur increases chlorophyll and decreases chlorosis. It also involves in the formation of glucosides or glucosinolates, which on hydrolysis increase the oil content and improve the quality of oilseeds. In most of the groundnut growing tracts of south-western, semi-arid central plain Agro-climatic Zones of Uttar Pradesh, the level of available sulphur reaches below the critical limit and groundnut crop is bound to suffer on account of sulphur deficiency.

Sulphur deficiency is increasing day by day because we are using only high analysis fertilizers (N, P and K), increased use of sulphur free fertilizers and intensive cultivation of high sulphur requiring crops which severely affect the soil health and also affect the economic returns. Sulphur, therefore now became a part of balanced fertilization. Sulphur deficiencies can only be corrected by the application of sulphur fertilizers. Several workers also reported that application of sulphur increased the yield as well as uptake of nutrients (Jaggi *et al.*, 1995) [9].

Sulphur exists in soil as free and adsorbed sulphate and in diverse organic and inorganic compounds. In the humid region, it is in organic forms, while in arid soils the sulphate salts of calcium, magnesium, sodium, and even potassium free dominant (Kanwar, 1976) [12]. Under taking of different forms of sulphur and factors affecting their distribution throughout the root zone penetration is essential in improving the sulphur nutrition of the crops growing with diversified root system. Sulphur can be applied to the soil through any suitable sulphur carrier's *viz.* gypsum, elemental sulphur, ammonium sulphate and potassium sulphate, *etc.* The choice of source depends on the crop, local availability, price and requirement of other nutrients. Among the sulphur supplying sources, gypsum and elemental sulphur are being abundantly used in sulphur deficient soil. Thus, present survey work was planned to conduct systematic soil survey to study the distribution of different forms of sulphur and their relationship with properties of soils of Banaskantha district under groundnut cultivation.

Materials and Methods

For the determination of different fractions of sulphur (total sulphur, organic sulphur, sulphate sulphur, non sulphate sulphur, water soluble sulphur, heat soluble sulphur) and various physico-chemical properties of soil (mechanical analysis, EC, pH, OC, P_2O_5 and K_2O) of Banaskantha district, soil samples were collected from groundnut growing fields.

Geographically, Banaskantha district is situated in northern part of Gujarat and falls under North Gujarat Agro Climatic Zone. It lies between 23° 30' to 24° 45'N latitudes and 71° 03' to 73° 02' E longitudes with an elevation of 154.52 Mt. above the mean sea level. It is surrounded by Barmer and Sirohi area of Rajasthan in north, Patan district in south, Sabarkantha district in east and Kutch district in the west. The district comprises of 6.58 per cent of total geographical area of the state. The total geographical area of district is 10,400 sq. km. having 14 talukas. Geographically, it is divided into two main parts *i.e.* Northeast hilly portion and western plains.

The region is characterized by arid and semi arid climate with extreme cold winter, hot and dry summer, rainfall is erratic and uneven involving intermittent long dry spell and late onset and early withdrawal of monsoon. In general monsoon commences in the last week of June or first week of July and retreats by the middle of September. Most of the precipitation is received from South-West monsoon concentrating in the month of July and August. The average annual rainfall of the season is about 600 mm. The minimum temperature of season is observed in the month of December and January. The rising in temperature starts from middle of February and reaches maximum in the month of May. It ranges from 30° to 45° C.

Geological area has different types of geological formation from archean to recent alluvium. In general, the soils of Banaskantha district are sandy to sandy loam in texture, having very low organic matter with poor moisture retention capacity. The soils are highly prone to water as well wind erosion. Fertile alluvial soil type is found in middle part of the district *i.e.* Deesa, Dantiwada and Deodar talukas, while clay to clay loam soils are found in eastern part of the district *i.e.* Danta and Amirgadh talukas. Salt affected soils are also present in western part of Banaskantha *i.e.* Tharad, Vav, Suigam and Bhabhar talukas.

Collected 140 representative surfaces (0-15 cm) soil samples from groundnut growing fields of Banaskantha district, in which ten soil samples from each taluka of district were collected by using multistage stratified random sampling method (Singh *et al.*, 1982) [25]. The soil samples were drawn with the help of stainless steel auger. The collected soil samples were air dried in shade. The dried soil samples were ground with the help of wooden mortar and pestle and pass through 2.0 mm sieve. The prepared samples were stored in polyethylene lined cloth bags for detailed analysis. During the course of sample processing all the precautions were taken to avoid any contamination. The soil samples were brought to laboratory for further analysis. The prepared soil samples were analyzed for their various physicochemical properties *viz.*, mechanical analysis, soil reaction, electrical conductivity, organic carbon, available phosphorus and potassium and different forms of sulphur. The standard analytical methods used for the analysis of soil samples are given in Table 1.

Results and Discussion

Status of different forms of sulphur

Soil samples collected from groundnut growing fields of Banaskantha district and analyzed them for different forms of sulphur i.e. heat soluble sulphur, organic sulphur, non-sulphate sulphur, sulphate sulphur, water soluble sulphur and total sulphur. The analysed data of different forms of sulphur and the taluka wise range and mean values are presented in Table 2.

Total sulphur

Total sulphur varied widely in different talukas of Banaskantha district. The data presented in Table 2 indicates that overall total sulphur ranged from 126.74 mg kg^{-1} to 410.50 mg kg^{-1} with a mean value of 145.72 mg kg^{-1}. The highest total sulphur (410.50 mg kg^{-1}) was recorded in Mudetha village of Deesa taluka and the lowest content (126.74 mg kg^{-1}) was obtained in Chadotar village of Palanpur taluka. The highest mean (169.09 mg kg^{-1}) value of total sulphur was recorded in Deesa taluka and followed by Kankrej taluka (149.88 mg kg^{-1}). The lowest mean (138.30 mg kg^{-1}) value of total sulphur was recorded in Palanpur taluka and followed by Deodar taluka (140.81 mg kg^{-1}). This might be due to the low organic matter, clay and silt content in soils of these areas. These results are in agreement with those reported by Jat and Yadav (2006) [10], Patel *et al.* (2011) [22] and Misal (2015) [17]. The relative abundance of different forms of sulphur in Banaskantha district was in the following order: Total sulphur > Non-sulphate > Organic sulphur > Heat soluble sulphur > sulphate sulphur > water soluble sulphur.

Organic sulphur

The data given in Table 2 indicates that the organic-S content in groundnut growing fields of Banaskantha district varied from 30.21 mg kg^{-1} to 67.24 mg kg^{-1} with a mean value of 49.79 mg kg^{-1}. The highest organic sulphur (67.24 mg kg^{-1}) was recorded in Limboi village of Vadgam taluka and the lowest content (30.21 mg kg^{-1}) was obtained in Jasali village of Deodar taluka. The highest (60.94 mg kg^{-1}) and lowest (42.04 mg kg^{-1}) mean value of organic-S were recorded in

Vadgam and Palanpur talukas of Banaskantha, respectively. The organic sulphur contributed to about 34.16 per cent of the total sulphur content. The quantity of organic sulphur in present investigation was lower than those reported from peat, muck, hilly, organic and acidic soils because the organic sulphur is a constituent of soil organic matter which is low due to rapid oxidation of organic matter by prevailing high temperature during summer month and low rainfall in these area (Bailley, 1985 and Singh *et al.*, 1993) [2, 27]. Similar results were obtained for organic-S by Patel and Patel (2008) [21] for the soils of Gandhinagar district, Jat and Yadav (2006) [10] for soils of Jaipur district, Patel *et al.* (2011) [22] for the soil of Banaskantha district.

Sulphate sulphur

The data presented in Table 2 explicits that the sulphate sulphur content of the soils of Banaskantha district ranged from 8.03 mg kg^{-1} to 46.35 mg kg^{-1} with a mean value of 9.98 mg kg^{-1}. The highest sulphate sulphur content (46.35 mg kg^{-1}) was recorded in Tirthgam village of Vav taluka and the lowest content (8.03 mg kg^{-1}) was obtained in Pepral village of Lakhani taluka. The highest mean value (14.68 mg kg^{-1}) of sulphate sulphur was recorded in Vav taluka while the lowest mean value (8.81 mg kg^{-1}) was recorded in Tharad taluka followed by Lakhani taluka (8.85mg kg^{-1}) of Banaskantha district. The sulphate sulphur contributed about 6.84 per cent of the total sulphur content in soil. About 69.30 percent soil samples were found low in sulphate sulphur content of the district. The lower value of sulphate sulphur in Banaskantha district might be due to the nature and properties of soils and environmental (hot and tropical) conditions, where, rainfall and topography did not allow the sulphate sulphur to accumulate in rhizosphere (Karwasara *et al.*, 1990) [13]. The results are in close conformed to the findings of Jat and Yadav (2006) [10], Patel *et al* (2011) [22] and Misal (2015) [17].

Non-Sulphate sulphur

Taluka wise range and mean values of non sulphate S are exhibited in table 2 revealed that the Non sulphate S in soil of Banaskantha varied from 34.69 mg kg^{-1} to 327.47 mg kg^{-1} with a mean value of 86.06 mg kg^{-1}. The highest non sulphate sulphur (327.47 mg kg^{-1}) was recorded in Mudetha village of Deesa taluka and the lowest content (34.69 mg kg^{-1}) was obtained in Tirthgam village of Vav taluka. The highest mean value of (110.52 mg kg^{-1}) non sulphate S was recorded in Deesa taluka followed by Dantiwada taluka (89.80 mg kg^{-1}) and Kankrej taluka (89.61 mg kg^{-1}). The lowest mean value of (69.69 mg kg^{-1}) non sulphate S was recorded in Vadgam taluka followed by Dhanera taluka (78.57 mg kg^{-1}).The non sulphate sulphur as described by Evens and Rost (1945) is the sulphur that remains unextracted after the removal of organic sulphur and sulphate sulphur and is mostly made up of insoluble compound of Ba, Ca, etc. occluded in and adsorbed on the carbonate of soil. The non sulphate sulphur contributed to about 59.01 per cent of the total sulphur content. The fractions of this forms of sulphur was greater in light texture soil compared to acidic, peat and organic soils. This might be due to rapid oxidation of organic matter and mineralization of sulphur (Hariram and Dwivedi, 1994) [7]. The value of non sulphate S are comparable with those reported by Kumar and Singh (2010) [15], Jat and Yadav (2006) [10] for soil of Jaipur, Patel *et al.* (2011) [22] for soil of Banaskantha and Misal (2015) [17].

Heat soluble sulphur

Taluka wise range and mean value of heat soluble sulphur of all the fourteen talukas of Banaskantha are presented in Table 2. The overall range and mean value of heat soluble S were 5.92 mg kg^{-1} to 34.27 mg kg^{-1} and 12.32 mg kg^{-1}, respectively. The highest heat soluble sulphur (34.27 mg kg^{-1}) was recorded in Mudetha village of Deesa taluka and the lowest content (5.92 mg kg^{-1}) was obtained in Sutharnesadi village of Bhabhar taluka. The highest mean value (14.34 mg kg^{-1}) of heat soluble sulphur was obtained in Deesa taluka followed by Kankrej taluka (12.72 mg kg^{-1}). While the lowest mean value (11.61 mg kg^{-1}) was observed in Bhabhar taluka and followed by Palanpur taluka (11.78 mg kg^{-1}). These findings are in close agreement with the finding of Deshmukh *et al.* (2004) [6], Patel (2004) [20] and Singh and Singh (2007) [26].

The specific forms of sulphur in soil that are available to plants are incompletely understood. Although, it has been demonstrated in nutrient culture that organic S compounds may be utilized by plants (Bardsley and Lancaster, 1960), it is generally accepted that most of the sulphur in soils is absorbed by plants in the sulphate form (Jordan and Ensminger, 1958) [11]. However, both organic sulphur and inorganic sulphur in soil may contribute to plant nutrition, depending upon on crop, soil and the particular cropping system.

Water soluble sulphur

Water soluble sulphur content of collected soil samples were varied from 6.20 mg kg^{-1} to 30.25 mg kg^{-1} with a mean value of 7.35 mg kg^{-1} (Table 2). The highest water soluble sulphur (30.25 mg kg^{-1}) was recorded in Tirthgam village of Vav taluka and the lowest content (6.20 mg kg^{-1}) was also obtained in Rampura village of Vav taluka. The highest mean value (9.17 mg kg^{-1}) of water soluble sulphur was recorded in Vav taluka and followed by Vadgam taluka (7.62 mg kg^{-1}). The lowest mean (6.74 mg kg^{-1}) water soluble sulphur was recorded in Tharad taluka followed by Dhanera taluka (6.97 mg kg^{-1}). The results are in the line of those reported by Jat and Yadav (2006) [10], Patel *et al.* (2011) [22] and Misal (2015) [17]. Generally, Water soluble sulphur in medium black soils is within 10 per cent of total sulphur. However, it varies from one percent in certain acid soils to 55 per cent of more sulphur as found in paddy soil.

Relationship between different forms of sulphur and physico-chemical properties of soil

The results on the relationship between different forms of sulphur with different soil properties are expressed in the forms of their coefficient of correlation value (‘r’) for the collected soil samples are presented in Table 3. Sand is negatively correlated with all forms of sulphur as well as various physic-chemical properties of soil. This indicates that the sand particles are attributed to less organic carbon accumulation and high leaching. Silt is highly significantly positively correlated with heat soluble sulphur and total sulphur and it has positive correlation with remaining forms of sulphur and all physico-chemical properties of soil except sand content of soil it has significant negative correlation (r=-0.692**) with sand content and with higher pH of the soil. Clay content of the soil positively correlated with all forms of sulphur and majority of physico-chemical properties of soil except sand content and pH. This might be due to appreciable quantity of sulphur is adsorbed on finer fraction of soil and its availability is increase with increase in fineness of particles. The association of clay mineral with organic matter and sulphate and non-sulphate bearing minerals might be responsible for such relationship, as reported by Kher and Singh (1993) [14] and Patel *et al.* (2011) [22].

The correlation coefficients of pH with different forms of sulphur and physico chemical properties of soils were found negative except silt content of soil. This might be due to the presence of H^+ and OH^- ions on the soil complex, where H^+ ion attracts SO_4^{-2} ions (Sharma and Gangawar, 1997) [24] causes decrease in sulphur content. EC was positively correlated with all forms of sulphur indicated that availability of sulphur was increased with increase in EC of soil may be due to the soil samples collected from the groundnut fields have safe limit of salt. Similar results were obtained by Jat and Yadav (2006) [10], Desmukh *et al.* (2004) [6] and Patel *et al.* (2011) [22].

The positive relationship of organic carbon with the all forms of sulphur and various physic-chemical properties of soils were recorded, except pH and sand content. Simultaneous increase in the status of organic sulphur with increase in organic carbon content (‘r’= 0.270**), may be due to organic matter which is a source of the nutrients especially N, P and S. Similar results were obtained by Jat and Yadav (2006) [10] and Patel *et al*. (2011) [22].

The available phosphorus was significantly positively correlated with total sulphur (‘r’= 0.228**), non sulphate sulphur (‘r’= 0.257**) and heat soluble sulphur (‘r’= 0.214*) and also positively correlated with remaining forms of sulphur. The available phosphorus was significantly positively correlated with all the soil properties except pH (‘r’= -0.125) and sand content (‘r’= -0.235**). Thus, the availability of phosphorous was reduced with increase in alkalinity hazards of soil on accounts of the accumulation of soluble salts and exchangeable sodium. Furthermore, the availability of phosphorus also increases with increase in organic carbon due to the formation of phosphorous humic complex which are easily assimilated by plants, anions replacement of phosphate by humation and the coating of sesquioxide by particles of humas to form a protective cover and thus reduced the phosphate fixing capacity of the soils. The similar findings were also reported by Akbari *et al.* (1993) [1], Jat and yadav (2006) [10] and Patel *et al.* (2011) [22].

The available potassium was positively correlated with all the forms of sulphur, It has significant positive correlation with EC (‘r’= 0.234**), OC (‘r’= 0.179*) and available phosphorus (‘r’= 0.374**). Potassium is also positively correlated with clay and silt but, it was negatively correlated with pH (‘r’= -0.014) and sand content (‘r’= -0.113). This might be due to the fact that at higher pH, the availability of potassium decreases at higher exchangeable sodium percentage. This was also is supported by adverse physical condition prevailing in the presence of excessive sodium as reported by Jat and Yadav (2006) [10] and Patel *et al.* (2011) [22].

Correlation among different forms of sulphur

Sulphur transformation and its availability in soils depend on its various forms. In order to judge the contribution of various forms of sulphur towards the availability of sulphur in soil, it becomes imperative to work out the correlation within the different forms of sulphur. The results of correlation among the distribution forms of sulphur are presented in Table 3.

The total sulphur has highly significant positive correlation with heat soluble sulphur (‘r’= 0.961**) and non sulphate sulphur (‘r’= 0.926**), while significant positive correlation with organic sulphur (‘r’= 0.169*). It was positively correlated with sulphate sulphur (‘r’= 0.075) and water soluble sulphur (‘r’= 0.037). Similar relationship was also reported by Jat and Yadav (2006) [10] and Patel *et al.* (2011) [22]. The organic sulphur was significantly positively correlated with heat soluble sulphur (‘r’=0.183*) and total sulphur (‘r’=0.169*), while positive correlated with sulphate sulphur (‘r’=0.098) and water soluble sulphur (‘r’=0.103) but negatively correlated with non sulphate sulphur (‘r’=-0.127).

Looking to the correlation between available forms of sulphur (SO_4^{-2}) and other forms of sulphur, it was highly significantly positively correlated with water soluble sulphur (‘r’=0.938**), while sulphate sulphur was positive correlated with heat soluble sulphur (‘r’=0.076), organic sulphur (‘r’= 0.098) and total sulphur (‘r’=0.075) but negatively correlated with non sulphate sulphur (‘r’= -0.072). The results are closely supported by Misal *et al.* (2017) [18]. Non sulphate sulphur was highly significantly positively correlated with total sulphur (‘r’= 0.926**) and heat soluble sulphur (‘r’= 0.879**), while negatively correlated with organic sulphur (‘r’= -0.127), sulphate sulphur (‘r’= -0.072) and water soluble sulphur (‘r’= -0.095).

Table 1: Standard analytical methods used for the analysis of soil samples

Sr. No.	Parameter	Method	Reference
1.	Mechanical analysis	International pipette method	Piper (1950)
2.	pH	Potentiometric	Jackson (1973)
3.	EC	Conductometric	Jackson (1973)
4.	Organic carbon	Walkley and Black’s wet digestion method	Jackson (1973)
5.	Available P_2O_5	Extraction with 0.5M $NaHCO_3$ (pH 8.5) Colorimetric	Olsen *et al*. (1954)
6.	Available K_2O	Extraction with 1N NH_4OAc (pH 7.0) Flame photometric	Jackson (1973)
7.	Total-S	KNO_3+ HNO_3 (9:4)	Chaudhary and Cornfield (1966)
8.	Organic-S	$Na(H_2PO_4)$	Bardsley and Lancaster (1965)
9.	Sulphate-S	0.15% $CaCl_2$	Williams and Steinbergs (1959)
10.	Water soluble-S	1% NaCl	Williams and Steinbergs (1959)
11.	Heat water soluble-S	1% NaCl after heating	Williams and Steinbergs (1959)
Non Sulphate-S		Subtraction =Total-S –(Organic-S + Sulphate-S)	

Table 2: Status of different forms of sulphur in soils of Banaskantha district

Sr. No.	Name of taluka	Forms of sulphur (mg kg^{-1})					
		Total-S	Organic-S	SO_4^{-2}S	Non-SO_4^{-2} S	Heat soluble S	Water soluble S
1	**Amirgadh**						
	Minimum	130.92	42.34	8.30	68.09	10.01	6.55
	Maximum	178.09	64.43	10.68	110.08	14.81	7.54
	Mean	146.56	48.76	9.47	87.90	12.17	7.08
2	**Bhabhar**						
	Minimum	137.88	39.35	8.71	83.93	5.92	6.83
	Maximum	153.20	50.12	10.36	99.10	12.98	7.54
	Mean	144.01	45.37	9.40	89.24	11.61	7.10
3	**Danta**						
	Minimum	130.92	40.01	8.85	61.82	11.14	6.83
	Maximum	158.38	63.61	10.68	99.20	13.40	8.10
	Mean	143.93	45.91	9.66	88.16	12.23	7.27
4	**Dantiwada**						
	Minimum	132.31	37.59	8.71	70.35	11.28	6.83
	Maximum	177.49	52.08	10.77	116.46	14.95	8.24
	Mean	146.08	45.83	10.05	89.80	12.38	7.45
5	**Deesa**						
	Minimum	135.97	40.88	8.85	77.77	11.71	7.12
	Maximum	410.50	61.55	13.48	327.47	34.27	8.50
	Mean	169.09	47.50	9.87	110.52	14.34	7.40
6	**Dhanera**						
	Minimum	136.49	50.81	8.71	68.37	11.57	6.83
	Maximum	150.42	64.43	9.67	86.03	12.83	7.12
	Mean	142.48	58.82	9.10	78.57	12.13	6.97
7	**Deodar**						
	Minimum	130.92	30.21	8.71	73.34	11.14	6.70
	Maximum	151.81	50.06	9.95	105.93	12.98	7.40
	Mean	140.81	46.17	9.28	85.36	11.99	7.03
8	**Kankrej**						
	Minimum	136.49	40.47	8.99	76.41	11.57	7.10
	Maximum	169.52	58.02	10.90	100.92	14.39	7.68
	Mean	149.88	50.12	9.84	89.61	12.72	7.33
9	**Lakhani**						
	Minimum	136.49	46.01	8.03	74.85	11.57	6.55
	Maximum	155.99	66.27	9.40	93.84	13.26	7.40
	Mean	144.43	51.89	8.85	83.69	12.28	7.02
10	**Palanpur**						
	Minimum	126.74	33.28	8.85	68.41	10.72	6.83
	Maximum	146.24	47.97	10.49	100.09	12.41	7.68
	Mean	138.30	42.04	9.80	86.46	11.78	7.36
11	**Suigam**						
	Minimum	137.88	45.75	8.17	74.24	11.71	6.60
	Maximum	160.17	60.65	10.91	99.89	13.68	7.82
	Mean	146.80	52.01	9.73	85.0	12.48	7.32
12	**Tharad**						
	Minimum	137.88	46.31	8.08	72.83	11.71	6.50
	Maximum	149.02	63.61	9.26	88.79	12.69	6.97
	Mean	143.31	54.61	8.81	79.09	12.19	6.74
13	**Vadgam**						
	Minimum	133.70	56.50	8.85	49.36	11.42	7.10
	Maximum	154.60	67.24	19.91	84.88	13.12	9.09
	Mean	141.64	60.94	11.02	69.69	12.06	7.62
14	**Vav**						
	Minimum	129.53	41.07	8.99	34.69	11.00	6.20
	Maximum	155.99	55.45	46.35	100.16	13.26	30.25
	Mean	142.76	47.10	14.68	80.98	12.14	9.17
Banaskantha district							
Minimum		126.74	30.21	8.03	34.69	5.92	6.2
Maximum		410.50	67.24	46.35	327.47	34.27	30.25
Mean		145.72	49.79	9.98	86.06	12.32	7.35

Table 3: Correlation coefficient (r) among different forms of sulphur and various soil properties of Banaskantha district**s**

	EC	**OC**	**Av. P_2O_5**	**Av. K_2O**	**Sand%**	**Clay%**	**Silt%**	**Heat S**	**Org-S**	**Non SO_4^{-2}**	**SO_4^{-2}**	**Water S**	**Total S**
pH	-0.201*	-0.070	-0.125	-0.014	-0.015	-0.089	0.136	-0.031	0.025	-0.088	-0.076	-0.083	-0.060
EC		0.233**	-0.125	0.234**	-0.035	0.037	0.014	0.051	0.081	0.052	0.064	0.039	0.057
OC			0.261**	0.179*	-0.261**	0.338**	0.025	0.095	0.270**	0.101	0.067	0.083	0.114
Av.P_2O_5				0.374**	-0.235**	0.277**	0.055	0.214*	0.156	0.257**	0.020	0.027	0.228**
Av.K_2O					-0.113	0.137	0.023	0.076	0.042	0.208*	0.003	0.027	0.098
Sand%						-0.813**	-0.692**	-0.383**	-0.129	-0.300**	-0.071	-0.055	-0.360**
Clay%							0.141	0.347**	0.064	0.295**	0.042	0.057	0.328**
Silt%								0.220**	0.139	0.143	0.070	0.023	0.204*
Heat S									0.183*	0.879**	0.076	0.039	0.961**
Org-S										-0.127	0.098	0.103	0.169*
Non SO_4^{-2}											-0.072	-0.095	0.926**
SO_4^{-2}												0.938**	0.075
Water S													0.037

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