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Effect of different sources of sulphur on yield and nutrient uptake by wheat

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Abstract
A pot experiment was conducted at Choudhary Charan Singh Haryana Agricultural University to study the effect of different sources of sulphur on yield and nutrient uptake by wheat. The data revealed that grain yield of wheat increased significantly with increasing level of sulphur over control (7.68 g/pot). The magnitude of increase in grain yield was 13.1, 17.0 and, 20.4 per cent at 20, 40 and 60 mg/kg sulphur application. The yield of wheat as affected by various sources and level of sulphur revealed that grain yield increased significantly with increasing level of sulphur over control. Amongst various sources of sulphur, the grain yield didn't vary significantly. The nitrogen in grain and straw indicate that differences in concentration of nitrogen in both grain and straw were differed significantly. The concentration of nitrogen was found higher (1.33%) at highest dose (60 mg/kg) as compared to lower dose. The concentration of nitrogen was found higher at highest dose of S as compared to its lower dose however, the magnitude of increase in nitrogen concentration was more in case of straw as compared to grain. There was no significant difference in concentration of phosphorus in wheat grain due to various sources and levels of sulphur application however in case of wheat straw the phosphorus content differed significantly with increasing level of sulphur application over control (0.49%). The uptake of phosphorus in both grain and straw differed significantly with the application of sulphur over control. The magnitude of decrease in potassium content was 2.0, 6.1 and 8.2 at 20, 40 and 60 mg/kg sulphur. The content of potassium in wheat grain decreased significantly at 60 mg/kg sulphur application whereas; at lower levels the decrease in potassium concentration was found to be non-significant. The uptake of potassium and S in grain increased significantly with increasing levels of sulphur over control.

Keywords: Wheat, sulphur, nitrogen and phosphorous

Introduction

Wheat (*Triticum aestivum* L.), which triggered Green revolution in the Indian subcontinent, is an important food grain providing nourishment nearly to 35 per cent people of the world. On global scale, the crop is grown over an area of 211.06 million ha with a production of 566.8 million tonnes. India is the second largest producer of wheat in the world next only to China and the crop has provided the fastest pace of growth to Indian agriculture. Among cereals, wheat is next to rice in area (24.23 million ha) and production (75.6 million tonnes) (Jagshoran *et al*., 2004) [1]. Wheat contributes about 60 per cent of daily protein requirement and more calories to world diet than any other food crop (Mattern *et al*., 1970) [2]. As main staple food, wheat continues to assume greater significance in the years to come both from grain productivity as well as quality point of view. Providing required quantity of quality grains to the growing population is an ever lasting challenge to the researchers. India will have to produce 105 million tonnes of wheat by 2020.

Sulphur (S), one of the most important nutrient for all plants and animals, is considered as the fourth major nutrient after nitrogen, phosphorous and potassium for agricultural crop production. Sulphur is a structural constituent of organic compounds, some of which are uniquely synthesized by plants, providing human and animals with essential amino acids (methionine cystine and cysteine). It is involved in chlorophyll formation, activation of enzymes and is a part of vitamins biotin and thiamine (B_1) (Hegde and Sudhakara babu, 2007) [3]. There are many other sulphur containing compounds in plants which are not essential, but may be involved in defense mechanisms against herbivores, pest and pathogens, or contribute to the special taste and odour of food plants. Sulphur improves oil and protein contents, flour quality for milling and baking, quality of tobacco and nutritive value of forages, etc. Role of sulphur in Indian agriculture is now gaining importance because of the recognition of its role in increasing crop production, not only of oil seeds, pulses, legumes and forages but also of many cereals (Singh *et al*., 2000) [4]. Sulphur deficiency in crops is gradually becoming widespread due to continuous use of sulphur free fertilizers, high yielding crop varieties, intensive multiple cropping systems coupled with higher productivity.

The transformation from traditional internal input-based agriculture to the present day external input-based agriculture has caused wide spread deficiency of sulphur. With the adoption of intensive farming, the farmers have shifted from using organic to inorganic high analysis sulphur free fertilizers leading to more widespread and intense sulphur deficiencies in Indian soils.

The efficiency of sulphur sources for various crops have been found different in upland and water logged conditions. The use of cheap sulphur sources like gypsum and pyrites have attracted the attention during last two decades. Although the information on agronomic efficiency of these sources is available for few crops in selected areas, however, their efficiency need to be verified under different agroclimatic conditions and different types of crops and soils. Therefore, the study becomes more important for those areas which are deficient in sulphur. Soils of south western districts of Haryana are sandy in texture with organic carbon less than 0.2 per cent and marginal in available sulphur, therefore, sulphur application in these areas is essential. In addition to the crop responses to sulphur application in different crops, the information on leaching behavior of sulphur in different soils is limited, particularly under field conditions in presence of standing crops. Sulphur is leached in soils as sulphate due to its anionic nature and solubility of its common salts. The leaching loss of sulphate is generally high in light textured soils. However, certain other factors like soil type, water application rates, initial water content, sulphur application rates, organic matter, calcium carbonate, soil pH and different sources of sulphur may affect the mobility of sulphates in soil. It has been reported that mobility of sulphate is quite high in soils having pH more than 7.0 sulphate sulphur may move with irrigation water to depth below rooting zone of the crops, if its application is followed by heavy irrigation. Therefore, there is need to study its movement in presence and absence of crops as affected by different factors.

Distribution of different forms of sulphur and their interrelationship with some important soil characteristics decide the sulphur supplying power of a soil by influencing its release and dynamics in soils. Several soil factors influence the availability of sulphur and hence the status of different forms of sulphur in soils varies widely with soil type.

Transformation/mineralization of sulphur in soil is another important aspect of sulphur availability and supply to the crops. Sulphur transformation is a bio-chemical reaction carried out by the micro-organisms present in the soil. Apart from the micro-organisms mineralization and transformation is influenced by many factors such as soil texture, structure, moisture content, temperature etc. Information regarding the transformation and mineralization of sulphur is very meagre in literature. Therefore, effects of these factors like organic matter and source of sulphur on sulphur transformation and mineralization need to be studied in more detail. When S is applied in the soil either through fertilizers or added incidentally it undergoes many chemical changes, and micro-organism are involved in the principle transformations. Organic form present in soils gets mineralized into inorganic ones. Transformation of S depends on many factors such as moisture content, aeration, temperature, pH, amount and nature of organic matter, soil type and time of reaction.

Materials and Methods

Collection and processing of soil samples

Bulk surface sandy soil samples (0-15 cm) was collected from village Balsamand, district Hisar. The soil sample was air dried ground and passed through 2 mm sieve. After mixing thoroughly, the soil was used for laboratory and screen house studies. The physico-chemical properties of soil are presented in Table 1.

Collection and processing of organic manures

Farm yard manure, poultry manure, pressmud, vermicompost was collected from Department of Agronomy, CCS Haryana Agricultural University, Hisar. It was first air dried at room temperature then ground and passed through 2 mm sieve before use.

Sulphur level: 0, 20, 40 and 60 mg kg^{-1} soil

Sulphur sources: (a) Elemental sulphur, (b) Gypsum, (c) Potassium sulphate (d) Pyrite

Table 1: Physico-chemical properties of the soil

Characteristics	Value
Texture	Sandy
Sand (%)	70.10
Silt (%)	17.80
Clay (%)	12.10
$CaCO_3$ (%)	0.40
pH (1:2)	8.11
$EC_{1:2}$ (dSm^{-1})	0.50
Organic C (%)	0.20
Available N (mg kg^{-1})	50.10
Available P (mg kg^{-1})	15.01
Available K (mg kg^{-1})	125.60
Available S (mg kg^{-1})	6.00
Available Zn (mg kg^{-1})	0.52
Available Mn (mg kg^{-1})	6.80
Available Cu (mg kg^{-1})	0.47
Available Fe (mg kg^{-1})	9.10

Imposition of treatments

To accomplish the objectives of the study, a screen house experiment was conducted in pots. Five kg air dried soil was spread on polyethylene sheet and required amount of either fertilizer, organic manure or in combinations as per above schedule were applied and thoroughly mixed. Half of nitrogen was applied through urea solution at the time of sowing and another half was applied 21 days after sowing. A basal dose of P, K and Zn @ 60, 75 and 25 mg kg^{-1} soil was added through potassium dihydrogen orthophosphate and Zn SO_4 $7H_2O$ solutions.

Sowing of wheat crop

Before sowing of wheat crop about 200g of soil was removed from each pot. The pot was irrigated with one litre of deionized water. On disappearance of free water from the surface, 10 seeds of wheat were placed eight in circle and two in centre of the pot. Then, these seeds were covered by spreading 200g of soil. Therefore, the pots were covered with newspaper to prevent drying out of soil. After 12 days, five plants in each pot were maintained. Intercultural operations and irrigation with deionized water were done as and when requires.

Harvesting and threshing

Crop was harvested at maturity. The plants were thoroughly washed with distilled water. The excess of water was removed by gentle shaking and pressing between two filter papers and then dried in oven at 50 ^{0}C. The grains and straw was separated and weighed separately from each pot.

Preparation of plant samples

The grains and straw were ground in willey mill using stainless steel sieve. Each sample was mixed thoroughly after grinding and stored in polythene bags. Then these samples were analyzed for total N, P and K in laboratory by following standard procedures.

Postharvest soil sampling

After harvesting the crop, one litre of distilled water was added to ach pot. When the surface of the pot appeared to be moist, a representative soil sample were taken and air dried, ground an passed through two mm sieve and stored in bags with proper numbers for further analysis.

C. Statistical analysis

All the experimental data was statistically analyzed by the method of analysis of variance (ANNOVA) as described by Panse and Shukhatme (1985). The significance of treatment effects were putted with the help of 'F' test and to judge the significance of difference between means of two treatments and critical differences (CD) were worked out as described by Cochran and Cox (1963).

Results and Discussion

Effect of different sources of sulphur on yield and nutrient uptake by wheat

Grain yield

The grain yield of wheat as affected by various sources and levels of sulphur is presented in Table 2. The data revealed that grain yield of wheat increased significantly with increasing level of sulphur over control (7.68 g/pot). The magnitude of increase in grain yield was 13.1, 17.0 and, 20.4 per cent at 20, 40 and 60 mg/kg sulphur application. The grain yield was found to be significant between 20 and 40 mg/kg sulphur application whereas further increase in sulphur application from 40 to 60 mg/kg the grain yield was observed to be insignificant. Amongst various sources of sulphur the grain yield didn't vary significantly however there was numerically increase in grain yield when potassium sulphate was used as source of sulphur as compared to elemental sulphur, gypsum and pyrite. Similar findings were reported by Patel *et al.* (2010) [5] on effect of levels and sources of sulphur on seed yield and quality of summer green gram and they revealed that sulphur levels significantly influenced on quality parameters besides growth and yield attributes *viz.*, plant height at 40 DAS and at harvest, number of branches plant^{-1}, seed and straw yields and protein content. Ali *et al.* (2012) also studied the effect of different levels of sulfur on the productivity of wheat to evaluate the effect of different S levels (0, 25, 50 and 75 kg S ha^{-1}) on growth of wheat. They reported that wheat grain yield was the maximum at the application of 50 kg S ha^{-1} and 26% more than control. However, economical analysis showed that maximum value cost ratio (3.52:1) was found where 25 kg ha^{-1} S was applied. Other workers also demonstrated the benefits of sulphur application (Eriksen and Mortensen, 2002; Kumar *et al.*, 2014; Shivay *et al.*, 2014) [6-8].

Table 2: Effect of different sources and levels of sulphur on grain yield (g/pot) of wheat

Levels of sulphur (mg/kg)	Sources of sulphur				
	Elemental sulphur	Gypsum	Potassium sulphate	Pyrite	Mean
0	7.71	7.72	7.60	7.70	7.68
20	8.70	8.68	8.84	8.54	8.69
40	8.98	8.97	9.29	8.88	9.03
60	9.21	9.14	9.54	9.07	9.25
Mean	8.65	8.63	8.82	8.55	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.33 Sulphur levels × Sulphur sources = 1.13					

Straw yield

The straw yield (Table 3) also increased with increasing level of sulphur over control (11.35 g/pot). The per cent increase in straw yield was 11.1, 21.0 and 29.6 at 20, 40 and 60 mg/kg sulphur application over control. The various sources of sulphur as well as interaction between sources and level were found to be non-significant. On a sandy loam soil in Kanpur, Niranjan and Singh (2005) [9] observed that the application of various organic sources and inorganic fertilizers significantly increased the grain yield of rice and wheat. The highest grain yield was recorded with green manure, followed by FYM. Similar observations have also been made by Chaudhary and Thakur (2007) [10].

Table 3: Effect of different sources and levels of sulphur on straw yield (g/pot) of wheat

Levels of sulphur (mg/kg)	Sources of sulphur				
	Elemental sulphur	Gypsum	Potassium sulphate	Pyrite	Mean
0	11.36	11.34	11.34	11.35	11.35
20	12.63	12.58	12.71	12.53	12.61
40	13.74	13.69	13.83	13.64	13.73
60	14.73	14.67	14.81	14.61	14.71
Mean	13.12	13.07	13.17	13.03	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.34 Sulphur levels × Sulphur sources = 0.68					

Effect of various sources and level of sulphur on nutrient concentration and uptake

Nitrogen concentration and uptake

A perusal of the data in Table 3 for concentration of nitrogen in grain and straw indicate that differences in concentration of nitrogen in both grain and straw were differed significantly. The concentration of nitrogen was found higher (1.33%) at highest dose (60 mg/kg) as compared to lower dose, however, the magnitude of increase in nitrogen concentration was more in case of straw as compared to grain. The per cent increase was 12.7, 17.3 and 20.9 in grain whereas the corresponding values was 52.4, 96.3 and 124.6 per cent in straw at 20, 40 and 60 mg/kg sulphur application, respectively over their respective controls.

The interaction between sources and level of sulphur were found to be non-significant. Similar trend was observed with respect to nitrogen uptake in wheat grain and straw except that increase in sulphur application from 40 to 60 mg/kg didn't affect uptake of nitrogen significantly (Table 4). Shivay *et al.* (2014) [8] while studying the effect of levels and sources of sulfur on yield, sulfur and nitrogen concentration and uptake and S-use efficiency in basmati rice observed that response to S application was obtained up to 45 kg S ha^{-1} and Bentonite-S out-performed other than three sources, namely, gypsum, ordinary super phosphate (OSP), and elemental S in several growth characters, yield attributes, S concentration, and uptake but not in grain yield.

Table 4: Effect of different sources and levels of sulphur on nitrogen content (%) in wheat

Levels of sulphur (mg/kg)	Sources of sulphur				
	Elemental sulphur	**Gypsum**	**Potassium sulphate**	**Pyrite**	**Mean**
Grain					
0	1.1	1.09	1.1	1.11	1.10
20	1.22	1.30	1.23	1.21	1.24
40	1.29	1.28	1.30	1.27	1.29
60	1.33	1.33	1.34	1.32	1.33
Mean	1.24	1.25	1.24	1.23	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.13 Sulphur levels × sulphur sources = 0.26					
Straw					
0	0.39	0 .38	0.39	0.38	0.39
20	0.53	0.53	0.54	0.51	0.53
40	0.63	0.62	0.64	0.61	0.63
60	0.67	0.66	0.68	0.66	0.67
Mean	0.56	0.55	0.56	0.54	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.04 Sulphur levels × sulphur sources = 0.09					

Table 4: Effect of different sources and levels of sulphur on nitrogen uptake (mg/pot) by wheat

Levels of sulphur (mg/kg)	Sources of sulphur				
	Elemental sulphur	**Gypsum**	**Potassium sulphate**	**Pyrite**	**Mean**
Grain					
0	84.8	84.1	83.6	85.4	84.70
20	106.1	112.8	108.7	105.1	108.18
40	115.8	114.8	120.7	112.7	115.20
60	122.4	121.5	128.2	119.7	122.95
Mean	107.3	108.3	110.3	105.7	
CD (p=0.05) sulphur levels and sulphur sources = 0.82 Sulphur levels × sulphur sources = 1.60					
Straw					
0	44.30	43.09	44.22	43.15	43.69
20	66.90	66.67	68.83	63.90	66.58
40	86.50	84.80	88.50	83.20	85.75
60	98.60	96.82	100.70	96.40	98.13
Mean	74.10	72.80	75.60	71.70	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.67 Sulphur levels × Sulphur sources = 1.30					

Phosphorus concentration and uptake

There was no significant difference in concentration of phosphorus in wheat grain (Table 5) due to various sources and levels of sulphur application however in case of wheat straw the phosphorus content differed significantly with increasing level of sulphur application over control (0.49%). It was further observed that phosphorus concentration in both grain and in straw decrease with increasing level of sulphur. The effect of various sources on content in wheat straw was significantly at par.

Table 5: Effect of different sources and levels of sulphur on phosphorus content (%) in wheat

Levels of sulphur (mg/kg)	Sources of sulphur				
	Elemental sulphur	**Gypsum**	**Potassium sulphate**	**Pyrite**	**Mean**
Grain					
0	0.49	0.49	0.48	0.49	0.49
20	0.48	0.48	0.47	0.48	0.48
40	0.47	0.47	0.46	0.47	0.47
60	0.46	0.46	0.46	0.46	0.46
Mean	0.48	0.48	0.47	0.48	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.07 Sulphur levels × Sulphur sources = 0.13					
Straw					
0	0.16	0.16	0.16	0.16	0.14
20	0.15	0.15	0.15	0.15	0.15
40	0.14	0.14	0.14	0.14	0.16
60	0.14	0.13	0.14	0.14	0.16
Mean	0.15	0.15	0.15	0.15	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.01 Sulphur levels × Sulphur sources = 0.03					

The uptake of phosphorus in wheat grain and straw differed significantly with the application of sulphur over control (37.45 mg/kg and 18.15 mg/kg, respectively). It was further observed that uptake of phosphorus was more in grain as compared to straw. The interaction between source and level of sulphur was found non-significant with respect to phosphorus uptake in both wheat grain and straw (Table 6). Dhage *et al.* (2014) observed the effect of various levels of phosphorus and sulphur on yield, plant nutrient content, uptake and availability of nutrients at harvest stages of soybean [*Glycine max* (L.)]. The treatment consisted of four levels of phosphorus (P_0, P_{30}, P_{60} and P_{90} kg P_2O_5 ha^{-1}) and four levels of sulphur (S_0, S_{20}, S_{40} and S_{60} kg ha^{-1}) applied through DAP and elemental sulphur, respectively.

Table 6: Effect of different sources and levels of sulphur on phosphorus uptake (mg/pot) by wheat

Levels of sulphur (mg/kg)	Sources of sulphur				
	Elemental sulphur	**Gypsum**	**Potassium sulphate**	**Pyrite**	**Mean**
Grain					
0	37.77	37.82	36.48	37.73	37.45
20	41.76	41.66	41.54	40.99	41.49
40	42.20	42.15	42.73	41.73	42.20
60	42.36	42.04	44.02	41.72	42.54
Mean	41.0	40.90	41.20	40.5	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.69 Sulphur levels × Sulphur sources = 1.39					
Straw					
0	18.17	18.14	18.14	18.16	18.15
20	18.94	18.87	19.06	18.79	18.92
40	19.23	19.16	19.36	19.09	19.21
60	20.12	19.07	20.73	20.45	20.22
Mean	19.2	18.8	19.3	19.1	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.64 Sulphur levels × Sulphur sources = 1.28					

Potassium content and uptake

The content of potassium in wheat grain decreased significantly at 60 mg/kg sulphur application whereas at lower levels the decrease in potassium concentration was found to be non-significant. The magnitude of decrease in potassium content was 2.0, 6.1 and 8.2 at 20, 40 and 60 mg/kg sulphur (Table 7). It was further noticed that potassium content in wheat grain didn't vary significantly due to various sources of sulphur application. The interaction between sources and levels was insignificant in case of wheat straw. The potassium content also increased with increasing level of sulphur over control (0.49%). However, the potassium concentration didn't vary significantly between 20 and 40 mg/kg sulphur application but increase in sulphur levels from 40 to 60 mg/kg resulted in significant increase in potassium content. The potassium content was found to be non-significant with respect to sources of sulphur. The interaction between both source and level of sulphur was also found to be non-significant.

The uptake of potassium in wheat grain increase significantly with increasing level of sulphur however this increase was non-significant between any two successive levels of sulphur applications. In case of wheat straw, potassium uptake increased with increasing level of sulphur application over control (115.30 mg/kg) as well as any two successive levels of sulphur application. The per cent increase in uptake was 26.1, 52.8 and 72.1 at 20, 40 and 60 mg/kg sulphur application over control. It was further observed that potassium sulphate as source of sulphur was found to be significantly better when compare with other sources of sulphur with respect to potassium uptake (Table 8). Sahu *et al.* (2015) [11] studied the effect of different levels of sulphur and FYM on yield and soil nutrient status of chickpea in Vertisol at Instructional Farm of Indira Gandhi Agricultural University, Raipur to estimate the fertilizer requirement of chickpea crop based on soil test levels using INM approach and concluded that chickpea crop required 0.47 kg S to produce one quintal of grain. Fertilizer and soil test efficiencies estimated were 12.0 and 21.5 per cent, respectively for sulphur. The FYM contribution for S nutrient was estimated at 1.93.

Table 7: Effect of different sources and levels of sulphur on potassium content (%) in wheat

Levels of sulphur (mg/kg)	Sources of sulphur				
	Elemental sulphur	Gypsum	Potassium sulphate	Pyrite	Mean
Grain					
0	0.49	0.49	0.49	0.49	0.49
20	0.47	0.48	0.47	0.48	0.48
40	0.45	0.46	0.46	0.47	0.46
60	0.44	0.45	0.45	0.46	0.45
Mean	0.46	0.47	0.47	0.48	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.03 Sulphur levels × Sulphur sources = 0.06					
Straw					
0	1.01	1.02	1.01	1.01	1.01
20	1.17	1.18	1.17	1.16	1.17
40	1.25	1.27	1.30	1.30	1.28
60	1.35	1.34	1.36	1.35	1.35
Mean	1.20	1.20	1.21	1.21	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.11 Sulphur levels × Sulphur sources = 0.23					

Table 8: Effect of different sources and levels of sulphur on potassium uptake (mg/pot) by wheat

Levels of sulphur (mg/kg)	Sources of sulphur				
	Elemental sulphur	Gypsum	Potassium sulphate	Pyrite	Mean
Grain					
0	37.77	37.82	37.24	37.73	37.64
20	40.89	41.66	41.54	40.99	41.27
40	40.41	42.15	42.73	41.73	41.76
60	40.52	41.13	42.93	41.72	41.58
Mean	39.90	40.69	41.11	40.54	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.60 Sulphur levels × Sulphur sources = 1.21					
Straw					
0	114.7	115.6	115.3	115.6	115.30
20	147.7	148.4	146.6	138.9	145.40
40	177.8	173.8	179.7	173.6	176.23
60	198.8	196.5	201.4	197.2	198.48
Mean	159.8	158.6	160.8	156.3	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.48 Sulphur levels × Sulphur sources = 0.95					

Sulphur in grain and straw

The data presented in Table 9 revealed that sulphur content in wheat grain increased significantly with increasing level of sulphur over control. The magnitude of increase was 0.7, 1.2 and 1.5 per cent at 20, 40 and 60 mg/kg sulphur application over control (0.08%), respectively. The various levels of sulphur did not influence the sulphur content significantly and was found to be almost at par. The interaction between sulphur level and it sources resulted in significant increase in sulphur content. In case of straw, the sulphur content also increased significantly over control (0.05%) whereas between sulphur levels of 40 and 60 mg/kg it was found to be significantly at par. The extent of increase was 1.8, 2.6 and 3.0 at 20, 40 and 60 mg/kg sulphur application, respectively over control. The sulphur content did not vary significantly with the influence of various sources of sulphur and found to be significantly at par. The interaction between sulphur level and its sources was found to be significant.

Table 9: Effect of different sources and levels of sulphur on sulphur content (%) in wheat

Levels of sulphur (mg/kg)	Source of sulphur				
	Elemental sulphur	Gypsum	Potassium sulphate	Pyrite	Mean
Grain					
0	0.08	0.09	0.08	0.08	0.08
20	0.14	0.14	0.16	0.13	0.14
40	0.17	0.18	0.19	0.17	0.18
60	0.19	0.2	0.21	0.19	0.2
Mean	0.15	0.15	0.16	0.14	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.03 Sulphur levels × Sulphur sources = 0.05					
Straw					
0	0.06	0.05	0.05	0.05	0.05
20	0.14	0.14	0.15	0.13	0.14
40	0.18	0.17	0.19	0.17	0.18
60	0.2	0.2	0.21	0.19	0.2
Mean	0.15	0.14	0.15	0.14	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.02 Sulphur levels × Sulphur sources = 0.05					

The uptake of sulphur was significantly influenced with increasing level of sulphur. It was further revealed that uptake of sulphur also differed significantly when its level increased from 20 to 40 mg/kg and further from 40 to 60 mg/kg sulphur. The uptake of sulphur was 0.63 mg/kg at 0 level whereas it was 1.82 at 60 mg/kg level of sulphur application (Table 10). The various sources of sulphur did not show any significant improvement in sulphur uptake by wheat grain, however, maximum uptake (1.44 g/pot) of sulphur was recorded under potassium sulphate followed by gypsum (1.33 g/pot). The interaction between sulphur levels and source sulphur was found to be significant. More or less similar trend was notice with respect to sulphur uptake in wheat straw. Singh *et al.* (2012) [12] while investigating effect of sulphur and zinc on rice performance and nutrient dynamics in plants and soil of Indo Gangetic Plains observed almost similar findings in respect of nutrients uptake.

Table 10: Effect of different sources and levels of sulphur on sulphur uptake (mg/kg) by wheat

Levels of sulphur (mg/kg)	Source of sulphur				
	Elemental sulphur	Gypsum	Potassium sulphate	Pyrite	Mean
Grain					
0	0.61	0.69	0.6	0.61	0.63
20	1.21	1.21	1.41	1.11	1.24
40	1.52	1.61	1.76	1.5	1.60
60	1.74	1.82	2.00	1.72	1.82
Mean	1.27	1.33	1.44	1.24	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.30 Sulphur levels × sulphur sources = 0.50					
Straw					
0	0.68	0.56	0.56	0.56	0.59
20	1.76	1.76	1.9	1.62	1.76
40	2.47	2.32	2.62	2.31	2.43
60	2.94	2.93	3.11	2.77	2.94
Mean	1.96	1.89	2.05	1.82	
CD (p=0.05) Sulphur levels and Sulphur sources = 0.40 Sulphur levels × sulphur sources = 0.60					

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