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Prashant Deo Singh
Ph.D. Research Scholar,
Dept. of Soil Science & Agri. Chemistry, S.V.P University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Pramod Kumar
Ph.D. Scholar Research,
Dept. of Agronomy, C.S. Azad University of Agricultural & technology, Kanpur, Uttar Pradesh, India

Abhilasha Pathak
Ph.D. Research Scholar,
Dept. of Soil Science & Agri. Chemistry, S.V.P University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Anand Singh
Ph.D. Research Scholar,
Dept. of Soil Science & Agri. Chemistry, S.V.P University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Sanjeev Singh
Ph.D. Research Scholar, Dept. of Agronomy, S.V.P University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Corresponding Author:
Prashant Deo Singh
Ph.D. Research Scholar,
Dept. of Soil Science & Agri. Chemistry, S.V.P University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Effect of different levels and sources of sulphur on soil properties & yield of mustard (*Brassica juncea* L.)

Prashant Deo Singh, Pramod Kumar, Abhilasha Pathak, Anand Singh and Sanjeev Singh

Abstract
A field experiment was carried out at Research Farm, Narendra Deva University of Agriculture & Technology, Narendra Nagar (Kumarganj), Ayodhya (U.P.) during *Rabi* season 2015-16 to study the "Effect of different levels and sources of sulphur on soil properties & yield of mustard (*Brassica juncea* L.)". The trial was laid out in Randomized Block Design with seven treatments *viz.*, RDF (NPK: 120:60:60 kg ha^{-1}), RDF + 20 kg S ha^{-1} through SSP, RDF + 40 kg S ha^{-1} through SSP, RDF + 20 kg S ha^{-1} through Sulphur Bentonite, RDF + 40 kg S ha^{-1} through Sulphur Bentonite, RDF + 20 kg S ha^{-1} through Phosphogypsum, RDF + 40 kg S ha^{-1} through phosphogypsum with three replications on silt loam soils having low organic carbon (0.32%), nitrogen (145.5 kg ha^{-1}), medium phosphorus (8.78 kg ha^{-1}) and potassium (188.5 kg ha^{-1}). Result showed that grain yield (19.36 q ha^{-1}) and stover yield (58.50 q ha^{-1}) were significantly higher under RDF + 40 kg S ha^{-1} through SSP. Harvest index was not influenced significantly due to different sulphur levels and sources. The soil pH, EC and OC in soil of experimental field were not influenced significantly due to different levels and sources of sulphur, but available nitrogen, phosphorus, potassium and sulphur were significantly maximum with the treatment RDF + 40 kg S ha^{-1} through SSP.

Keywords: Mustard, sulphur, phosphogypsum, bentonite, SSP etc.

Introduction
Rapeseed and mustard (*Brassica juncea* L.) are the major *Rabi* oil seed in India and stand next to groundnut in the oil seed economy. Rapeseed and mustard are the most important edible oils of northern and eastern parts of India. Rapeseed-Mustard is the third important oilseed crop in the world after soybean (*Glycine max* L.) and palm oil (*Elaeis guineensis jacq*. L.). Among the seven edible oilseed cultivated in India, rapeseed-mustard (*Brassica* spp.) contributes 28.6% in the production of oilseeds. The global production of rapeseed-mustard and its oil is around 38-42 and 12-14 million tonnes, respectively. India contributes 8.3% and 19.8% of world acreage and production, respectively. Oilseed crops are generally cultivated under, moisture stress condition particularly in rainfed areas under deficient nutrient supply which are the main cause of its low productivity. Improved plant types play an important role in raising the seed yield of the crop. Development of high yielding varieties of mustard has been one of the major concerns for the scientists because use of the improved varieties alone accounts for 15-20 percent increase in productivity. This is probably because of their altered morphology which results into efficient utilization of water, nutrients and radiation.

The fertilizers have played a prominent role in increasing the oilseed production. Balance use of fertilizer is the key to achieve higher production and increase nutrient use-efficiency. About 50 percent increase in agricultural production in post green revolution era is attributed to the use of fertilizers. The use of chemical fertilizers would maintain the agricultural production in future. Use of optimal dose of primary, secondary and micronutrients ensure better and sustainable yield, while correcting some of the nutrients deficiencies.

Rapeseed and mustard crop belongs to cruciferae family which preferentially need sulphur (s) for their growth and development. Sulphur is called as the fourth major essential element for plant. For better productivity sulphur plays a multiple role, as well as quality of oilseeds (Biswas *et al*. 1995) [1]. 3-5 units of edible oil generated by each unit of fertilizer S. Sulphur application also has marked effect on soil properties and is used as soil amendment such as gypsum and pyrite to improve the availability of other nutrients in soil. The oil seed crops are the most affected as their requirement of sulphur is higher than other crops. Sulphur, as forth major nutrient with nitrogen, phosphorus and potassium, is a constituent of three sulphur containing amino acids (cysteine, cysteine and methionine), which are the building blocks of protein and about 90% of plant S is present in these amino acids. Sulphur improves protein and oil content in seeds. It is also associated with special metabolism in plant and the structural characteristics of protoplasm. In agricultural system with low sulphur inputs, soil organic matter is a major source of S and the transformations between organic and inorganic S pools are important for the supply of S to the plants. Sulphur fertilizers are most commonly available as either soluble sulphate or elemental forms (S). Elemental S is totally unavailable to plants. Elemental S must be oxidized by soil microbes to SO_4-S before it becomes available to crops. Thus, it takes considerably more time for S to become available, compared to soluble sulphate forms of fertilizer. The rate of conversion from S to plant available SO_4-S mainly depends on the particle size to which the product degrades and the method of application. Yield of mustard increased with the increasing dose of S from 0 to 60 kg ha^{-1}. Higher yield was obtained with 60 kg S ha^{-1} resulting in 17.9% increase over control Ray *et al.* (2014) [3]. Therefore, present study was taken up to study the effect of different levels and sources of sulphur on soil properties, growth and yield of mustard.

Materials and Methods

A field experiment was conducted at PCP (Instructional Research Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) during Rabi season of 2015-16. The Farm is located 42 km away from Faizabad city on Faizabad- Raibarelli road and 24 km away from Jagdishpur side and 85 km from Lucknow - Raibarelli road at 26.47˚ N latitude and 82.12˚ E longitude and about 113 meters above the mean sea level (M S L). In order to determine the physico-chemical characteristics and fertility status, the soil sample were collected from different places at random with the help of soil auger to a depth of 0-25 cm prior to application of fertilizers. The soil sample representing the whole field was taken and analyzed in laboratory for physico-chemical properties. The result of mechanical and physico-chemical analysis are given in Table 1.

Table 1: Physico-chemical characteristics of the experimental sites

Physico-chemical characteristics		Value	Method applied
A. Mechanical analysis			
(i)	Sand (%)	26.00	Hydrometer method (Boyoucos, 1936)
(II)	Silt (%)	52.50	
(III)	Clay (%)	21.50	
(IV)	Textural class	Silt loam	Triangular method (Lyon *et al.*, 1952)
B. Chemical properties			
(I)	pH (1.25 soil water ratio)	8.20	Glass electrode pH meter (Jackson, 1973) [2]
(II)	Organic carbon (%)	0.32	Walkley & Black's rapid titration method (Walkley and Black, 1934)
(III)	EC dS/m at 25 ^{0}C	0.31	Conductivity meter (Jackson, 1973) [2]
(IV)	Available N (kg/ha)	145.5	Alkaline permanganate method (Subbiah & Asija, 1956)
(V)	Available P (kg/ha)	8.78	Olsen's method (Olsen *et al.*, 1954)
(VI)	Available K (kg/ha)	188.5	Flame photometer (Jackson, 1973) [2]
(VII)	Available S (kg/ha)	15.23	0.15% $CaCl_2$, (Williams & Steinbergs, 1959)

Mustard cultivar NDR-8501 was grown with three sources of Sulphur (SSP, Sulphur Bentonite, and Phospho-gypsum) and at three levels (0, 20 and 40 kg S ha^{-1}). Irrigation scheduling, fertilizer application and intercultural operations were followed as per normal agronomic practices. The experiment was laid out in Randomized Block Design (RBD) with 21 treatment and three replications. On the basis of the gross plot size, half dose of the nitrogen and the required quantity of SSP, phosphogypsum and sulphur bentonite on the basis of sulphur content were applied in the treatments at the time of final land preparation and mixed in the soil. Remaining half dose of the nitrogen was applied at first irrigation of mustard crop. Sulphur was supplied through SSP, phosphogypsum and sulphur bentonite as per treatments in each plot. Recommended (120:60:60) dose of NPK was also applied in each plots. Nitrogen was supplied through Urea, Phosphorus through the DAP and Potash was supplied through MOP. Grain yield was recorded at harvest for all the treatments. Surface soil sample were collected and analyzed for pH, electrical conductivity (EC), organic carbon (OC) and available N, P, K and S as per standard methods (Jackson 1973) [2].

Result and Discussion

1. Yield of mustard crop

Grain and stover yields of mustard were affected significantly due to various levels of sulphur application. Significant improvement in grain yield as well as in stover yield was observed with successive increase in level of sulphur from 20 – 40 kg ha^{-1}. Grain yield was adversely affected by crop sown with only 100% RDF as compared to sowing with different levels of sulphur.

(a) Grain yield

The grain yield of Indian mustard increased significantly with increasing rates of sulphur up to 40 kg S ha^{-1}, however, difference between 20 and 40 kg S ha^{-1} was not significant. The maximum grain yield (19.36 q ha^{-1}) of mustard was obtained with application of 100% RDF + 40 kg S ha^{-1} through SSP; which was being at par with 100% RDF + 40 kg S ha^{-1} through sulphur bentonite and 100% RDF + 40 kg S ha^{-1} through phosphogypsum which was significantly superior over rest of the treatments. The minimum yield was recorded in control treatment (100% RDF).

(b) Stover yield

The stover yield of mustard influenced significantly by levels and sources of sulphur which has been presented in Table 2. The maximum stover yield (58.50 q ha^{-1}) of mustard was obtained with application of 100% RDF + 40 kg S ha^{-1} through SSP; being at par with 100% RDF + 40 kg S ha^{-1} through sulphur bentonite and 100% RDF + 40 kg S ha^{-1} through phosphogypsum, which was significantly superior over rest of the treatments. The minimum stover yield was recorded with 100% RDF (45.64 q ha^{-1}).

The significant increase in grain and stover yields of mustard were largely a function of improved growth and the consequent increase in different yield components due to adequate supply of major plant nutrient under successive increase in nutrient doses. This has resulted to enhanced rate of photosynthesis and carbohydrate metabolism as influenced by sulphur application which leads to higher grain yield and stover yield. The highest grain yield and stover yield were recorded 100% RDF + 40 kg S ha^{-1} through SSP. Such increase trends were also reported by Yadav *et al*. (2010).

Table 2: Effect of different levels and sources of sulphur on grain yield, stover yield and harvest index

Treatments	Yield (q ha^{-1})		
	Grain	Stover	Harvest index
T_1–RDF (NPK: 120:60:60 kg ha^{-1})	14.58	45.64	24.21
T_2-RDF+20kg S ha^1 through SSP	16.78	53.84	23.76
T_3- RDF +40 kg S ha^{-1} through SSP	19.36	58.50	24.88
T_4- RDF+ 20kg S ha^{-1} through Sulphur Bentonite	16.32	53.34	23.42
T_5- RDF+ 40kg S ha^{-1} through Sulphur Bentonite	18.29	56.18	24.56
T_6-RDF+ 20kg S ha^{-1} through Phosphogypsum	15.84	51.67	23.46
T_7- RDF+ 40kg S ha^{-1} through phosphogypsum	17.35	54.34	24.20
SEm$\pm$	0.73	1.51	-
CD (P=0.05)	2.25	4.64	-

2. Effect on soil properties

The different level and sources of sulphur tended to have a marked effect on the properties of soil after the crop harvest.

(a) Soil pH, Electrical conductivity and Organic carbon

It is evident from the data in Table-3 that effect of different levels and sources of sulphur on the soil pH, electrical conductivity and organic carbon content was non- significant. Increasing levels of sulphur from 0 to 40 kg S ha^{-1} decreased the soil pH, while increased the organic carbon content (%) as compared to their initial values. However, effect was non-significant. Application of 40 kg S ha^{-1} recorded the maximum value of organic carbon (0.41%) and lowest being with sowing under T_1- RDF. This could be ascribed due to alteration of soil reaction by sulphate and calcium ions released by SSP into the soil.

Table 3: Effect of different levels and sources of sulphur on pH, EC and Organic carbon content of soil after harvest.

Treatments	pH	EC (dSm^{-1})	OC (%)
T_1– RDF (NPK: 120:60:60 kg ha^{-1})	8.19	0.34	0.34
T_2-RDF+20kg S ha^1 through SSP	8.13	0.28	0.37
T_3-RDF+40kg S ha^{-1} through SSP	8.08	0.32	0.41
T_4- RDF+ 20kg S ha^{-1} through Sulphur Bentonite	8.14	0.26	0.36
T_5- RDF+ 40kg S ha^{-1} through Sulphur Bentonite	8.09	0.31	0.39
T_6-RDF+ 20kg S ha^{-1} through Phosphogypsum	8.16	0.25	0.36
T_7- RDF+ 40kg S ha^{-1} through phosphogypsum	8.10	0.30	0.38
SEm$\pm$	0.08	0.03	0.02
CD (P=0.05)	NS	NS	NS

(b) Available Nitrogen in soil

The data presented in Table 4 indicated that available nitrogen of soil varied with various sources and sulphur levels. The maximum availability of nitrogen (152.75 kg ha^{-1}) was obtained with RDF + 40 S kg ha^{-1} through SSP, followed by (152.45 kg ha^{-1}) with RDF + 40 kg S ha^{-1} through sulphur bentonite and the minimum availability (147.97 kg ha^{-1}) of available nitrogen with 100% RDF but non-significant difference was found among the treatments.

(c) Available Phosphorus in soil

The results pertaining to available phosphorus in soil after harvest have been presented in Table 4. The maximum available phosphorus (12.45 kg ha^{-1}) was obtained with treatment T_3 and the minimum (9.01 kg ha^{-1}) in T_1 but there was no significant difference among the treatments.

(d) Available potassium in soil

The data pertaining to available potassium in post-harvest soil have been presented in Table 4. Content of available K varies between 190.50 kg ha^{-1} to 196.21 kg ha^{-1}. The maximum available potassium (196.21 kg ha^{-1}) was obtained at 100% RDF + 40 kg S ha^{-1} through SSP while lowest (190.5 kg ha^{-1}) with control treatment but statistically non-significant difference was found among the treatments in case of available potassium.

(e) Available sulphur in soil

The data pertaining to available sulphur of soil have been presented in Table 4. The maximum available sulphur (18.78 kg ha^{-1}) was found with T_3 and minimum available sulphur (15.07 kg ha^{-1}) with 100% RDF (control) but non-significant difference was found among the treatments.

Table 4: Effect of different levels and sources of sulphur on available N, P, K and S content (Kg ha^{-1}) in soil

Treatments	Available N	Available P	Available K	Available S
T_1- RDF (NPK: 120:60:60 kg ha^{-1})	147.96	9.01	190.50	15.07
T_2-RDF + 20 kg S ha^{-1} through SSP	148.80	9.88	191.18	16.60
T_3-RDF + 40 kg S ha^{-1} through SSP	152.75	12.45	196.21	18.78
T_4- RDF + 20 kg S ha^{-1} through Sulphur Bentonite	148.40	9.80	191.00	15.93
T_5- RDF + 40 kg S ha^{-1} through Sulphur Bentonite	152.45	11.02	195.93	18.22
T_6-RDF + 20 kg S ha^{-1} through Phosphogypsum	148.20	9.45	190.00	15.63
T_7- RDF + 40 kg S ha^{-1} through phosphogypsum	152.10	10.80	195.46	17.43
SEm±	2.02	1.27	1.37	0.89
CD (P=0.05)	NS	NS	NS	NS

Conclusion
The present study indicates that crop fertilized with 100% RDF + 40 kg S ha^{-1} through SSP produced significantly the highest grain and stover yield followed by sowing under RDF + 40 kg S ha^{-1} through sulphur bentonite. However, there is a need to verify results in multi-location trials across the country following diverse soil and climate conditions.

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