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SOIL SCIENCE

Effect of Different Sources of Sulphur on Growth, Productivity and Oil Content of *Brassica campestris* var. toria in the Red Soil of Odisha

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ABSTRACT

A field experiment of two years was conducted during the *rabi* seasons of 2014-15 and 2015-16 at Instructional Farm of Krishi Vigyan Kendra (Nabarangpur), Umerkote, Nabarangpur, Odisha, India to study the effect of different sources with the graded doses of sulphur on growth, productivity and the oil content of Mustard (*Brassica camprestris* var. toria). The experiment was laid out in the randomized block design with three replications and nine treatments viz; T_1 30 kg S ha^{-1} as SSP, T_2 45 kg S ha^{-1} as SSP, T_3 60 kg S ha^{-1} as SSP, T_4 30 kg S ha^{-1} as Gypsum, T_5 45 kg S ha^{-1} as Gypsum, T_6 60 kg S ha^{-1} as Gypsum, T_7 30 kg S ha^{-1} as Elemental sulphur, T_8 45 kg S ha^{-1} as Elemental sulphur, T_9 60 kg S ha^{-1} as Elemental sulphur along with an untreated control. Significantly highest seed yield (12. 47 qha^{-1}) resulted under the application of sulphur @ 60 kgha^{-1} as Single Super Phosphate (SSP) due to the significant increment in the yield attributes studied when compared to control (7.15 q ha^{-1}). The sulphur application @ 45 kgha^{-1} as SSP which had given the seed yield 12.47 q ha^{-1} was *at par* with the seed yield of sulphur application @ 60 kgha^{-1} as SSP. Yield advantages due to the application of Gypsum @ 45 kgha^{-1}, 60 kgha^{-1} and Elemental sulphur 45 kgha^{-1}, 60 kgha^{-1} were 60.69%, 62.09% and 47.13%, 57.90%, respectively over control (7.15 q ha^{-1}). The oil content in the seed was highest with the application of sulphur @ 60 kgha^{-1} (44.62%). The oil content of mustard was almost at *par* with both the sources of sulphur viz; SSP and Gypsum.

Highlights

- Sulphur promotes growth, productivity and oil content in mustard.
- SSP and gypsum as source of sulphur are best suited for the cultivation of *Brassica campestris* var. toria in the red soil of Odisha.

Keywords: *Brassica campestris* var *toria*, sulphur, source, yield, oil content

Oil seed plays a vital role in Indian economy. It occupies almost 5% of the gross national product and 10% of the value of the agricultural product. In India, rape seed and mustard account for 16.61% of the total oil seeds area (40010.22 thousand ha), produces 11.47% of total oil seeds (68651.4 thousand MT) and is also occupying the 2nd position in the area next to soybean and the 3rd position in production next to soybean (1st) and groundnut (2nd), (Ministry of agriculture, GOI 2014). *Brassica campestris* var. *toria* commonly called as *toria* is an important oil seed crop of Odisha. It is cultivated in 116 thousand ha of land in Odisha, (DAFP 2012-13) in the *rabi* season, in an upland and medium land condition. The cultivated soils are mostly red soils, acidic, low in organic carbon, low to medium in available phosphorous, medium to high in available K and deficient in sulphur also. The average yield of *toria* is 422 kgha^{-1} in Odisha which is much lower than the national average 1188 kgha^{-1} (Ministry of

Agriculture GOI 2014). The average oil content of the mostly cultivated mustard is around 35%.

Sulphur deficiency affects the yield and the quality of crop as it is involved in protein and enzyme synthesis as well as it is a constituent of amino acids like methionine (21% S), cystein (26% S) and cystine (21% S). Approximately 90% of plant sulphur is present in these amino acids (Tandon and Messick, 2002). Sulphur is involved in the formation of chlorophyll, glucosides, glucosinolates, activation of enzyme and sulphydryl (-SH) linkages that are the source of pungency in oil. So, the oil seed crops require more amount of sulphur, thus it absorbs more amount from the soil. It has been reported that the removal of sulphur per ton of grain is 3 kg in cereals as against 12 kg in oilseeds (Tandon 1995). Rapeseed and mustard have the highest requirement of sulphur among all the oilseed crops (Hedge and Babu 2007). Oil content can be increased by the application of sulphur in rapeseed and mustard (*Brassica species*) (Sharma and Jalali 2001; Kumar *et al.* 2006; Pandey and Ali 2012; Kumar R and Trivedi S.K. 2012).

In Odisha Condition, being a short duration crop, *toria* draws less attention for sulphur application. So there is a great scope to increase the productivity and the oil content of *toria* in Odisha by sulphur application. Therefore the study was under taken to know the effect of different sources with graded doses of sulphur on growth, productivity and oil content of Brassica *campestris* var *toria* in the red soil of Odisha.

MATERIALS AND METHODS

A field trial of two years was conducted at the Instructional Farm of Krishi Vigyan Kendra (Nabarangpur), Umerkote, Nabarangpur, Odisha, India during the *rabi* seasons of 2014-15 and 2015-16. The soil of the experimental site was sandy loam having bulk density 1.51 g cc^{-1}, particle density 2.65 g cc^{-1}, hydraulic conductivity 1.62 cm h^{-1}, pore space 43.2%, $pHw_{(1:2)}$ 5.60, EC 0.04 dSm^{-1}, SOC 3.8 g kg^{-1}, CEC 3.61 $cmole(p^{+})kg^{-1}$, available N 174.5 $kgha^{-1}$, available P(Brays'1)18.9 $kgha^{-1}$, available K 343.4 $kgha^{-1}$, available S 11.6 $kgha^{-1}$, available Ca 161.3 $kgha^{-1}$, and available Mg 19.6 $kgha^{-1}$ (Table 1). The crop var *toria* (M 27) was sown on November 1st and 3rd during 2014-15 and 2015-16, respectively. The experiment was conducted in the randomized block design with three replications. Besides an untreated control, there were nine treatments of different doses and sources of sulphur i.e. T_1 30 kg S ha^{-1} as SSP, T_2 45 kg S ha^{-1} as SSP, T_3 60 kg S ha^{-1} as SSP, T_4 30 kg S ha^{-1} as Gypsum, T_5 45 kg S ha^{-1} as Gypsum, T_6 60 kg S ha^{-1} as Gypsum, T_7 30 kg S ha^{-1} as Elemental sulphur, T_8 45 kg S ha^{-1} as Elemental sulphur, and T_9 60 kg S ha^{-1} as Elemental sulphur. The crop was fertilized with half the dose of Nitrogen (40 $kgha^{-1}$), full dose of Phosphorous (80 kg P_2O_5 ha^{-1}) and full dose of Potassium (40 $kgha^{-1}$) as the basal and the rest half dose of nitrogen (40 $kgha^{-1}$) was applied after the first irrigation. The Nitrogen, Phosphorous and Potassium were applied through the source of Urea, Triple Super Phosphate and Muriate of Potash respectively. SSP was used as a source of sulphur and its phosphorous content was adjusted with Triple Super Phosphate as per treatments. The Elemental Sulphur was applied 15 days before sowing for better oxidation of its sulphur. Seeds were uniformly treated with bavistin @ 1.5 g per kg of seed before sowing. The crop was raised following all the recommended agronomic practices and harvested on the 15th and the 17th of January during 2015 and 2016 respectively.

In order to study the observations, random sampling technique was followed to study the various agronomic characters like plant height, number of branches per plant, number of siliqua per plant and the number of seeds per siliqua. Ten plants had been selected randomly in each plot and peg marked as sample plants for taking above observations. The crop was harvested when 85-90% of the siliqua turned yellow. One row from each side and three plants from each end of the row were removed to eliminate the border effect and then net plots were harvested, sundried and threshed by the wooden stick to get the seed and stover yields.

RESULTS AND DISCUSSION

Effects on the Growth of the Plant

Plant height

Application of sulphur increased the plant height (65.78 cm to 72.11cm) when compared to the untreated control (53.67 to 53.87 cm)at different years of experiment (Table 2). The pooled data revealed that the plant height increased by 30.93,

Table 1: Physico-chemical properties and methods followed for analysis of soil and plant sample of the experimental plot

Sl. No	Physicochemical and biochemical properties of soil and plant	Procedures followed	Results
1	Bulk density	Core sample method (Black 1965)	1.51 g cc^{-1}
2	Particle density	Pycnometer method (Black 1965)	2.65 g cc^{-1}
3	Hydraulic conductivity	Core sample method (Klute 1965),	1.62 cm h^{-1}
4	Mechanical analysis	Bouyoucus hydrometer method (Piper, 1950)	Sandy loam
5	pH	Potentio metric method (Jackson, 1967)	5.60
6	EC	Conductivity meter method(Jackson 1967)	0.04 dSm^{-1}
7	Soil Organic carbon	Walkey and Black titration method (Piper, 1950),	3.8 g kg^{-1}
8	CEC	Neutral normal acetate extraction method (Chapman 1961)	3.61 cmole(p^+)kg^{-1}
9	Available N	Alkaline permanganate method (Subhiah Asija, 1956)	174.5 $kgha^{-1}$
10	Available P	Brays'1 method (Jackson 1967)	18.9 $kgha^{-1}$
11	Available K	Flame photo meter method (Jackson 1967)	343.4 $kgha^{-1}$
12	Available S	0.15% $CaCl_2$ extraction method (Massoumi and Cornfield, 1963)	11.6 $kgha^{-1}$
13	Available Ca and Mg	Complexometric EDTA titration (Jackson 1967),	Ca 161.3 $kgha^{-1}$, Mg 19.6 $kgha^{-1}$.
14	Oil content in seed	Soxhlet apparatus (Hughes, 1965)	Table 3

34.07, 34.10, 29.50, 34.07, 34.07, 22.34, 22.35 and 29.46% respectively in the treatments of T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8 and T_9 over control. The highest plant height (72.11 cm) that resulted for the application of sulphur @ 60 $kgha^{-1}$ as SSP (T_3) was 10.25, 15.59, 52.64, 52.57, 15.75 and 34.10% higher over the treatments T_1, T_4, T_7, T_8, T_9 and control (T_{10}), but statistically was *at par* with the results for application of sulphur @ 45 $kgha^{-1}$ as SSP (T_2), application of sulphur @ 60 $kgha^{-1}$ as Gypsum (T_6) and application of sulphur @ 45 $kgha^{-1}$ as Gypsum (T_5).

The results corroborated with the findings of the earlier researchers Moinuddin *et al.* (2012); Piri *et al*. (2011); Kapur *et al*. (2010).

Effects on the number of primary branches

Application of sulphur increased the number of primary branches (4.1 to 5.3) when compared to the untreated control (3.2) at different years of experiment (Table 2). The pooled data revealed that the number of primary branches increased by 56.52, 62.5, 62.5, 50.0, 62.5, 62.5, 28.13,28.13 and 43.75% respectively in the treatments of T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8 and T_9 over control. The highest number of primary branches (5.2) that resulted for the application of sulphur @ 60 $kgha^{-1}$ as SSP (T_3) was statistically at par with the results for the application of sulphur @ 45 $kgha^{-1}$ as SSP (T_2), application of sulphur @ 60 $kgha^{-1}$ as Gypsum (T_6) and application of sulphur @ 45 $kgha^{-1}$ as Gypsum (T_5) but with 4.0, 3.3, 21.15, 21.15, and 13.04% of increase in the result over the application of sulphur @ 30 $kgha^{-1}$ as SSP (T_1), application of sulphur @ 30 $kgha^{-1}$ as Gypsum (T_4), and application of sulphur @ 30 $kgha^{-1}$ as Elemental sulphur (T_7), application of sulphur @ 45 $kgha^{-1}$ as Elemental sulphur (T_8) and application of sulphur @ 60 $kgha^{-1}$ as Elemental sulphur (T_9) respectively.

The results corroborated with the findings of the earlier researchers Sardana (2011), Kapur (2010), Singh and Meena (2004).

Effects on Yield

Effects on the number of *siliqua* per plant

Application of sulphur increased the number of siliqua per plant irrespective of the sources and doses (Table 2). The pooled data for both the years revealed that the number of siliqua per plant increased significantly by 31.53, 44.33, 44.33, 29.75, 36.45, 37.64, 26.60, 31.72 and 33.99% in the treatments

Table 2: Effect of different sources of sulphur on growth and yield attributes of *Brassica campestris* var toria

Treat-ments	Plant Height (cm)			No. of Primary branches per plant			No. of siliqua per plant			No. of seeds per siliqua		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	70.39	70.41	70.4	4.9	5	5	133.4	133.7	133.5	6.2	6.2	6.2
T_2	72.08	72.1	72.09	5.2	5.3	5.2	146.4	146.7	146.5	6.7	6.7	6.7
T_3	72.11	72.12	72.11	5.2	5.3	5.2	146.4	146.7	146.5	6.7	6.7	6.7
T_4	69.62	69.64	69.63	4.8	4.8	4.8	131.4	132	131.7	5.9	5.9	5.9
T_5	72.08	72.1	72.09	5.2	5.2	5.2	138.4	138.7	138.5	6.4	6.4	6.4
T_6	72.08	72.1	72.09	5.2	5.2	5.2	139.7	139.7	139.7	6.5	6.5	6.5
T_7	65.77	65.79	65.78	4.1	4.2	4.1	128.4	128.7	128.5	5.9	5.9	5.9
T_8	65.78	65.8	65.79	4.1	4.1	4.1	133.7	133.7	133.7	6.2	6.3	6.3
T_9	69.6	69.62	69.61	4.6	4.6	4.6	135.7	136.4	136	6.4	6.4	6.4
T_{10}	53.67	53.87	53.77	3.2	3.2	3.2	101.4	101.7	101.5	5.8	5.8	5.8
SE(d)	0.016	0.017	0.009	0.04	0.05	0.03	0.463	0.453	0.375	0.038	0.043	0.038
CD (5%)	0.034	0.035	0.020	0.09	0.11	0.07	0.987	0.964	0.799	0.079	0.092	0.082
cv(%)	8.04	7.97	8.00	13.98	13.93	13.92	9.22	9.19	9.20	5.13	5.11	5.11

T_1, T_2,T_3, T_4, T_5, T_6, T_7, T_8 and T_9, respectively over control (101.5). The highest number of siliqua per plant (146.5) that resulted due to the application of sulphur @ 60 kgha^{-1} as SSP (T_3) was statistically *at par* with the result for the application of sulphur @ 45 kgha^{-1} as SSP (T_2).

The results corroborated with the findings of the earlier researchers Jaga (2013), Chauhan and Tikoo (2002).

Effects on the number of seeds per siliqua

Application of sulphur increased the number of seeds per siliqua irrespective of the sources and doses (Table 2). The pooled data for both the years revealed that the number of seeds per siliqua increased significantly by 6.9, 15.52, 15.52, 1.72, 10.34, 12.07, 1.72, 8.62 and 10.34% in the treatments T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8 and T_9, respectively over control (5.8). The highest number of seeds per siliqua (6.7) that resulted due to the application of sulphur @ 60 kgha^{-1} as SSP (T_3) was statistically *at par* with the result for the application of sulphur @ 45 kgha^{-1} as SSP (T_2).

The results corroborated with the findings of the earlier researchers Jaga (2013), Chauhan and Tikoo (2002), Rana *et al*. (2005).

Effects on seed yield

The seed yields were significantly influenced by the application of different doses of sulphur when compared to the untreated control. Application of sulphur @ 30 kgha^{-1} as elemental sulphur increased the pooled seed yield by 32.72% over the untreated control (7.15 q ha^{-1}). Application of sulphur @ 60 kgha^{-1} as SSP significantly recorded more seed yield (75.38%) over control. The increase in seed yield due to the application of sulphur @ 30 kgha^{-1} as SSP, 45 kgha^{-1} as SSP, 30 kgha^{-1} Gypsum, 45 kg ha^{-1} as Gypsum, 60 kgha^{-1} as Gypsum, 45 kgha^{-1} as Elemental sulphur, 60 kgha^{-1} as Elemental sulphur were 46.29, 74.41, 34.27, 60.7, 62.1, 47.13 and 57.9% over control during the 2 years of experiment. The seed yields were *at par* with the treatments of application of sulphur @ 45 kgha^{-1} & 60 kgha^{-1} as SSP and almost *at par* with the treatments of application of sulphur @ 45 kgha^{-1} & 60 kgha^{-1} as Gypsum.

Such an increase in seed yield might have been attributed to better crop growth i.e. plant height and improvement in yield attributes. These results corroborated with the findings of the earlier researchers Chauhan and Tikkoo (2002); Dayanada and Meena (2002), Kumar and Yadav (2007); Kapur *et al.* (2010); Kumar Satish *et al.* (2011); Kumar and Trivedi (2012).

Effects on stover yield

The stover yields were also significantly influenced by the application of different doses of sulphur when compared to the untreated control. Application of sulphur @ 30 kgha^{-1} as elemental sulphur increased the pooled stover yield by 27.18% over untreated

Table 3: Effect of different sources of sulphur on yield and oil content of *Brassica campestris* var toria

Treatments	Seed yield qha^{-1}			Stover yield qha^{-1}			Oil content in seed (%)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	10.42	10.49	10.46	23.04	23.08	23.06	39.67	40.17	39.92
T_2	12.43	12.49	12.47	24.47	24.57	24.52	43.17	43.34	43.25
T_3	12.52	12.55	12.54	24.68	24.67	24.68	44.57	44.67	44.62
T_4	9.59	9.62	9.6	22.65	22.69	22.67	39.17	39.34	39.25
T_5	11.48	11.51	11.49	24.47	24.57	24.52	42.94	43.34	43.14
T_6	11.57	11.61	11.59	24.58	24.62	24.6	43.17	43.17	43.17
T_7	9.44	9.53	9.49	19.07	19.2	19.14	38.64	39.34	38.99
T_8	10.46	10.57	10.52	20.07	20.07	19.14	41.34	41.34	41.34
T_9	11.23	11.33	11.29	22.34	22.47	22.4	42.64	43.17	42.9
T_{10}	7.07	7.23	7.15	15.04	15.07	15.05	36.47	36.07	36.27
SE(d)	0.05	0.032	0.039	0.211	0.20	0.174	0.17	0.22	0.13
CD (5%)	0.106	0.068	0.083	0.45	0.426	0.37	0-36	0.47	0.27
cv(%)	14.86	14.47	14.66	13.75	13.73	13.73	6.10	6.28	6.18

control (15.05 q ha^{-1}). Application of sulphur @ 60 kgha^{-1} as SSP significantly recorded more stover yield (63.99%) over control. The increase in stover yield due to the application of sulphur @ 30 kg ha^{-1} as SSP, 45 kgha^{-1} as SSP, 30 kgha^{-1} Gypsum, 45 kgha^{-1} as Gypsum, 60 kgha^{-1} as Gypsum, 45 kgha^{-1} as Elemental sulphur, 60 kgha^{-1} as Elemental sulphur were 53.22, 62.92, 50.63, 62.92, 63.46, 27.18 and 48.84% over control during the 2 years of experiment. The stover yields were *at par* with the treatments of the application of sulphur @ 45 kg ha^{-1} & 60 kgha^{-1} as SSP as well as Gypsum and in the treatments of application of sulphur @ 30 kgha^{-1} & 45 kgha^{-1} as Elemental sulphur.

The beneficial effect of sulphur application probably induced the synthesis of growth promoting substances which would stimulate the root growth, cell elongation and protein synthesis resulting in better plant growth. Like seed yield, these results corroborated with the findings of the earlier researchers Chauhan and Tikoo (2002); Dayanada and Meena (2002); Kumar and Yadav (2007); Kapur *et al.* (2010); Kumar Satish *et al.* (2011); Kumar and Trivedi (2012).

Effects on Oil Content

The results related to oil content in seed during 2014-15 and 2015-16 as well as the pooled data for both the years are presented in Table 3. The application of sulphur @ 60 kgha^{-1} as SSP increased the oil content by 37.50% when compared to the untreated control (32.45%) whereas the treatment for application of sulphur @ 45 kgha^{-1} as SSP also increased the oil content by 33.28% when compared to the untreated control. The treatment for the application of sulphur @ 60 kgha^{-1} as SSP increased the oil content by 3.34, 3.36,7.93 and 4.01% respectively, over the application of sulphur @ 45 kgha^{-1} as Gypsum, 60 kgha^{-1} as Gypsum, @ 45 kgha^{-1} as Elemental sulphur, 60 kgha^{-1} as Elemental sulphur.

Mustard is a high sulphur demanding crop. Sulphur promotes oil synthesis and it is an important constituent of seed protein, amino acid, enzymes and glucosinolate (Shekhawat *et al.* 2012). Comparatively higher oil content in seed with increasing doses of sulphur as SSP might be due to higher solubility of SSP in such soils favouring higher uptake of sulphur. These results corroborated with the findings of the earlier researchers Chauhan and Tikoo (2002); Kumar and Trivedi (2012); Pandey and Ali (2012).

CONCLUSION

The increase in growth, productivity and oil content of *Brassica campestris* var. toria in the red soil of Odisha were significantly high for each successive addition of sulphur up to 45 kgha^{-1} irrespective of its sources viz; SSP, Gypsum and Elemental sulphur. However, the application of sulphur @ 60 kgha^{-1} as SSP had significantly resulted in the highest oil content in the seed. The results of the above parameters for SSP as source of sulphur were very closely followed by Gypsum which in turn was followed by Elemental sulphur.

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