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Performance of different sources of sulphur on growth & yield of mustard in middle gangetic plains of Bihar

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Abstract
A field experiment was established at Saran district of Bihar to evaluate the effect of different sources of sulphur (*i.e.*, Phosphogypsum: T_1, Bentonite: T_2 & Control: T_3) on yield and economics of mustard. The experiment comprised three treatments and seven replication performed under Randomised Block Design during *rabi* season (2018-19). Results revealed that application of bentonite and phosphogypsum improved the seed yields of mustard by 35.7 &15.6%, respectively over control. Similarly, number of seeds/siliqua & stover yields were recorded the highest in bentonite application which was followed by phosphogypsum and control. With the application of bentonote the highest restoration of available sulphur in soil followed by phosphogypsum whereas, availability of sulphur was lowered by 1.6 times as compared to initial value of soil. A satisfactory seed yields in treatment T_2 reflected to the highest net return (Rs. 42994.0/ha) & cost benefit ratio (1:3.4). In conclusion the bentonite sulphur source was performed better for mustard cultivation in middle gangetic plains of Bihar.

Keywords: Musturd, bentonite, phosphogypsum, yield, economics

1. Introduction

Mustard is a major *rabi* oil seed crop of India. They occupy a prominent place being next in importance to groundnut, both in area and production, meeting the fat requirement of about 50 per cent population in the state of Uttar Pradesh, Punjab, Rajasthan, Madhya Pradesh, Bihar, Orissa, West Bengal and Assam. India is the largest producer of mustard in the world. The production of mustard in India is around 16.2 million tonnes which accounts for about 18.0% of the total oil seed production of the country, and 30% of total oilseed production of India. Area under mustard in Bihar is 0.82 lakh hectare with 0.76 lakh tonnes production and 926 kg/ha productivity (FAI, 2012) [5]. India is the third largest producer of rapeseed-mustard (Piri *et al.*, 2011) [13] having 5.90 million hectares area with 6.41 million tonnes production, but the average yield of rapeseed-mustard in India is only 1145 kg/ha (Economic survey 2013) [4] due to the lack of optimum use of nutrients and improper water management.

The productivity of mustard is very low mainly because of imbalanced use of fertilizers. Most of the farmers are not aware of importance and application time of commercially available sulphur containing fertilizers in nearby market. Sulphur is essential for synthesis of proteins, vitamins and sulphur containing essential amino acids and is also associated with nitrogen metabolism. Besides, sulphur application in mustard has also been reported to increase the yield and oil per centage. To achieve this objective, agricultural scientists have laid more emphasis on improving production of oilseeds through proper nutrition. However, to achieve high yields and the rates of S fertilizer should be recommended on the basis of available soil S and crop requirement.

Soils, which are deficient in sulphur, cannot on their own provide adequate sulphur to meet crop demand resulting in sulphur deficient crops and sub-optimal yields (Chattopaddhyay *et al.*, 2012) [3]. Continuous removal of S from soils by plant uptake has led to widespread S deficiency and soil S budget (Aulakh *et al.*, 1977) [2] all over the world. Sulphur deficiencies have been reported from over 70 countries worldwide including India. Deficiency of sulphur in Indian soils is on increase due to intensification of agriculture. Application of sulphur was reported to increase yield attributes and yield of Indian mustard (Kumar *et al*. 2011, Patel *et al*. 2009) [9, 12]. Sulphur is associated with the production of oilseed crops of superior nutritional and market quality.

Application of different sulphur source significantly influenced the seed, stover yield and sulphur uptake of mustard (Kumar *et al*., 2018) [11]. Sulphur improves the production as well as nutritional and market quality.

In sulphur deficient soil, the efficiency of applied NPK fertilizers may be seriously affected and crop yield may not be sustainable (Ahmad *et al*., 1999) [1]. Application of different sulphur fertilizers at 10-50 kg S/ha significantly increased the seed yield of rapeseed and mustard crops ranging from 5.2-26.7% as compared to control (Ahmad *et al*., 1999) [1]. Information available on the suitability of sulphur containing fertilizers in mustard is not sufficient. Therefore, the aim of the study was to evaluate the performance of different sources of sulphur on growth & yield of mustard.

2. Material and Methods
2.1 Material
2.1.1 Study site characteristics
A field experiment was conducted during *rabi* season 2018-19 at farmers fields od district Saran, Bihar under the supervision of Krishi Vigyan Kendra, Manjhi, Saran, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. The area falls in subtropical, humid agro-climatic zone of Bihar. The average annual rainfall of the area is about 800-1100. The soil of the experimental site was sandy loam in texture with alkaline pH (8.6), low in organic carbon content (0.41%) and low to medium available N, P, K & S (205.0, 11.5 115.0 kg/ha and 8.5 mg kg^{-1}), respectively.

2.1.2 Treatments and experimental design
An experiment on different sources of sulphur was established at seven farmer field of Saran district of Bihar under supervision of Krishi vigyan Kendra, Manjhi, Saran (Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur) during *rabi* 2018-19 (one season). The experiment was laid out in Randomized Block Design, replicated seven times within a block and involved three treatments i.e., T_1: RDF + 30 Kg Sulphur (Phosphogypsum-14% S); T_2: NPK + 30 Kg Sulphur (Bentonite- 90% S); T_3: RDF (80:40:40: NPK).

2.1.3 Field preparation
Before the execution of experiment, the field was well ploughed by tractor followed by planking. Weeds, stones, pebbles, etc. were removed from the field. Twenty one plots of dimension of 5.0 × 5.0 m were made.

2.1.4 Nutrient application and sowing
Half dose of N along with full dose of P and K were applied as basal. Remaining N was top dressed in two equal splits at 25 and 45 days after sowing. Different doses of sulphur were applied through treatment wise sulphur sources as basal. Seed sowing of mustard (var. R. Suphalam) was done on 27 November 2018 having row to row distance 45 cm with seed rate of 5 kg/ha. Thinning was done three weeks after sowing to maintain a plant to plant distance of 10- 15 cm. The crop was harvested on 15th March 2019.

2.1.5 Irrigation
Two irrigations (4 cm) were done after sowing of seeds first irrigation at pre-bloom stage whereas, second irrigation at pod filling stage.

2.1.6 Plant protection and weed management
Pesticide was used for the crop protection against major and minor pests. Insecticide (Endosulfan 2 ml/l) and Fungicide (Carbendazim @ 2 g/l) were applied at the time of disease and pest infestation. Weed management was done manually at the time of weed infestation.

2.2 Methods
2.2.1 Soil sampling and analyses
Soil sampling was done before execution of experiment at 15 cm soil depth for analysis of organic carbon and N, P, K, & S nutrients. After harvest of crop only sulphur content was analysed as per method suggested by Williams and Steinbergs (1959) [18].

2.2.2 Yield and yield attributes
Twenty five selected siliqua taken from respective plant were threshed, seeds were counted and average number of seeds was recorded as number of seeds/siliqua. From the individual plot, the crop of net plot area was harvested and dried. After air drying, the produce was threshed and seeds were cleaned. The final seed weight was recorded in kg/per plot and converted into q/ha. The stover yield was calculated by subtracting the grain yield from the biological yield of the respective plots and expressed as kg/ha and finely converted into q/ha.

2.2.3 Economic analysis
The benefit-cost ratio was calculated by considering the variable as well as fixed inputs and prevailing market rates, the expenditure incurred on various inputs and operations. The fixed cost includes tillage, seed & seed sowing, irrigation, pesticide, harvesting and transportation. Similarly variable cost included fertilizer. The cost of human labour used for tillage, seeding, irrigation, fertilizer and pesticide application, weeding and harvesting of crops was based on person-days per hectare. Simultaneously, gross returns were worked out for each treatment based on quality and market prices of the produce. The net returns were worked out by deducting the cost incurred from the gross return of the particular treatment. Benefit cost (B: C) ratio was calculated by dividing the net return by total cost of production.

2.2.4 Statistical analysis
The data generated from present investigation were subjected to statistical analysis using the statistical package SPSS 13.0 software (Analyse - General Linear Model-Univariate) (SPSS Inc., Chicago, USA). The same letters with table value represent statistically identical values of the examined sulphur application according to Tukey's HSD test determining the least significant difference (LSD) at 5% for testing the significant difference among the treatment means (Gomez and Gomez, 1984) [6].

3. Results and discussion
3.1 Yield & yield attributes
Results of experiment revealed that treatment T_2 performed significantly better in terms of growth attributes, yields, economics and restoration of available sulphur as compared to other treatments (Table 1 & Figure 1). The application of bentonite as sulphur source with recommended dose of NPK (T_2) had recorded the highest number of seed per siliqua, stover & seed yield which ultimately got the highest gross and net return followed by T_1 & T_3 (Table 1 & Figure 1). The per cent increment in number of seed per siliqua, stover & seed yield under treatment T_2 were 10.7, 12.8 & 35.7% over T_3 may be attributed to sulphur's play an essential role for plant growth through its effect on biochemical functioning related to enzyme activation (Sharma, 1994) [16]. Application of sulphur along with recommended dose of NPK improved growth and yield attributes of mustard might be due to the maximum availability of NPK nutrients as well as sulphur's

play an essential role for plant growth through its effect on biochemical functioning related to enzyme activation(Kumar *et al*., 2018, Sharma *et al*., 1994) [11, 17]. Singh *et al*. (2005) [17] confirmed that application of sulphur increased the growth of mustard over no S addition due to better root development and also the increased leaf area of crop causing higher photosynthesis and assimilates metabolic activities. Our results are close conformity with Jat *et al*. (2003) [7], Sah *et al*. (2013) [15], (Khanpara *et al*., 1993) [8].

Table 1: Performance of sulphur on yield attributes yields, economics and available sulphur in soil

Treatments	Number of seeds/ siliqua	Stover yields (q/ha)	Seed yields (q/ha)	Available SO_4^{2-}S (mg/kg)	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	C:B ratio
T_1	11.6a	48.5a	12.6b	8.0 b	16574a	51660b	35086b	1:3.1a
T_2	12.4b	49.9a	14.8a	12.5a	17686a	60680a	42994a	1:3.4a
T_3	11.2a	44.2b	10.9b	5.2b	16306a	44690b	28384c	1:2.7b
LSD $_{(P=0.05)}$	0.70	1.10	1.50	3.20	NS	7560	4585	0.03

NS: not significant; T1: RDF + 30 Kg Sulphur (Phosphogypsum- 14% S); T2: NPK + 30 Kg Sulphur (Bentonite- 90% S); T3: RDF (80:40:40: NPK); Different letters in a column indicate significant difference (at 5% level) between the means according to Tukey's HSD test.

3.2 Available sulphur
The availability of sulphate sulphur was significantly the highest in treatment T2 as compared to rest of the treatment. Whereas, treatment T_1 & T_2 were statistically at par with each other (Table 1). When compared of sulphur content in soil to initial value recorded before initiation of experiment the increment was recorded under bentonite treated plot was 56.2% due to the higher content of sulphur in bentonite. However, treatment T_1 & T_3 were produced similar effect on available sulphur in soil.

3.3 Economics
The cost of cultivation was not significantly affected by application of different sulphur sources but the highest cost of cultivation involved in treatment T_2 which was statistically at par with each other (Table 1 & Figure 2). Due to the maximum yield was obtained in treatment T2 which reflect the maximum gross & net return as well as cost benefit ratio. Almost similar cost benefit ratio was recorded with the application of bentonite and phosphogypsum as a sulphur sources whereas, the lowest cost benefit ratio was recorded with recommended dose of NPK alone.

4. Correlation
In present study, positive correlations (R^2=1) were observed between number of seeds/ silique & stover yields (Figure 3); stover yield & seed yield (Figure 4) of mustard among all the treatments. Similarly a polynomial relationship (R^2=0.996) was recorded positive in between seed yield & available sulphur (Figure 5), and seed yield & net return (R^2=0.999) among different treatments of sulphur (Figure 6). This may be due to that cauliflower crop have high sulphur requirements and higher rate of sulphur uptake improved the metabolic activities of vitamins, biotin, thiamine and coenzyme A in plants (Rattan and Goswami, 2009) [14].

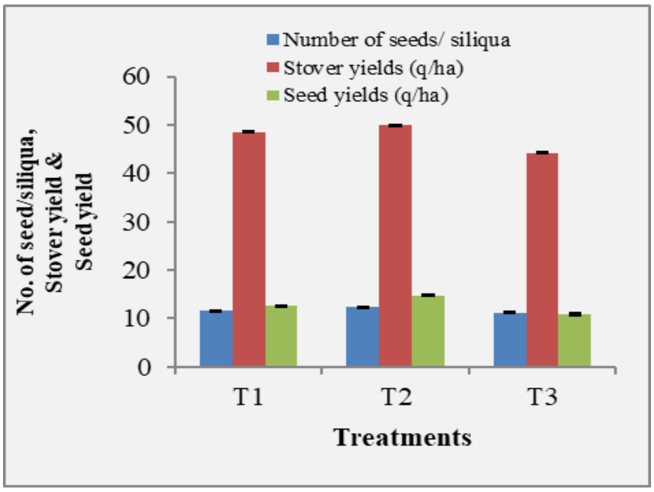

Fig 1: Performance of sulphur on yield attributes & yields of mustard. Vertical bars indicate ± S.E. of mean of the observed values.

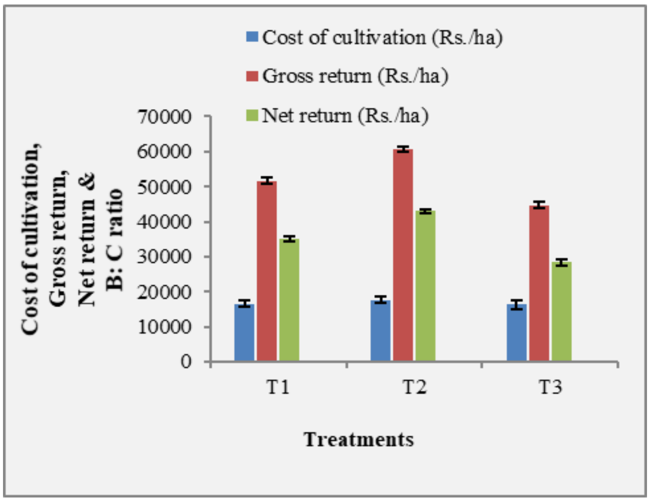

Fig 2: Performance of sulphur on economics of mustard. Vertical bars indicate ± S.E. of mean of the observed values.

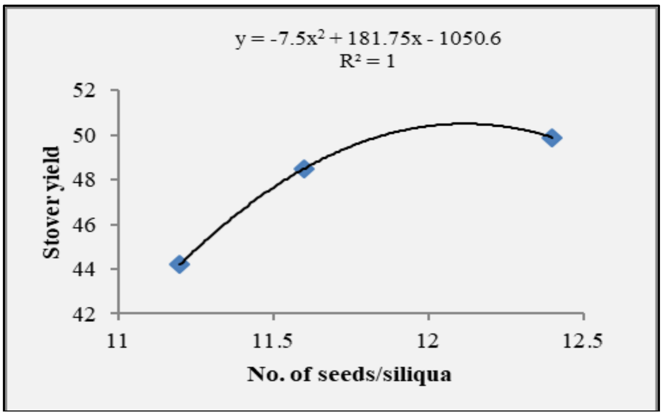

Fig 3: Polynomial relationships among number of seeds/ silique and stover yields of mustard.

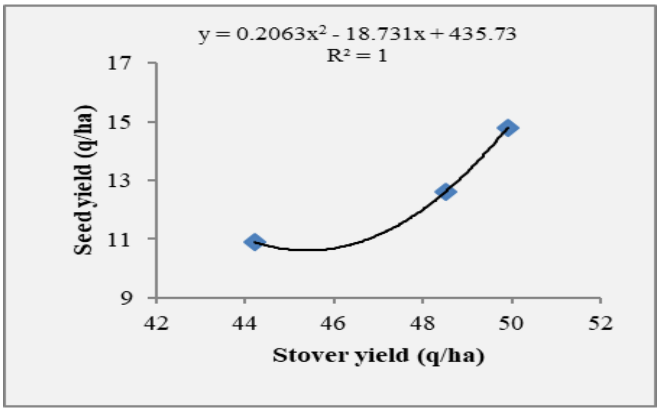

Fig 4: Polynomial relationships among stover and seed yields of mustard.

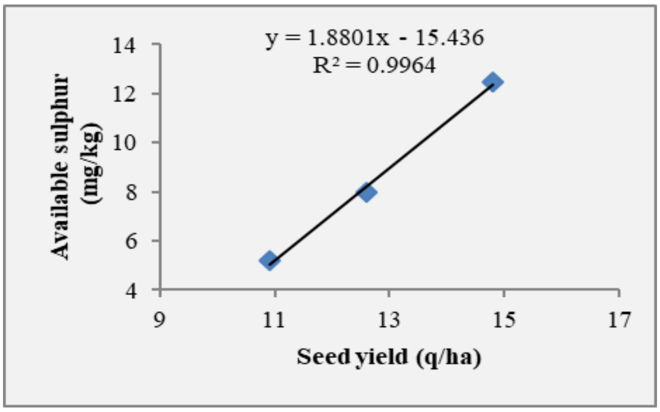

Fig 5: Polynomial relationships among seed yields of mustard and available sulphur of soil.

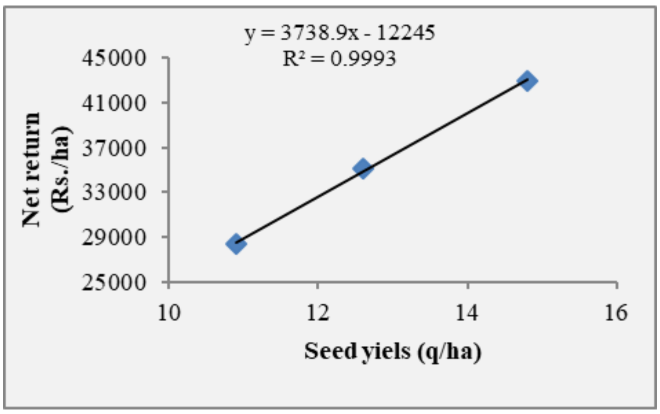

Fig 6: Polynomial relationships among seed yield and net return of mustard.

5. Conclusion

In conclusion application of sulphur sources long with recommended dose of NPK were produced significant effect on growth and yield attributes economics as well as availability of soil sulphur. Among all treatment the bentonite associated treatment was the most effective for musturad in Middle Gangetic plains of Bihar.

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