Impact of improved forms of sulphur on NPK status of soil under mustard (Brassica juncea L.) cultivation

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Abstract
A field experiment was conducted at Agriculture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University during rabi season of 2016-17 to evaluate the effect of improved sulphur (S) formulations on the status of available macronutrients in soil at various growth stages of mustard. Results revealed that the nitrogen (N), phosphorus (P), and potassium (K) content of soil decreased with increasing the dose of Gromor Rapid Blue® from 5 to 7.5 kg acre\(^{-1}\). Residual N and K status of the soil were found highest when Micronized S was applied @3kg acre\(^{-1}\), whereas application of Gromor Sulphamax @10kg acre\(^{-1}\) gave better results in increasing the P content of soil. At vegetative stage, maximum increase in NPK level over control was recorded, i.e. 34.4, 49.0, and 11.6% with application of Micronized S @3kg acre\(^{-1}\), Gromor Sulphamax @10kg acre\(^{-1}\), and Gromor Rapid Blue® 7.5 kg acre\(^{-1}\), respectively. During this study, the available nutrient content of soil was in decreasing trend as the crop progressed and maximum available nutrient content was observed at vegetative stage.

Keywords: Improved S, bentonite S, micronized S, available nutrients, mustard

Introduction
The fertilizer sector is the major input factor in improving crop yield over the current trends in recent times. Developed countries already reached the peak of agriculture production, on the other hand developing countries like India is still far behind. The fertilizer sector is the major deciding factor which can speed up the agriculture production as it accounts for 50% of crop yields \([1]\). Sulphur (S) is the 13\(^{th}\) most abundant element in the earth crust and fourth major plant nutrient. With the increasing use of high analysis NPK containing fertilizers \([2]\) and controlled emission of gases from industries after strict government rules, S deficiency in soil and crop becomes a major issue. Sulphur is a very important nutrient which can affect crop yield and quality. Oilseed crops are very sensitive to S deficiency. Among oilseed, mustard is very sensitive to S deficiency [3]. Among all the factors part and parcel of soil, S ratio which is very important for plants. High dose of nitrogenous fertilizer improve the N status of soil but the effects are limited in oilseed crop because of low S status. The high value of N: S ratio than optimum prevent efficient uptake of N by plants. Under such condition, slow-release bentonite S fertilizers can provide the S at the optimum amount and throughout the crop growth. Bentonite S contains elemental sulphur (S\(_e\)) which first convert into sulphate form than plant uptake it. Conversion of Bentonite S into sulphate form depends upon the particle size of granules, moisture content of the soil, the climatic condition of an area, the microbial population of the rhizosphere \([4]\). Among all the factors particle size of granules is very important because one can control that. Example of such formulations are Gromor Sulphamax and Gromor Rapid Blue® which contain S in the elemental form with optimum particle size. Bentonite S fertilizers contain bentonite clay which breaks under wet condition and breakdown of granules facilitate greater surface area to be worked down by S oxidizing bacteria like Thiobacillus. Easy breakdown of bentonite particles accelerates the conversion of S\(_e\) for plants.
This research aims to investigate the fertility status of soil at various growth stage of mustard as affected by improved S formulation.

Materials and Methods
A field experiment was conducted during rabi season of 2016-17 on S-deficient alluvial soils of Varanasi region situated at 25°18' N latitude, 83°03' E longitude with an altitude of 87 meters above mean sea level. The experimental soil was sandy loam (Inceptisols, Typic Ustochrept) in texture having pH (1:2 soil water ratio) of 7.6, EC (1:2 soil water ratio) of 0.24 dS m⁻¹, organic carbon of 3.7 g kg⁻¹. The initial nutrient status of the soil (Table 1) revealed that it was low in 0.15% CaCl₂ extractable S (8.9 mg kg⁻¹), low in available N (197.70 kg ha⁻¹), medium in available P (15.30 kg ha⁻¹), and moderately high in available K (254 kg ha⁻¹). After the field preparation, the selected test crop viz., mustard (variety: Indian mustard ‘RH-749’) was sown @6 kg ha⁻¹ with 30cm x 30cm spacing. The recommended dose of fertilizer was 120-60-60 [4, 5] which was applied through urea, DAP, and MOP, respectively in all the plots except in absolute control. At the time of sowing, half of the N, whole dose of P₂O₅, and K₂O were applied as basal, while the rest of the N dose was top-dressed just after the first irrigation. The experiment was laid out in a randomized block design having six treatment combinations which were replicated 4 times, viz. T₁: Absolute control; T₂: Sulphamax @ 10 kg acre⁻¹; T₃: Gromor Rapid Blue® @ 5 kg acre⁻¹; T₄: Gromor Rapid blue® @ 7.5 kg acre⁻¹; T₅: Gromor Rapid blue® @ 10 kg acre⁻¹; T₆: Micronized sulphur @ 3 kg acre⁻¹. Soil samples were collected from 0-15cm depth before sowing and at vegetative, flowering, pod development, and at harvest using standard protocol. Samples were then shade-dried, ground, and sieved through 2 mm sieve, and there after analyzed for available N using alkaline permanganate method by Subiah and Asija, (1956) [6], available P by Olsen et al. (1954) [7], available K through neutral N ammonium acetate extract using flame photometer as outlined by Jackson, (1973) [8].

Table 1: Initial properties of study soil

| S. No. | Soil parameter | Value   |
|-------|----------------|---------|
| 1.    | pH             | 7.6     |
| 2.    | EC (dS m⁻¹)    | 0.24    |
| 3.    | Organic carbon (g kg⁻¹) | 3.7     |
| 4.    | Available N (kg ha⁻¹) | 197.7   |
| 5.    | Available P (kg ha⁻¹) | 15.3    |
| 6.    | Available K (kg ha⁻¹) | 254     |
| 7.    | Available S (mg kg⁻¹) | 8.9     |

Results and Discussion

Available N in the soil at various growth stages

The data pertaining to N status of soil as affected by levels and sources of sulphur are presented in Table 2. With the application of recommended NPK and various S fertilizer elements at different levels, the available nutrient status varied significantly. Available fertility status of soil showed a decreasing trend as the crop attains maturity and was observed highest at leaf production stage which possibly helps in translocation to reproductive growth stage and lowest after harvest. As the crop grows, it takes nutrients from the soil and consequently, nutrients get depleted from the soil. Fertilizer (N) application as basal and top dressing (one month after sowing) resulted in a higher content of nutrients in the soil at the early growth stage. Treatments showed significant variation in terms of available N level in the soil at various growth stages, with increasing sulphur doses because of negligible competition between sulphate ion (SO₄²⁻) and nitrate ion (NO₃⁻). The maximum decrease in N level was recorded in micronized S treatment. Available N was recorded maximum at 30, 60, 90 days after sowing (DAS) and at harvesting in micronized S plot while second best treatment at 30 and 60 DAS was T₂ and at 90 DAS and harvesting was T₆. Similar finding was observed by Gaighane et al. (2015) [9] and Alam et al. (2014) [10]. With the increasing level of S, there was an increase in available N status of the soil. Abhiram et al. (2016) [11] reported that application of ammonium sulphate @30kg S ha⁻¹ positively increased the nutrient status of soil at all the growth stages while nutrient content of soil keeps on decreasing as the crop matures.

Table 2: Effect of improved sulphur formulations on available N (kg ha⁻¹) in the soil at various physiological growth stages

| Treatments | 30DAS | 60DAS | 90DAS | Maturity |
|------------|-------|-------|-------|----------|
| T₁         | 195.7 | 190.4 | 185.5 | 161.3    |
| T₂         | 262.1 | 232.6 | 215.9 | 193.1    |
| T₃         | 258.9 | 227.5 | 203.3 | 190.3    |
| T₄         | 255.4 | 221.6 | 200.3 | 187.9    |
| T₅         | 260.9 | 231.4 | 219.1 | 192.4    |
| T₆         | 264.1 | 238.2 | 223.5 | 196.5    |

Available P in the soil at various growth stages

The application of various advanced S formulation did not show any noteworthy effect on the dynamics of phosphorus content in soil in between treatments (Table 3). A significant difference among various treatments was observed after 90 days of sowing, the difference maybe because of the slow release nature of S formulation. Sulphate ion and phosphate ion both posses’ negative charge and this may be the reason of variation in phosphorus content at 90 DAS. Results found during the field experiment are inclose conformity with the findings of Raja et al. (2007) [12]. They observed that the available P and other nutrient in sesame field were in decreasing trend with the advancement of growth stage. As the crop mature they produce more biomass and subsequently accumulate more nutrients which ultimately render the soil less in nutrient content. Among the different treatments, P content was low in the micronized plots in comparison to Gromor Rapid Blue® and Gromor Sulphamax. Available P level in soil was found highest in T₃ at all the growth stages and lowest in control. The second best treatment with respect to P level was treatment T₅. Basum etal. (2018) [13] also observed that with increasing rate of S from 0 to 30 kg ha⁻¹ there was an increase in P content of soil at harvest of rapeseed.
Available K in the soil at various growth stages
Effect of S fertilization on difference of K content was not very prominent in between treatments except with absolute control plot (Table 4). Significant changes were observed at harvesting stage only and at other stages soil K was more or less same in all the treatments. Observed differences in between treatments can be attributed to differential uptake pattern by crop. At 30 and 60 DAS available K was recorded highest in T6 which was at par with T2 and lowest was in control plot. Available K was highest in T4 and T3 at 90 DAS and harvest, respectively. At 90 DAS and harvest, available K in T1 and T6 was more or less same. Kumar and Singh, (2016) observed that as the crop develops K content of rice field sequence in an Inceptisol of Assam. Higher the crop growth more is the nutrient uptake and less will be the fertility status of soil. Similar positive balance of K level with increasing rate of S in sandy loam soils of Udaipur, Rajasthan has been reported by Solanki et al. (2018).

Table 4: Effect of improved sulphur formulations on available K (kg ha⁻¹) in the soil at various physiological growth stages

| Treatments          | 30DAS | 60DAS | 90DAS | Maturity |
|---------------------|-------|-------|-------|----------|
| T1                  | 249.4 | 236.3 | 221.1 | 210.3    |
| T2                  | 272.7 | 264.9 | 242.4 | 231.1    |
| T3                  | 279.1 | 270.4 | 247.9 | 233.4    |
| T4                  | 275.9 | 269.2 | 251.5 | 239.3    |
| T5                  | 269.3 | 262.1 | 246.6 | 238.9    |
| T6                  | 271.3 | 266.4 | 249.8 | 241.6    |
| SEm ±               | 2.52  | 2.04  | 2.78  | 1.90     |
| CD (P=0.05)         | 7.95  | 6.43  | 8.76  | 5.99     |

T1: Control; T2: Gromor Sulphamax @ 10 kg acre⁻¹; T3: Gromor Rapid Blue® S @ 5 kg acre⁻¹; T4: Gromor Rapid Blue® S @ 7.5 kg acre⁻¹; T5: Gromor Rapid Blue® S @ 10 kg acre⁻¹; T6: Micronized S @ 3 kg acre⁻¹

Conclusion
Application of different improved forms of S at various rates has a significant effect on the available nutrient status of soil at all the growth stages of mustard crop. Micronized S @ 3 kg acre⁻¹ increased the available NK status of soil to a level greater than other treatments. On the other hand, available P status of soil at all the growth stages comes followed the opposite trend and was found maximum in plots treated with Gromor Sulphamax @ 10S kg acre⁻¹. Fertility status of soil was found to be lowest in absolute control plots where the crop was grown without application of NPK fertilizers.

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