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Sonam Singh
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Tusarkanta Behera
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Rajesh Kumar Singh
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Amitava Rakshit
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Corresponding Author:
Sonam Singh
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

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

Sonam Singh, Tusarkanta Behera, Rajesh Kumar Singh and Amitava Rakshit

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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 13th 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 a widely grown and demanded crop in India. Deficiency of Sin mustard (*Brassica juncea* L.) at any stage of crop growth can seriously damage the yield and quality of the crop. Sulphur along with nitrogen (N) plays a very critical role in plant development that's why N: S is considered very important. As per facts, nitrogenous fertilizers are mobile in soil and because of this nature split application is recommended instead of full dose as basal application. Application of N in split doses and a single dose of S at the time of sowing can alter optimum N: 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^o) 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 [3]. 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^o 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 (Inceptisol, Typic Ustochrept) in texture having pH (1:2 soil water ratio) of 7.6, EC (1:2 soil water ratio) of 0.24dS m^{-1}, organic carbon of 3.7g kg^{-1}. The initial nutrient status of the soil (Table 1) revealed that it was low in 0.15% $CaCl_2$ extractable S (8.9mg kg^{-1}), low in available N (197.70kg ha^{-1}), medium in available P (15.30kg ha^{-1}), and moderately high in available K (254kg ha^{-1}). After the field preparation, the selected test crop viz., mustard (variety: Indian mustard 'RH-749') was sown @6kg ha^{-1} with 30cm×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 P_2O_5 and K_2O 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.

T_1: Absolute control; T_2: Sulphamax @ 10 kg $acre^{-1}$; T_3: Gromor Rapid Blue® @ 5 kg $acre^{-1}$; T_4: Gromor Rapid blue® @ 7.5 kg $acre^{-1}$; T_5: Gromor Rapid blue® @ 10 kg $acre^{-1}$; T_6: Micronized sulphur @3kg $acre^{-1}$. 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 with 2 mm sieve, and there after analyzed for available N using alkaline permanganate method by Subbiah 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 (SO_4^{-2}) and nitrate ion (NO_3^-). 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 T_2 and at 90 DAS and harvesting was T_5. Similar finding was observed by Gajghane *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
T_1	195.7	190.4	185.5	161.3
T_2	262.1	232.6	215.9	193.1
T_3	258.9	227.5	203.3	190.3
T_4	255.4	221.6	200.3	187.9
T_5	260.9	231.4	219.1	192.4
T_6	264.1	238.2	223.5	196.5
SEm±	1.30	2.68	1.23	3.11
CD (P=0.05)	4.08	8.45	3.89	9.79

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 $acre^{-1}$

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 T_2 at all the growth stages and lowest in control. The second best treatment with respect to P level was treatment T_3. Basumatary (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.

Table 3: Effect of improved sulphur formulations on available P (kg ha^{-1}) in the soil at various physiological growth stages

Treatments	30DAS	60DAS	90DAS	Maturity
T_1	14.4	12.7	11.5	9.8
T_2	22.8	20.3	17.1	15.2
T_3	19.4	18.1	16.9	14.8
T_4	18.1	17.4	16.1	13.9
T_5	17.8	16.6	15.3	13.0
T_6	16.8	15.3	13.9	12.6
SEm±	0.79	0.63	0.61	0.46
CD (P=0.05)	2.48	1.99	0.51	1.45

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}

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 T_3 which was at par with T_4 and lowest was in control plot. Available K was highest in T_4 and T_6 at 90 DAS and harvest, respectively. At 90 DAS and harvest, available K in T_4 and T_6 was more or less same. Kumar and Singh, (2016) [14] observed that as the crop develops K content of rice field decrease. Differential uptake pattern of crop is a result of strong root system and good crop stand. 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) [15].

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
T_1	249.4	236.3	221.1	210.3
T_2	272.7	264.9	242.4	231.1
T_3	279.1	270.4	247.9	233.4
T_4	275.9	269.2	251.5	239.3
T_5	269.3	262.1	246.6	238.9
T_6	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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