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Integrated sulphur management in rapeseed (*Brassica campestris*)-blackgram (*Vigna mungo*) sequence in an Inceptisols of Assam

A. BASUMATARY*, K. GOSWAMI, D. OZAH, S. HAZARIKA AND G. TIMSENA

Department of Soil Science, Assam Agricultural University, Jorhat-785013, Assam

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ABSTRACT

A field experiment was conducted at the Instructional cum Research Farm, Assam Agricultural University, Jorhat during 2012-15 to assess the effect of sulphur alone and in different combination with farmyard manure, biofertilizer and lime on crop yields and uptake of nutrients by the crops and soil fertility status under rapeseed-blackgram sequence. Integrated sulphur nutrient management significantly influenced the crop yields over application of sulphur alone. Among the different integrated treatment combinations, application of 30 kg S ha^{-1} along with 50% recommended dose of NPK plus 1/10 lime plus 2 t ha^{-1} FYM produced the highest crop yields and uptake of N, P, K and S for both rapeseed and blackgram crop. Organic carbon and available nutrient status were found to be higher in treatments receiving integrated application of sulfur along with farmyard manure, lime and biofertilizer in different treatment combination over application of sulphur alone.

Key words: Integrated sulphur management, crop yield, nutrient uptake, soil fertility, rapeseed-blackgram sequence

INTRODUCTION

Sulphur plays a multiple role in the nutrition of rapeseed and blackgram. Now, Sulfur(S) is emerging as the third most important nutrient after nitrogen and phosphorus if extensiveness of deficiencies and not the amounts absorbed by crops is used as the criteria. At present its deficiency is one of the major constraints for sustainable growth and production of several field crops. Hence, the importance of sulphur is being increasingly emphasized in the recent past because of its deficiency being widely reported in different parts of India. In Assam, sulphur deficiency is becoming widespread due to continuous use of high analysis S-free fertilizers, increase in nutrient removal per hectare than addition and restricted use of organic manures coupled with its leaching due to high annual rainfall (>2000mm). About 10.1 to 20.0% soils from Inceptisols, 6.7 to 8.3% from Alfisols and 26.0% from Entisols were found deficient in available sulphur in Assam and needed sulphur fertilization for increasing crop production (Basumatari *et al.* 2010 and Das *et al.* 2011). The deficiency of sulphur is one among several constraints for low yield in Assam and its deficiency affects the quality of produce and leads to yield loss.Integrated sulphur management improves the availability of sulphur in soil and thereby it maintains high levels of soil productivity and fertility by influencing various physico-chemical properties of soil. Rapeseed and blackgram are the important crops cultivated in Assam. Adequate sulfur is very much crucial for oil seeds and pulse crops as it is directly responsible for the oil yield production and quality of pulse and show high response to S fertilization than cereals. Generally the sulphur applied to main crop leaves residual effect to succeeding crops. The positive influence of residual effect of sulphur on yield and uptake of many crops were reported by several workers (Bharathi and Poongothai 2008 and Dutta *et al.*2013) The beneficial effect of integrated sulfur management under rapeseed-rice in Assam was illustrated in the findings of Basumatary and Talukdar (2011). However, influence of integrated sulphur management on performance of crop productivity and improvement of soil fertility under rapeseed-blackgram is not yet investigated till now in Assam. Keeping these facts in view, present study was undertaken to assess the integrated effect of sulphur along with farmyard manure, biofertilizer and lime on crop yields and fertility status of soil under rapeseed-blackgram sequence.

MATERIALS AND METHODS

Field experiments were conducted in three consecutive years from 2012-15 on sandy loam soil at the Instructional cum Research Farm, Assam Agricultural University, Jorhat located at latitude of $26^0$48'N and longitude of $95^0$50'E. The initial soil of the experimental field was acidic in reaction (pH 4.6) having organic carbon 5.8 g kg^{-1}, available N 235.20 kg ha^{-1}, available P_2O_5 23.25 kg ha^{-1}, available K_2O 114.60 kg ha^{-1}, available S 7.25 kg ha^{-1}, exchangeable Ca^{2+} 1.2 cmol (p^+) kg^{-1} and exchangeable Mg^{2+} 0.8 cmol (p^+) kg^{-1}. The experiment was laid out in randomized block design with ten treatments and three replications .The treatments consisted of Control (100% NPK), 15 kg Sha^{-1} + 100%NPK, 30 kg Sha^{-1} + 100% NPK, 45 kg S ha^{-1} + 100%NPK, 15 kg Sha^{-1} + 50% NPK + 1/10 lime + 2t FYM ha^{-1}, 30 kg S ha^{-1} + 50% NPK + 1/10 lime + 2t FYM ha^{-1}, 45 kg Sha^{-1} + 50% NPK + 1/10 lime + 2t FYM ha^{-1}, 15 kg Sha^{-1} +25% NPK + Biofertilizer + 2t FYM ha^{-1}, 30kg Sha^{-1} +25% NPK + Biofertilizer + 2t FYM ha^{-1}, 45 kg S ha^{-1} +25% NPK + Biofertilizer + 2t FYM ha^{-1}. The sulphur was applied through gypsum. The direct sulphur management treatments were studied with rapeseed (Var. TS-38) and its residual effect was studied in the succeeding *Rabi* blackgram (Var KU301). A basal dose of 40 kg N, 35 kg P_2O_5 and 15 kg K_2O ha^{-1} to rapeseed and 10 kg N, 35 kg P_2O_5 and 10 kg K_2O ha^{-1} to blackgram was applied at the time of sowing through urea, diammonium phosphate and muriate of potash. The N, P, K and S content of FYM were 0.50, 0.26, 0.60 and 0.32%, respectively and incorporated into the soil 15 days prior to sowing of rapeseed. Rapeseed seeds were inoculated with azobacter (50 g of culture per kg of seeds) + phosphate solubilizing bacteria (50 g of culture per kg of seeds). After the harvest of rapeseed, blackgram was grown as residual crop in the same plot without application of sulphur. Seeds were inoculated with rhizobium culture + phosphate solubilizing bacteria culture each at a rate of 50 g kg^{-1} of seeds. Seed/grain and stover/straw samples were collected and dried samples were digested in di-acid mixture and the aliquots were used for analysis of phosphorus content by vanadomolybdate method (Jackson, 1973), potassium content by flame-photometer, calcium content by versene titration method (Jackson 1973) and sulphur content by turbidimetric method (Chesnin and Yien, 1951). Nitrogen content was determined by modified Kjeldahl method as described by Jackson (1973) after digesting completely with concentrated sulphuric acid using digestion mixture. The post harvest soil samples were collected after harvest of each crop and analyzed for organic carbon (Walkley and Black,1934), available N (Subbiah and Asija, 1956), P (Bray and Kurtz 1945), K (Jackson, 1973).Available S was analyzed after extraction with 0.15% $CaCl_2$ solution (Chesnin and Yien, 1951).

RESULTS AND DISCUSSION

Crop yields

Application of integrated sulphur nutrient management significantly influenced the crop yield of rapeseed over application of sulphur alone. Results (Table 1) revealed that application of sulphur along with farmyard manure, biofertilizer and lime recorded significantly higher yield as compare to application of sulphur alone. Among integrated treatments, application of 30 kg S ha^{-1} along with 50% NPK + 1/10 lime and 2 t FYM ha^{-1} resulted significantly the highest grain (10.1q ha^{-1}) and stover yield (30.2 q ha^{-1}) of rapeseed and resulted an increase in seed yield of 2.1 q ha^{-1} and stover yield of 5.1 q ha^{-1}over that of application of 30kg S ha^{-1} +100% NPK. This increase in yield might be due to direct effect of sulphur, farmyard manure and lime on crop growth which encouraged conducive physical environment leading to better aeration, root density and higher supply of absorption of nutrients. The effect of S fertilization appears to be due to vigorous growth of plant as their presences in plant system suggest greater availability of metabolites and nutrients synchronized to demand for growth and development of reproductive structure. A similar increase in yields was also reported by many other workers (Basumatary and Talukdar, 2007; Basumatary and Talukdar, 2011 and Singh, 2017).

Table1: Effect of integrated sulphur management on crop yields (mean of 3 years)

Treatment	Rapeseed yield (q ha^{-1})		Blackgram yield (q ha^{-1})	
	Seed	Stover	Grain	Stover
T_1:Control(100% NPK)	6.8	22.4	7.2	10.5
T_2: 15kg Sha^{-1} + 100%NPK	7.9	24.4	8.0	11.9
T_3: 30 kg Sha^{-1} + 100% NPK	8.0	25.1	8.1	12.0
T_4:45 kg Sha^{-1} + 100% NPK	7.5	23.9	7.7	11.2
T_5:15 kg Sha^{-1} +50%NPK + 1/10lime+ 2tFYM ha^{-1}	8.9	27.7	8.8	12.8
T_6:30 kg Sha^{-1} +50% NPK+1/10lime+ 2tFYM ha^{-1}	10.1	30.2	9.4	14.1
T_7:45 kg Sha^{-1} +50% NPK+1/10lime +2tFYM ha^{-1}	8.5	26.1	8.6	12.4
T_8:15 kg Sha^{-1} + 25% NPK + Bioferti.+2tFYM ha^{-1}	8.7	26.6	8.4	13.0
T_9:30 kg Sha^{-1} +25% NPK+Biofertil +2tFYM ha^{-1}	8.5	27.1	8.6	12.8
T_{10}:45 kg Sha^{-1} +25%NPK +Bioferti.+2tFYMha^{-1}	8.1	25.4	8.2	12.3
SEm±	0.2	0.5	0.1	0.2
CD (P=0.05)	0.6	1.4	0.5	0.7

In blackgram, marked positive residual effect of addition of sulphur and farmyard manure to proceeding rapeseed was noticed in terms of grain and stover yield of black gram (Table1).The data clearly showed the profound effect of addition of sulphur, farmyard manure and lime in increasing the grain and stover yield over that of single application of inorganic fertilizer of sulphur alone. Residual effect was more prominent under treatment receiving application of 30 kg S ha^{-1} along with 50% NPK+ 1/10 lime + 2 t FYM ha^{-1} and recorded significantly the highest grain (9.4 q ha^{-1}) and stover yield (14.1 q ha^{-1}) of blackgram. The magnitude of increase in grain and stover yield was 1.3 and 2.1 q ha^{-1} over that of application of 30kg S ha^{-1} +100% NPK. Such increase in yields might be due to improvement in physical and chemical environment of soil as residual effect of addition of farmyard manure, lime and sulphur. A similar finding was reported by Basumatary and Talukdar (2011).

Table 2: Total uptake (kg ha^{-1}) of major nutrients and sulphur by rapeseed and blackgram (mean of 3 years)

Treatment	Nitrogen		Phosphorus		Potassium		Sulphur	
	Rape Seed	Black Gram	Rape Seed	Black Gram	Rape Seed	Black Gram	Rape Seed	Black Gram
T_1:Control(100% NPK)	50.31	31.15	5.20	3.27	40.31	9.24	6.29	1.60
T_2: 15kg Sha^{-1} + 100%NPK	57.67	35.25	6.02	3.97	43.89	11.89	8.67	2.22
T_3: 30 kg Sha^{-1} + 100% NPK	60.37	35.45	6.27	4.09	44.76	11.97	8.80	3.09
T_4:45 kg Sha^{-1} + 100% NPK	54.14	32.93	5.98	4.10	42.92	11.01	9.49	2.17
T_5:15 kg Sha^{-1} +50%NPK + 1/10lime+ 2tFYM ha^{-1}	64.59	37.92	9.40	4.69	53.19	13.82	10.84	3.65
T_6:30 kg Sha^{-1} +50% NPK+1/10lime+ 2tFYM ha^{-1}	74.06	42.71	9.98	5.06	59.33	14.54	12.31	4.25
T_7:45 kg Sha^{-1} +50% NPK+1/10lime +2tFYM ha^{-1}	62.93	37.42	7.72	4.29	51.42	12.48	10.94	3.02
T_8:15 kg Sha^{-1} + 25% NPK + Bioferti.+2tFYM ha^{-1}	60.18	38.59	6. 90	4.15	49.18	12.50	8.91	3.10
T_9:30 kg Sha^{-1} +25% NPK+Biofertil +2tFYM ha^{-1}	60.97	38.88	7.03	4.08	53.15	12.88	9.93	3.21
T_{10}:45 kg Sha^{-1} +25%NPK +Bioferti.+2tFYMha^{-1}	55.46	37.25	6.84	3.79	48.64	12.37	9.85	3.26
SEm±	1.23	0.61	0.18	0.11	0.89	0.55	0.59	0.27
CD (P=0.05)	2.98	1.48	0.45	0.27	2.17	1.33	1.23	0.55

Nutrient uptake

Application of sulphur either alone or in combination with farmyard manures, biofertilizer and lime significantly influenced the uptake of nitrogen, phosphorus, potassium and sulphur by rapeseed over control (100%NPK). Results (Table 2) showed that significantly higher uptake of N, P, K and S were recorded in treatment receiving application of 30 kg S ha^{-1} along with 50% NPK+ 1/10 lime + 2 t FYM ha^{-1}. This higher nutrient uptake of N, P, K and S under integrated treatments might be due to supplementation of soil reservoir on mineralization of farm yard manure as well as enhanced microbial activity and thereby helped in balancing the nutrients in soil solution and thus enhanced uptake of nutrients (Basumatary and Talukdar, 2007). Further, sulphur is an essential constitute of enzymes involved in nitrogen metabolism and its application improves the growth of roots and shoots in sulphur deficient soil, so plant roots enhance the uptake rate of N,P,K and S. The above results showed high S uptake resulting in corresponding increase in uptake of N, P and K by rapeseed plants which suggested a close relations between uptake of S and that of the three macro nutrients (NPK). Similar observations were also reported by Kour *et al.* (2014).

Residual effect of integrated sulphur management progressively increased the N, P, K and S uptake by blackgram. The trend of nutrient uptake was similar to rapeseed. Similar findings with interaction in the uptake pattern of S and other nutrients were also reported by Lanjewar and Selukar (2005); Giri *et al.* (2005); Sarangthem *et al.* (2008) and Saiborne and Lenka (2014).

Fertility status of soil

Organic carbon

Application of sulphur either alone or in combination with farmyard manure, lime and biofertilizer brought a significant variation in the content of organic carbon in soil (Table 3). Significant increase in the organic carbon content was recorded after rapeseed and blackgram crops in treatments where sulphur was applied along with farmyard manure, biofertilizer and lime and exhibited an improvement of 0.8 to 1.7gkg^{-1} over initial value. Among the integrated treatments, higher value was recorded in the treatment T_6 (30 kg S ha^{-1} +50% NPK+ 1/10lime +2t FYM/ha) followed by T_5 (15 kg S ha^{-1} +50% NPK+ 1/10lime +2t FYMha^{-1}) and found at par with each other. This increase might be due to addition of organic manure and lime which stimulate the growth and activity of microorganisms and thus higher production of biomass might have increased the organic carbon content in soil.

Table 3: Organic carbon and primary nutrient status in soil after the harvest of rapeseed and blackgram (mean of 3 years)

Treatments	Organic carbon (g kg^{-1})		Available N (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kg ha^{-1})	
	Rape seed	Black gram	Rape seed	Black gram	Rape seed	Black gram	Rape seed	Black gram
T_1	5.40	5.50	216.00	218.00	19.70	20.95	110.50	95.67
T_2	6.00	6.20	247.50	250.33	22.25	23.10	112.65	101.32
T_3	6.10	6.50	253.00	255.50	22.45	23.38	113.30	104.70
T_4	5.90	6.10	250.00	254.00	21.33	22.67	112.20	104.65
T_5	7.10	7.50	279.33	283.17	25.57	26.19	117.08	108.90
T_6	7.50	7.70	281.25	283.75	25.99	26.80	117.71	109.75
T_7	6.80	7.00	277.33	275.67	24.83	25.75	116.28	108.04
T_8	7.00	7.30	272.50	273.75	24.73	25.57	115.53	107.57
T_9	6.80	7.00	274.00	278.17	24.48	25.17	115.97	107.50
T_{10}^{-1}	6.60	6.80	274.75	275.42	23.75	24.50	115.90	107.70
SEm±	0.01	0.01	1.63	1.32	0.52	0.46	0.42	1.25
CD(P=0.05)	0.04	0.02	4.85	3.91	1.54	1.35	1.25	3.71

Primary nutrients

Integrated use of sulphur with farmyard manure, biofertilizer and lime had a significant influence on primary nutrient status in soil. Data (Table 3) on primary nutrient content of soils after harvest of rapeseed revealed that available content of N, P_2O_5 and K_2O were significantly higher in the integrated treatments receiving sulphur along with farmyard manure, biofertilizer and lime over application of inorganic sulphur and control. All the treatments under integration of organic, inorganic and biofertilizer registered higher status of available nitrogen, phosphorus and potassium contents as compared to application of chemical fertilization. Among the treatments, available nitrogen was found highest in treatment receiving 30 kg S ha^{-1} +50% NPK+1/10 lime + 2 t FYM ha^{-1} and resulted in an improvement of 46.05 and 48.55 kg ha^{-1} over initial value after harvest of rapeseed and blackgram crops, respectively. The possible reason for higher nitrogen content in the integrated management might be ascribed that addition of organic and inorganic nitrogen in integration narrowed the C: N ratio of FYM and enhanced mineralization rate resulting rapid conversion of organically bound N to inorganic forms (Singh *et al.* 2014). Similarly, availability of P_2O_5 might be attributed to reduction in the fixation of the water soluble P and mineralization of organic P mediated by microbes present in the FYM and thus enhance the P_2O_5 content of soils. The results were in confirmation with the reports of Singh *et al.* (2014). Same trend of treatments were observed in case of available phosphorus. In respect of available potassium, the available potassium content in soils was also found to be higher in the integrated treatments as compared to other treatments. The application of farmyard manure along with inorganic fertilizers might have reduced fixation and release of K in the exchange site as a result of organic matter –clay interaction. In respect of available K_2O, application of 30 kg S ha^{-1} +50% NPK+ 1/10lime + 2 t FYM ha^{-1} resulted the highest content of available K_2O and recorded an improvement of 3.11 kg ha^{-1} over initial value However, available K_2O content in all the treatments was lower than initial value after harvest of Black gram. This indicates depletion of potassium from soil and therefore mining of K after harvesting. This might be attributed to higher removal by the crops than addition. Similar negative balance of potassium has also been reported by Borkakati *et al.* (2001) and Sanyal *et al.* (2014).

Secondary nutrients

Results revealed that integrated use of sulphur with farmyard manure, biofertilizer and lime registered higher content of available sulphur than that of single application of inorganic S and control (Table 4). The highest content of available sulphur was also recorded in the same treatment ($T_{6)}$ after harvest of both the crops. This might be due to addition of sulphur and farmyard manure which contain S as a constituent element and thus mineralization of this organic source might have released proportionate amount of sulphate that was adsorbed by colloidal complex and contributed to accumulate of more amount of sulphur over single application of inorganic sulphur. Similar observations were also reported by Dutta *et al.* (2013). It is important to note here that despite of applying 40 kg S ha^{-1}, the post harvest available S content was found to be highest where 30 kg S ha^{-1} was applied along with 50% NPK, lime and FYM. This might possibly be due to the reason that a portion of applied S might had moved to the subsoil and was unavailable for plants at least in the short term (Khalid *et al.* 2009). Data (Table 4) further revealed that application of sulphur either alone

Table 4: Secondary nutrients status in soil after the harvest of rapeseed and blackgram

Treatments	Available sulphur (mg kg^{-1})		Exchangeable Ca [cmol (p^+) kg^{-1}]		Exchangeable Mg [cmol (p^+) kg^{-1}]	
	Rape seed	Black gram	Rape seed	Black gram	Rape seed	Black gram
T_1 Control(100% NPK)	5.53	5.40	1.10	1.13	0.70	0.72
T_2 15kg Sha^{-1} + 100%NPK	11.36	10.17	1.32	1.34	1.00	1.03
T_3 30 kg Sha^{-1} + 100% NPK	12.47	10.52	1.37	1.40	1.03	1.07
T_4 45 kg Sha^{-1} + 100% NPK	12.43	10.05	1.40	1.43	1.07	1.10
T_5 15kg Sha^{-1}+50%NPK+1/10lime+ 2tFYM ha^{-1}	14.87	12.52	1.43	1.47	1.13	1.17
T_6 30kgSha^{-1}+50% NPK+1/10lime+ 2tFYM ha^{-1}	15.36	12.62	1.53	1.57	1.23	1.27
T_7 45kgSha^{-1}+50% NPK+1/10lime +2tFYM ha^{-1}	14.39	12.34	1.50	1.50	1.17	1.20
T_8 15kgSha^{-1}+25% NPK + Bioferti.+2tFYM ha^{-1}	13.81	11.89	1.47	1.47	1.10	1.13
T_9 30kgSha^{-1} +25% NPK+Biofertil +2tFYM ha^{-1}	14.19	11.16	1.47	1.50	1.17	1.20
T_{10} 45kgSha^{-1}+25%NPK+Bioferti.+2t FYMha^{-1}	13.57	11.32	1.50	1.52	1.13	1.17
SEm±	0.37	0.69	0.06	0.04	0.06	0.04
CD(P=0.05)	1.08	2.02	0.14	0.12	0.18	0.13

or in combination with farmyard manure, biofertilizer and lime resulted in an improvement of 4.11 to 8.11 and 2.29 to 5.37 mg kg^{-1} of sulphate sulphur over initial value after harvest of rapeseed and blackgram, respectively while it was depleted under control. This improvement might be due to relatively less absorption of sulphur by crops than its supply while depletion might be due to removal of sulphur by crops. Similar observation was reported by Kumar *et al.* (2011). Similar trend of observation was observed in respect of exchangeable calcium and magnesium content in soil. After harvest of crops, exchangeable calcium content was observed to vary within treatments. Exchangeable calcium was recorded highest in the treatment receiving 30 kg S ha^{-1} +50% NPK+ 1/10lime + 2tFYM ha^{-1} and resulted in an improvement of 0.33and 0.37[cmol (p^+) kg^{-1}] after harvest of rapeseed and blackgram, respectively over initial value while it was depleted under control. This might be due to application of gypsum, lime and farmyard manure. After gypsum application, there was a sharp increase in calcium content in soil solution causing the displacement of Al from the soil exchange complex. Most of the calcium released from gypsum applied was held by negatively charged sites on the soil surface and thus increased accumulation of calcium in soil. In respect of exchangeable magnesium, similar trend of treatment was observed and found buildup of 0.43 and 0.47 [cmol (p^+) kg^{-1}] after harvest of rapeseed and black gram, respectively over initial value.

From the study, it could be inferred that soil productivity was influenced significantly by integrated sulphur management. Among integrated treatments, application of 30 kg S ha^{-1} along with 50% NPK + 1/10 lime and 2 t FYM ha^{-1} was found better in terms of obtaining high crop yields and improvement in soil fertility status both in direct and residual phase over application of sulphur alone under rapeseed-blackgram sequence in an Inceptisols of Assam.

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