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Integrated Sulphur Management in Rapeseed (*Brassica campestris*)-Blackgram (*Vigna mungo*) Sequence in an Inceptisol of Assam

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A field experiment was conducted in three consecutive years during 2012-15 at Instructional *cum* Research Farm, Assam Agricultural University, Jorhat, Assam to assess the effect of integrated sulphur (S) management on soil fertility status and crop yields under rapeseed-blackgram sequence. The present study comprised of ten treatments, consisting of three levels of S either alone or in different combinations with farmyard manure (FYM), biofertilizer and lime. The results indicated that application of 30 kg S ha^{-1} along with 50% recommended dose of NPK plus $^{1}/_{10}$ lime plus 2 t FYM ha^{-1} produced the highest seed yield (10.1 q ha^{-1} and uptake of N, P, K and S (74.0, 9.98, 59.3 and 12.3 kg ha^{-1}) by rapeseed, respectively and its residual effect was also found prominent in producing maximum grain yield (9.4 q ha^{-1}) and uptake of N, P, K and S (42.7, 5.06, 14.5 and 4.25 kg ha^{-1}) by blackgram, respectively. Organic carbon and available primary and secondary nutrient status were found to be highest in treatment receiving application of 30 kg S ha^{-1} along with 50% recommended dose of NPK plus $^{1}/_{10}$ lime plus 2 t FYM ha^{-1} and exhibited an improvement of 1.9 g kg^{-1}, 48.5 kg ha^{-1}, 3.6 kg ha^{-1} and 5.3 mg kg^{-1} of organic carbon, available N, P and S, respectively over initial value after harvest of three cycle of cropping sequence.

Key words: Crop yield, integrated sulphur management, available nutrients and rapeseed-blackgram sequence

Sulphur (S) plays a multiple role in the nutrition of rapeseed (*Brassica campestris*) and blackgram (*Vigna mungo*). Now, S is emerging as the third most important nutrient after nitrogen (N) and phosphorus (P) 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 S is being increasingly emphasized in the recent past because of its deficiency being widely reported in different parts of India (Tandon and Messick 2007). In Assam, S deficiency is becoming widespread due to continuous use of high analysis S-free fertilizers, increase in nutrient removal ha^{-1} than addition and restricted use of organic manures coupled with its leaching due to high annual rainfall (>2000 mm). About 10.1 to 20.0% soils of Inceptisols, 6.7 to 8.3% of Alfisols and 26.0% of Entisols were found deficient in available S in Assam and needs S fertilization for increasing crop production (Das *et al.* 2011; Rajkonwar *et al.* 2016). The deficiency of S is one among several constraints for low yield in Assam and its deficiency affects the quality of produce and leads to yield loss.

Integrated S management improves the availability of S in soil and thereby it maintains high levels of soil productivity and fertility by influencing various physicochemical properties of soil. Rapeseed and blackgram are the important crops cultivated in Assam. Adequate S 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 S applied to main crop leaves residual effect to succeeding crops. The positive influence of residual effect of S on yield and uptake of many crops were reported by several workers (Dutta *et al*. 2013; Kour *et al*. 2014) The beneficial effect of integrated S management under rapeseed-rice in Assam was illustrated in the findings of Basumatary and Talukdar (2011). However, influence of integrated S 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

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undertaken to study the integrated effect of S along with farmyard manure (FYM), 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 year from 2012-15 on sandy loam soil at the Instructional *cum* Research Farm, Assam Agricultural University, Jorhat, Assam located at latitude of 26°48′ N and longitude of 95°50′ E. The research site has a typical subtropical climate with a mean annual rainfall 151.6 cm during the period (2012-15). The minimum and maximum mean annual temperature ranged from 18.9-19.3°C and 29.2-29.7°C, respectively. The soil of the experimental field was acidic in reaction (pH 4.6) having organic carbon 5.8 g kg^{-1}, available N 235.2 kg ha^{-1}, available P_2O_5 23.2 kg ha^{-1}, available K_2O 114.6 kg ha^{-1}, available S 7.3 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 T_1: control (100% NPK), T_2: 15 kg S ha^{-1} + 100% NPK, T_3: 30 kg S ha^{-1} + 100% NPK, T_4: 45 kg S ha^{-1} + 100% NPK, T_5: 15 kg S ha^{-1} + 50% NPK+ $^1/_{10}$ lime + 2 t FYM ha^{-1}, T_6: 30 kg S ha^{-1} + 50% NPK + $^1/_{10}$ lime + 2 t FYM ha^{-1}, T_7: 45 kg S ha^{-1} +50% NPK + $^1/_{10}$ lime + 2 t FYM ha^{-1}, T_8: 15 kg S ha^{-1} +25% NPK + biofertilizer + 2 t FYM ha^{-1}, T_9: 30 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-1}, T_{10}: 45 kg S ha^{-1} +25% NPK + biofertilizer + 2 t FYM ha^{-1}.

The S was applied through gypsum. The direct S management treatments were studied with rapeseed (var. TS-38) and its residual effect was studied in the succeeding *rabi* blackgram (Var PU301). 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 (DAP) and muriate of potash (MOP). 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. For biofertilizer treatment, rapeseed seeds were inoculated with *Azobacter* and phosphate solubilizing bacteria @ 50 g each kg^{-1} of seeds as seed coating at the time of sowing. After the harvest of rapeseed, blackgram was grown as residual crop in the same plot without application of S. Blackgram seeds were inoculated with *Rhizobium* and phosphate solubilizing bacteria @ 50 g each kg^{-1} of seeds as seed coating at the time of sowing. Crop yields were recorded after harvest and representative seed/grain and stover /straw samples were digested and analyzed for concentration of N, P, K and S content in seed and stover/straw by standard methods *viz.*, modified Kjeldahl's vanadomolybdate, flame photometer and turbidemetric method, respectively. The initial and post-harvest soil samples were collected and analyzed for organic carbon (Walkley and Black 1934), available N (Subbiah and Asijia 1956), P (Bray and Kurtz 1945) and K and exchangeable Ca and Mg (Jackson 1973). Available S was analyzed after extraction with 0.15% $CaCl_2$ solution (Chesnin and Yien 1951). The results of the experiments were analyzed statistically using analysis of variance for various parameters at 5% level of significance.

Results and Discussion

Crop yields

Application of integrated S nutrient management significantly influenced the crop yield of rapeseed over application of S alone. Results (Table 1) indicated that application of 30 kg S ha^{-1} along with 50% NPK + $^1/_{10}$ lime and 2 t FYM ha^{-1} (T_6) resulted significantly the highest seed (10.1 q 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 30 kg S ha^{-1}+100% NPK. This increase in yield might be due to direct effect of S, FYM 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 presence 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 2011; Singh 2017).

Among the integrated S treatments, it was observed that crop yields were decreased when S was integrated at a rate of 45 kg ha^{-1} (T_7 and T_{10}) as compared to integrated use of S at a rate of 30 kg ha^{-1} (T_6 and T_9). This decrease might be due to reduced uptake of N, P, K and S (Table 2) and lower content of primary and secondary nutrients in soil (Table 3) as compared to treatment T_6 and T_9. A similar finding was reported by Basumatary *et al.* (2018).

In blackgram, marked positive residual effect of addition of S and FYM to proceeding rapeseed was

Table 1. 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: 15 kg S ha^{-1} + 100% NPK	7.9	24.4	8.0	11.9
T_3: 30 kg S ha^{-1} + 100% NPK	8.0	25.1	8.1	12.0
T_4: 45 kg S ha^{-1} + 100% NPK	7.5	23.9	7.7	11.2
T_5: 15 kg S ha^{-1} + 50% NPK + $^1/_{10}$ lime + 2 t FYM ha^{-1}	8.9	27.7	8.8	12.8
T_6: 30 kg S ha^{-1} + 50% NPK + $^1/_{10}$ lime + 2 t FYM ha^{-1}	10.1	30.2	9.4	14.1
T_7: 45 kg S ha^{-1} + 50% NPK + $^1/_{10}$ lime + 2 t FYM ha^{-1}	8.5	26.1	8.6	12.4
T_8: 15 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-1}	8.7	26.6	8.4	13.0
T_9: 30 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-1}	8.5	27.1	8.6	12.8
T_{10}: 45 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-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

Table 2. Total uptake (kg ha^{-1}) of major nutrients and S 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)	50.3	31.2	5.20	3.27	40.3	9.24	6.29	1.60
T_2: 15 kg S ha^{-1} + 100% NPK	57.7	35.3	6.02	3.97	43.9	11.9	8.67	2.22
T_3: 30 kg S ha^{-1} + 100% NPK	60.3	35.5	6.27	4.09	44.8	12.0	8.80	3.09
T_4: 45 kg S ha^{-1} + 100% NPK	54.1	32.9	5.98	4.10	42.9	11.0	9.49	2.17
T_5: 15 kg S ha^{-1} + 50% NPK + $^1/_{10}$ lime + 2 t FYM ha^{-1}	64.6	37.9	9.40	4.69	53.2	13.8	10.8	3.65
T_6: 30 kg S ha^{-1} + 50% NPK + $^1/_{10}$ lime + 2 t FYM ha^{-1}	74.1	42.7	9.98	5.06	59.3	14.5	12.3	4.25
T_7: 45 kg S ha^{-1} + 50% NPK + $^1/_{10}$ lime +2 t FYM ha^{-1}	62.9	37.4	7.72	4.29	51.4	12.5	10.9	3.02
T_8: 15 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-1}	60.2	38.6	6. 90	4.15	49.2	12.5	8.91	3.10
T_9: 30 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-1}	61.0	38.9	7.03	4.08	53.2	12.9	9.93	3.21
T_{10}: 45 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-1}	55.4	37.3	6.84	3.79	48.6	12.4	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

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: Control (100% NPK)	5.40	5.50	216.0	218.0	19.7	20.9	110.5	95.7
T_2: 15 kg S ha^{-1} + 100% NPK	6.00	6.20	247.5	250.3	22.3	23.1	112.6	101.3
T_3: 30 kg S ha^{-1} + 100% NPK	6.10	6.50	253.0	255.5	22.5	23.4	113.3	104.7
T_4: 45 kg S ha^{-1} + 100% NPK	5.90	6.10	250.0	254.0	21.3	22.7	112.2	104.7
T_5: 15 kg S ha^{-1} + 50% NPK + $^1/_{10}$ lime + 2 t FYM ha^{-1}	7.10	7.50	279.3	283.2	25.6	26.2	117.1	108.9
T_6: 30 kg S ha^{-1} + 50% NPK + $^1/_{10}$ lime + 2 t FYM ha^{-1}	7.50	7.70	281.2	283.7	26.0	26.8	117.7	109.8
T_7: 45 kg S ha^{-1} + 50% NPK + $^1/_{10}$ lime + 2 t FYM ha^{-1}	6.80	7.00	277.3	275.7	24.8	25.8	116.3	108.0
T_8: 15 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-1}	7.00	7.30	272.5	273.7	24.7	25.6	115.5	107.6
T_9: 30 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-1}	6.80	7.00	274.0	278.2	24.5	25.2	116.0	107.5
T_{10}: 45 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-1}	6.60	6.80	274.7	275.4	23.7	24.5	115.9	107.7
SEm±	0.01	0.01	1.63	1.32	0.52	0.46	0.42	1.25
CD (P=0.05)	0.40	0.20	4.85	3.91	1.54	1.35	1.25	3.71

noticed in terms of grain and stover yield of black gram (Table 1). The data clearly showed the profound effect of addition of S, FYM and lime in increasing the grain and stover yield over that of single application of inorganic S fertilizer alone. Residual effect was more prominent under treatment receiving aapplication 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 30 kg S ha^{-1} + 100% NPK. Similar improvement in crop yields were also recorded under integrated S treatments (T_5 to T_{10}) as compared to treatments receiving application of inorganic S fertilizer alone (T_2 to T_4). Such increase in yields might be due to improvement in physical and chemical environment of soil as residual effect of addition of FYM, lime and S. Among the treatments, it was noticed that crop yields under T_7 and T_9 were found statistically at par for both rapeseed and blackgram. It was evident from table 2 and 3 that available nutrient status and uptake of N, P, K and S were found at par under these two treatments and thus might be contributed similar effects in increasing crop yields. A similar finding was reported by Basumatary and Talukdar (2011).

Nutrient uptake

Application of S either alone or in combination with FYM, biofertilizer and lime significantly influenced the uptake of N, P, K and S by rapeseed crop 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 and 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 FYM 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, S is an essential constitute of enzymes involved in N metabolism and its application improves the growth of roots and shoots in S 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 S 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 Sarangthem *et al*. (2008) and Saiborne and Lenka (2014).

Fertility Status of Soil

Organic carbon

Application of S either alone or in combination with FYM, 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 S was applied along with FYM, biofertilizer and lime and exhibited an improvement of 0.8 to 1.7 g kg^{-1} over initial value. This improvement might be due to continuous application of FYM for three years which in turn enhanced crop productivity resulting incorporation of larger biomass and thus raised the soil organic carbon. Among the integrated treatments, higher value was recorded in the treatment T_6 (30 kg S ha^{-1} +50% NPK+ $^1/_{10}$ lime + 2 t FYM ha^{-1}) followed by T_5 (15 kg S ha^{-1} + 50% NPK + $^1/_{10}$ lime + 2 t FYM ha^{-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. Verma *et al.* (2017) reported that integrated soil management comprising 50% NPK + FYM @ 5 t ha^{-1} + lime @ 5 t ha^{-1} significantly improved soil organic carbon in an acid soil of Meghalaya.

Primary nutrients

Integrated use of S with FYM, 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 and K were significantly higher in the integrated treatments receiving S along with FYM, biofertilizer and lime over application of inorganic S and control. All the treatments under integration of organic, inorganic and biofertilizer registered higher status of available N, P and K contents as compared to application of chemical

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

Treatments	Available S (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: 15 kg S ha^{-1} + 100% NPK	11.4	10.2	1.32	1.34	1.00	1.03
T_3: 30 kg S ha^{-1} + 100% NPK	12.5	10.5	1.37	1.40	1.03	1.07
T_4: 45 kg S ha^{-1} + 100% NPK	12.4	10.1	1.40	1.43	1.07	1.10
T_5: 15 kg S ha^{-1} + 50% NPK + $^{1}/_{10}$ lime + 2 t FYM ha^{-1}	14.9	12.5	1.43	1.47	1.13	1.17
T_6: 30 kg S ha^{-1} + 50% NPK + $^{1}/_{10}$ lime + 2 t FYM ha^{-1}	15.4	12.6	1.53	1.57	1.23	1.27
T_7: 45 kg S ha^{-1} + 50% NPK + $^{1}/_{10}$ lime + 2 t FYM ha^{-1}	14.4	12.3	1.50	1.50	1.17	1.20
T_8: 15 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-1}	13.8	11.9	1.47	1.47	1.10	1.13
T_9: 30 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-1}	14.2	11.2	1.47	1.50	1.17	1.20
T_{10}: 45 kg S ha^{-1} + 25% NPK + biofertilizer + 2 t FYM ha^{-1}	13.6	11.3	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

fertilization. Among the treatments, available N 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 46.0 and 48.5 kg ha^{-1} over initial value after harvest of rapeseed and blackgram crops, respectively. The possible reason for higher N content in the integrated management might be ascribed that addition of organic and inorganic N 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 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 status of soils. The results were in confirmation with the reports of Singh *et al.* (2014). Similarly, the available K status of soils were found to be higher in the integrated treatments as compared to other treatments. The application of FYM 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, application of 30 kg S ha^{-1} + 50% NPK+ $^{1}/_{10}$ lime + 2 t FYM ha^{-1} resulted in highest content of available K and recorded an improvement of 3.1 kg ha^{-1} over initial value. However, available K content of the soil in all treatments was lower than initial value after harvest of blackgram. This indicates depletion of K 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 K has also been reported by Borkakati *et al*. (2001) and Sanyal *et al*. (2014).

Secondary nutrients

Results revealed that integrated use of S with FYM, biofertilizer and lime registered higher content of available S than that of single application of inorganic S and control (Table 4). The highest content of available S was also recorded in the same treatment (T_6) after harvest of both the crops. This might be due to addition of S and FYM 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 more amount of S 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 S either alone or in combination with FYM, biofertilizer and lime resulted in an improvement of 4.10 to 8.10 and 2.80 to 5.30 mg kg^{-1} of sulphate-S 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 S by crops than its supply while depletion might be due to removal of S by crops. Similar observation was reported by Kumar *et al*. (2011).

Similar trend of observation was observed in respect of exchangeable Ca and Mg. After harvest of crops, exchangeable Ca of the soil was observed to vary within treatments. Exchangeable Ca was recorded highest in the treatment receiving 30 kg S ha^{-1} + 50% NPK+ $^1/_{10}$ lime + 2 t FYM ha^{-1} and resulted in an improvement of 0.33 and 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 FYM. After gypsum application, there was a sharp increase in Ca content in soil solution causing the displacement of Al from the soil exchange complex. Most of the Ca released from gypsum applied was held by negatively charged sites on the soil surface and thus increased accumulation of Ca in soil. In respect of exchangeable Mg, similar trend of treatment was observed with the build-up 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 S management. Integrated use of S along with either $^1/_{10}$ lime plus 2 t FYM ha^{-1} or biofertilizer plus 2 t FYM ha^{-1} was better in terms of obtaining high crop yields and improvement in soil fertility status both in direct and residual phase over application of S alone under rapeseed-blackgram sequence in an Inceptisols of Assam.

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