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Influence of sulphur on yield, quality and uptake of different nutrients by rapeseed

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Abstract
Two field experiments were conducted in succession (two years) to study the effect of sulphur on yield, quality and uptake of different nutrients by rapeseed crop grown in a *Topic haplaquept* soil. Different doses of sulphur and FYM with recommended doses (RDF) of fertilizers N, P and K along with sulphur oxidising bacteria (SOB) were used as treatment materials. Uptake of N, P, K and S were estimated at branching, flowering and harvesting stages of the crop. Yields of biomass (stover and seeds) and quality parameters (oil and protein content) of rapeseed were determined. Results revealed that highest stover (31.57 q ha^{-1}) and seed yield (12.87q ha^{-1}) were recorded in T_7 (RDF of NPK + S at 15 kg ha^{-1} + FYM at 5 t ha^{-1} + SOB at 7.5 kg ha^{-1}) and T_8 (RDF of NPK + S at 30 kg ha^{-1} + FYM 2.5 t ha^{-1} + SOB at 7.5 kg ha^{-1}) treated plots respectively. Highest oil content (41.9%) was recorded in T_7 treatment which is 19.6 percent more over control. Highest protein content (22.8%) in the seeds was recorded in T_8 treated plot which is 16.2% more over control. Uptake of N, P, K and S by stover was found more at branching and flowering stage in T_7 followed by T_8 treated plot. Application of higher dose of S along with sulphur oxidising bacteria (SOB) resulted higher seed yield of rapeseed. Lowest N: S ratio of 3.68 was observed in T_7 treatment which indicates that FYM plays important role in narrowing down the N:S ratio.

Keywords: Rapeseed, nutrient uptake, sulphur oxidising bacteria, N: S ratio, oil and protein content

1. Introduction
Sulphur plays an important role in enhancing the yield and quality of crops specially oil seed crops. It improves the crop growth and yield attributes by regulating the metabolic and enzymatic processes including photosynthesis and respiration (Rao *et al*. (2001) [1]. The use efficiency of added S through external sources is also very low, being only 8 to10 percent (Hegde and Murthy, 2005) [2]. An insufficient S supply can affect yield and quality of the crops, caused by the S requirement for protein and enzyme synthesis (Scherer, 2001) [3]. Sulphur deficiencies have been reported from more than 70 countries worldwide and 120 districts throughout India (Tandon, 1991) [4]. As per latest available data, 41 percent soil samples tested were deficient in available S in India (Singh, 2008) [5]; (Singh and Kumar, (2012) [6]; (Singh *et al*. (2015) [7]. Sulphur deficiency has been reported at alarming frequency for cereals, pulses, oil seeds (Mathew *et al*. 2013) [8] and bulb crops (Chandel *et al*. (2012) [9]. Inoculation of S-oxidisers increases growth, biomass and yield of rapeseed even in the absence of externally applied S source (Joseph *et al*. (2014) [10]. The essential nutrients in the soil occur in complex form, not readily bio-available to the plants or in water soluble forms. Microbes play an important role in making these complex forms bio-available to the plants (Grayston *et al*. (1998) [11]. *Thiobacilli* play an important role in sulphur oxidation in the soil. Sulphur oxidation is the most important step of S-cycle which improves soil fertility. It results in the formation of sulphate, which can be utilized by plants, while the acidity produced by oxidation helps to solubilise plant nutrients and improves fertility (Vidyalaxmi *et al*. (2009) [12]. Inoculation of SOB promotes yield and oil content of oilseed crop. Keeping above information in view, two field experiments with same treatment combinations were conducted in succession to study the effect of sulphur and sulphur oxidising bacteria on improvement of yield and some quality parameters of rapeseed in a *Typic haplaquept* soil.

2. Materials and methods
Two field experiments in succession with same treatments were carried out at Sub Divisional Adaptive Research Farm ($23^0$96'27" N latitude and $88^0$04'96"E longitude) located at Kandi in Murshidabad district of West Bengal, India. The experimental field was divided into 24

plots (4.5 x 5.0 m) to accommodate eight treatments with three replications. Rapeseed (cv. *Binay*) was grown in the plots with different treatment combinations. The experiment was conducted with randomized block design adopting following treatments:

T_0 = Control, No S but RDF NPK
T_1 = RDF* of NPK + S at 15 kg ha^{-1}
T_2 = RDF of NPK + S at 30 kg ha^{-1}
T_3 = RDF of NPK + S at 15 kg ha^{-1} + FYM 5 t ha^{-1}
T_4 = RDF of NPK + S at 30 kg ha^{-1} + FYM at 2.5 t ha^{-1}
T_5 = Two splits of N but full P and K + S at 15 kg ha^{-1} + FYM at 5 t ha^{-1}
T_6 = Three splits of N but full P and K + S at 30 kg ha^{-1} + FYM at 2.5 t ha^{-1}
T_7 = RDF of NPK + S at 15 kg ha^{-1}+ FYM 5 t ha^{-1}+ S oxidizing bacteria at 7.5 kg ha^{-1}
T_8 = RDF of NPK+ S at 30 kg ha^{-1} + FYM at 2.5 t ha^{-1} + S oxidizing bacteria at 7.5 kg ha^{-1}
*Recommended dose of fertilizer (N: P: K: 40:20:20)

A Composite soil sample was collected from the experimental field for determination of soil properties. Periodical soil and plant samples were collected at branching, flowering and harvesting stages of the crop for analysis of N, P, K and S contents in soil and its uptake by rapeseed crop. Seed yield was estimated from net plot after discarding border rows. The weight of seeds was converted to q ha^{-1}. Physical and chemical properties of the initial soil sample was analysed following standard procedures and are presented in the Table 1. Plant samples (stover and seeds) were collected and analysed separately for N, P and K content following the standard procedures (Jackson, 1973) [13]. Total sulphur in plant samples was determined by $HClO_4$ acid digestion method (Chapman and Pratt, 1961) [14]. Sulphur content in all the extracts was determined turbidimetrically (Chesnin and Yien, 1951) [15]. The oil from seed was extracted with petroleum ether and protein content was calculated by multiplying N content with 6.25. Uptake of nutrients was calculated adding nutrient content in seeds and stover then multiplied with yield of seeds and stover respectively.

Nitrogen was applied through Urea (46% N) as basal in all the treatments except T_5 and T_6 where N was applied in split at branching and flowering stages of crop. Phosphorus and potassium were applied as basal in the form single super phosphate (16% P) and Muriate of Potash (60% K) respectively. Elemental sulphur (96% S) was applied as a source of sulphur. *Thiobacillus ferroxidans* was used as sulphur oxidising bacteria. The desired amount of bacteria formulation was weighed and mixed with suitable amount of soil for convenient of application in the plots as per treatments.

The data were analyzed statistically for all the parameters. Analysis of variance as well as critical difference was calculated at 5 percent level of significance to test the significance of means as described by Gomez and Gomez (1984) [16].

Table 1: Physical and chemical properties of soil collected from the experimental field.

Parameters	Value	Parameters	Value
Bulk Density (Mg m^{-3})	1.31	Total Sulphur (mg kg^{-1})	88.42
Water Holding Capacity (%)	46.23	EDTA extractable Fe (mg kg^{-1})	115.27
Saturated Hydraulic conductivity (cm hr^{-1})	1.17	EDTA extractable Cu (mg kg^{-1})	3.67
Oxidizable Organic carbon (g 100gm^{-1})	1.13	EDTA extractable Mn (mg kg^{-1})	5.72
pH (1:2.5)	6.43	EDTA extractable Zn (mg kg^{-1})	0.82
Available Nitrogen (kg ha^{-1})	196.5	Cation Exchange Capacity (mg kg^{-1})	14.83
Available P_2O_5 (Bray's) (kg ha^{-1})	27.30	Sand (%)	46.4
Available K_2O (kg ha^{-1})	135.45	Silt (%)	18.0
SO_4-S (mg kg^{-1})	6.35	Clay (%)	35.6
Adsorbed Sulphur (mg kg^{-1})	3.22	Textural Class: *Clay loam*	
Organic Sulphur (mg kg^{-1})	72.93	Soil Taxonomy: *Typic Haplaquept*	

3. Results and discussion
3.1. Nitrogen content
Changes in N content and dry matter yield at different growth stages of rapeseed are presented in Table 2. Highest amount of N content and uptake by stover were found in T_7 treated plot followed by T_8. N content increased with the application of sulphur in all the stages of crop growth. Mean N content in stover was found to be 1.13, 1.72 and 0.43 percent at branching, flowering and harvesting stage of crop growth. The lowest value of N uptake by stover was found at harvesting stage. This is due to higher production of dry matter as well as formation of seeds as N is converted to protein in seeds. Lowest content of N in stover at harvesting stage is due to the more amounts of an accumulation in seeds. However, Lowest N content was found in control plot which received only RDF of NPK. Application of split doses of N increased its uptake than N applied as basal. This is due to the application of N at growing period when crop needs and hence loss is reduced. On the other hand, application of sulphur oxidizing bacteria increases stover yield and N uptake by the crop. Higher straw yield of rapeseed was due to plant growth promoting activity of the inoculated sulphur oxidising bacteria (Joseph *et al*. (2014) [10]. Again, highest N percentage, dry matter yield and N-uptake by both stover and seeds were recorded in rapeseed treated with recommended doses of N, P and K fertilizer along with higher dose of FYM (5 t ha^{-1}) as well as S-oxidizing bacteria (T_7). This is due to supply of higher amount of available N to crops through mineralization of higher amount of applied FYM. Similar observations were also recorded earlier by Singh and Singh (2005) [17]. Application of RDF along with FYM, S and S-oxidizing bacteria showed higher order of N-percentage and dry matter production in rapeseed. Integration of FYM and S along with S-oxidizing bacteria resulted significantly higher N-uptake than that of RDF or RDF+S or RDF+S+FYM.

Table 2: Changes in N content, dry matter yield and N uptake of stover and seeds at different growth stages of rapeseed grown under different treatment combinations

Treatment	Stages of crop growth											
	Branching			Flowering			Harvesting					
							Stover			Seeds		
	N (%)	Dry matter Yield (kg ha^{-1})	N uptake (kg ha^{-1})	N (%)	Dry matter Yield (kg ha^{-1})	N uptake (kg ha^{-1})	N (%)	Dry matter Yield (kg ha^{-1})	N uptake (kg ha^{-1})	N (%)	Dry matter Yield (kg ha^{-1})	N uptake (kg ha^{-1})
T_0	1.02	376.8	3.84	1.31	787.0	10.31	0.36	2174.0	7.8	3.2	872	27.47
T_1	1.07	392.3	4.20	1.45	1056.0	15.31	0.38	2331.0	8.8	3.4	939	31.6
T_2	1.11	398.5	4.42	1.61	1121.0	18.05	0.41	2487.0	10.2	3.5	995	34.3
T_3	1.13	410.0	4.63	1.72	1243.0	21.38	0.42	2573.0	10.8	3.5	1062	37.1
T_4	1.16	412.0	4.78	1.78	1289.0	22.94	0.44	2646.0	11.6	3.5	1098	38.6
T_5	1.14	415.0	4.73	1.85	1532.0	28.34	0.45	2797.0	12.6	3.6	1156	41.0
T_6	1.17	414.0	4.84	1.89	1475.0	27.88	0.46	2829.0	13.0	3.6	1189	42.7
T_7	1.19	420.0	5.00	1.94	1652.0	32.05	0.49	3157.0	15.5	3.7	1274	46.6
T_8	1.18	418.0	4.93	1.91	1595.0	30.46	0.49	3073.0	15.1	3.7	1287	47.1
Mean	1.13	406.3	4.60	1.72	1305.6	22.97	0.43	2674.1	11.7	3.5	1096.9	38.5
SEm (±)	0.028	21.6	0.31	0.02	10.86	0.47	0.027	5.74	0.89	0.02	6.20	0.23
CD (P=0.05)	0.085	64.7	0.93	0.08	32.56	1.41	0.08	17.19	2.66	0.07	18.59	0.70

3.2. Phosphorus content

Highest P content of 0.18, 0.28 0.17 percent was recorded in stover at branching, flowering and harvesting stage respectively in T_7 treated plot followed by T_8 (Table 3). Mean phosphorus content in stover was found to be 0.14, 0.24 and 0.14 percent at branching, flowering and harvesting stages with mean uptake being 0.56, 4.63 and 3.80 kg ha^{-1} respectively. Irrespective of crop growth stages, application of S in soil increased P uptake compared to the control plot where S was not applied. Dry matter yield of rapeseed was increased gradually from 0.4 to 2.67 t ha^{-1} from branching to harvesting stages of crop growth. Highest P – uptake was recorded at harvesting stage as the stover yield was found maximum with the effect of sulphur application on growth and dry matter production of the crop (Singh and Singh, 2005)[17]. Combined application of phosphorus and sulphur enhanced the nutrients, crude protein and oil contents in oilseed crops. Beside this, interaction effect of P and S is significant in enhancing the sulphur containing amino acids viz. *cystine*, *cystein* and *methionine* content in oil seed crops (Kumar *et al*. (2017) [18].

Table 3. Changes in P content, dry matter yield and P uptake of stover and seeds at different growth stages of rapeseed grown under different treatment combinations

Treatment	Stages of crop growth											
	Branching			Flowering			Harvesting					
							Stover			Seeds		
	P (%)	Dry matter yield (kg ha^{-1})	P uptake (kg ha^{-1})	P (%)	Dry matter yield (kg ha^{-1})	P uptake (kg ha^{-1})	P (%)	Dry matter yield (kg ha^{-1})	P uptake (kg ha^{-1})	P (%)	Dry matter yield (kg ha^{-1})	P uptake (kg ha^{-1})
T_0	0.09	376.8	0.34	0.19	787.0	1.50	0.11	2174.0	2.39	0.83	872	7.24
T_1	0.11	392.3	0.43	0.21	1056.0	2.22	0.12	2331.0	2.80	0.85	939	7.98
T_2	0.12	398.5	0.48	0.22	1121.0	2.47	0.13	2487.0	3.23	0.87	995	8.66
T_3	0.13	410.0	0.53	0.23	1243.0	2.86	0.13	2573.0	3.34	0.88	1062	9.35
T_4	0.13	412.0	0.54	0.23	1289.0	2.96	0.14	2646.0	3.70	0.88	1098	9.66
T_5	0.15	415.0	0.62	0.25	1532.0	3.83	0.15	2797.0	4.20	0.9	1156	10.40
T_6	0.15	414.0	0.62	0.25	1475.0	3.69	0.15	2829.0	4.24	0.92	1189	10.94
T_7	0.17	420.0	0.71	0.28	1652.0	4.63	0.17	3157.0	5.37	0.96	1274	12.23
T_8	0.18	418.0	0.75	0.27	1595.0	4.31	0.16	3073.0	4.92	0.95	1287	12.23
Mean	0.14	406.3	0.56	0.24	1305.5	3.16	0.14	2674.11	3.80	0.89	1096.89	9.85
SEm (±)	0.014	21.58	0.07	0.015	10.85	0.21	0.012	5.73	0.406	0.013	6.200	0.189
CD (P=0.05)	0.043	64.71	0.22	0.046	32.55	0.64	0.037	17.19	1.217	0.040	18.589	0.567

3.3. Potassium content

Stover yield and uptake of K were found maximum at harvesting stage of the crop as it produces maximum dry matter (Table 4). At harvest, highest K content of 0.41 percent in stover was recorded in T_7 followed by T_8 treatment. However, highest amount of K was recorded in seeds of 1.53 percent K in T_8 treatment. Results showed that, mean K content in stover was found to be 1.15, 1.24 and 0.37 percent in branching, flowering and harvesting stages of crop. Lowest K content in stover was recorded at harvest is due to the conversion of plant nutrients and metabolites which are translocated into seeds. Highest uptake of K of 12.94 and 19.69 kg ha^{-1} by stover and seeds was recorded in T_7 and T_8 treated plots respectively. Increase in K uptake may be attributed to the increased seed yield and K content in seeds due to S application. Balanced fertilization encouraged utilization of more amount of K by the rapeseed crop showing highest percent of K, highest dry matter production and K-uptake by stover and seeds in T_7 treatment particularly because of inoculation of S-oxidizing bacteria. Similar observation is also recorded earlier by Upadhyay (2012) [19]. It is also reported that the optimum supply of K and S enhance the grain yield and protein content (Balpande, 2016) [20].

Table 4: Changes in K content, dry matter yield and K uptake of stover and seeds at different growth stages of rapeseed grown under different treatment combinations Sulphur Sulphur

Treatment	Stages of crop growth											
	Branching			Flowering			Harvesting					
							Stover			Seeds		
	K (%)	Dry matter Yield (kg ha^{-1})	K uptake (kg ha^{-1})	K (%)	Dry matter Yield (kg ha^{-1})	K uptake (kg ha^{-1})	K (%)	Dry matter Yield (kg ha^{-1})	K uptake (kg ha^{-1})	K (%)	Dry matter Yield (kg ha^{-1})	K uptake (kg ha^{-1})
T_0	1.09	376.8	4.11	1.17	787	9.21	0.31	2174.0	6.74	1.36	872.0	11.86
T_1	1.12	392.3	4.39	1.21	1056	12.78	0.34	2331.0	7.93	1.42	939.0	13.33
T_2	1.14	398.5	4.54	1.23	1121	13.79	0.34	2487.0	8.46	1.43	995.0	14.23
T_3	1.15	410.0	4.72	1.23	1243	15.29	0.37	2573.0	9.52	1.45	1062.0	15.40
T_4	1.15	412.0	4.74	1.24	1289	15.98	0.37	2646.0	9.79	1.46	1098.0	16.03
T_5	1.17	415.0	4.86	1.27	1532	19.46	0.38	2797.0	10.63	1.46	1156.0	16.88
T_6	1.17	414.0	4.84	1.27	1475	18.73	0.38	2829.0	10.75	1.46	1189.0	17.36
T_7	1.2	420.0	5.04	1.29	1652	21.31	0.41	3157.0	12.94	1.50	1274.0	19.11
T_8	1.19	418.0	4.97	1.28	1595	20.42	0.40	3073.0	12.29	1.53	1287.0	19.69
Mean	1.15	406.3	4.69	1.24	1305.56	16.33	0.37	2674.1	9.89	1.45	1096.8	15.99
SEm (±)	0.022	21.58	0.32	0.028	10.859	0.404	0.021	5.73	0.700	0.027	6.20	0.330
CD (P=0.05)	0.066	64.71	0.96	0.083	32.555	1.210	0.064	17.19	2.099	0.080	18.59	0.990

Percent were found in T_7 treatment at branching, flowering and harvesting stage (Table 5). However, seeds accumulated highest quantity of S (0.99 percent). Mean S content in plant was found of 0.25, 0.45 and 0.14 percent with mean uptake 1.03, 6.05 and 3.81 kg ha^{-1} at branching, flowering and harvesting stages of the crop respectively. Sulphur content in stover increased as crop grows from branching to harvesting stage. S – Uptake has also been increased gradually from branching to harvesting stage. However, irrespective of treatments, lowest S content in stover was recorded at harvest. It may be due to the accumulation of sulphur in seeds as S is the principle component of oil. Many workers have reported that oil seed crop requires fairly large quantity of S for synthesis and conversion of amino acids into protein and glucosides into oil in seed (Bhat *et al*. (2007) [21] have reported increased S uptake by rapeseed inoculated with heterotrophic sulphur oxidising bacteria. This may be attributed to the acidifying effect of SOB on the microenvironment around rapeseed roots and solubilisation of other elements which are taken up by plants (Joseph *et al*. 2014) [10]. Application of nitrogen in soil further increased the biomass yield. Due to presence of lower amount of S fertilizer and inoculation of S-oxidizing bacteria, more amount of S is mineralized from FYM which becomes available to the growing rapeseed crop. The balanced nutrient application make higher nutrient available to plants resulting more height and dry matter accumulation. The results find support of earlier investigations carried out by Shukla *et al*. (2002) [22].

Table 5: Changes in S content, dry matter yield and S uptake of stover and seeds at different growth stages of rapeseed grown under different treatment combinations

Treatment	Stages of crop growth											
	Branching			Flowering			Harvesting					
							Stover			Seeds		
	S (%)	Dry matter Yield (kg ha^{-1})	S uptake (kg ha^{-1})	S (%)	Dry matter Yield (kg ha^{-1})	S uptake (kg ha^{-1})	S (%)	Dry matter Yield (kg ha^{-1})	S uptake (kg ha^{-1})	S (%)	Dry matter yield (kg ha^{-1})	S uptake (kg ha^{-1})
T_0	0.19	376.8	0.72	0.38	787	2.99	0.07	2174	1.52	0.81	872	7.06
T_1	0.20	392.3	0.78	0.42	1056	4.44	0.11	2331	2.56	0.92	939	8.07
T_2	0.22	398.5	0.88	0.42	1121	4.71	0.12	2487	2.98	0.93	995	9.25
T_3	0.25	410.0	1.03	0.43	1243	5.34	0.14	2573	3.60	0.93	1062	9.88
T_4	0.26	412.0	1.07	0.44	1289	5.67	0.14	2646	3.70	0.95	1098	10.43
T_5	0.27	415.0	1.12	0.46	1532	7.05	0.16	2797	4.48	0.95	1156	10.98
T_6	0.28	414.0	1.16	0.49	1475	7.23	0.16	2829	4.53	0.96	1189	11.41
T_7	0.31	420.0	1.30	0.53	1652	8.76	0.18	3157	5.68	0.98	1274	12.49
T_8	0.30	418.0	1.25	0.52	1595	8.29	0.17	3073	5.22	0.99	1287	12.74
Mean	0.25	406.3	1.03	0.45	1305	6.05	0.14	2674	3.81	0.93	1096.9	10.26
SEm (±)	0.017	21.6	0.12	0.04	10.8	0.28	0.01	5.73	0.43	0.01	6.20	0.194
CD (P=0.05)	0.052	64.7	0.37	0.14	32.6	0.85	0.04	17.2	1.30	0.06	18.6	0.58

Table 6: Yield and quality of rapeseed under different treatment combinations

Treatments	Oil content (%) in seeds		Protein content (%) in seeds		N and S content (%) in seeds			Seed yield (q ha^{-1})		Stover yield (q ha^{-1})	
	Content	% increase Over control	Content	% increase over control	N	S	N:S ratio	Yield	% increased compared to Control	Yield	% increased Compared to Control
T_0	35.04	-	19.69	-	3.15	0.81	3.89	8.72	-	21.74	-
T_1	37.21	6.19	21.06	6.97	3.37	0.86	3.92	9.39	7.68	23.31	7.22
T_2	38.05	8.59	21.56	9.51	3.45	0.93	3.71	9.95	14.11	24.87	14.40
T_3	38.66	10.33	21.81	10.78	3.49	0.93	3.75	10.62	21.79	25.73	18.35
T_4	38.98	11.24	22.00	11.73	3.52	0.95	3.71	10.98	25.92	26.46	21.71
T_5	39.24	11.99	22.19	12.68	3.55	0.95	3.74	11.56	32.57	27.97	28.66
T_6	39.89	13.84	22.44	13.95	3.59	0.96	3.74	11.89	36.35	28.29	30.13
T_7	41.92	19.63	22.75	16.18	3.64	0.99	3.68	12.74	46.10	31.57	45.22
T_8	41.54	18.55	22.81	16.18	3.65	0.98	3.72	12.87	47.59	30.73	41.35
Mean	38.95		21.83		2.20	0.95		10.97		26.74	
SEm (±)	1.16		1.27		0.024	0.0154		0.0620		0.0574	
CD (P=0.05)	2.69		0.29		0.073	0.0635		0.1859		0.1720	

3.4. Oil content

Highest oil content (41.9%) in rapeseed was found in T_7 followed by T_8 (41.5%) treated plot. The lowest or minimum percentage of oil was recorded in control plot (35.0%) which received only recommended dose of fertilizer (RDF, N-P-K: 20-40-40). The results clearly showed that application of 15 and 30 kg S ha^{-1} increased the oil content at 6.19 and 8.59% respectively. Application of 15 and 30 kg S ha^{-1} with FYM has also increased the oil content in seeds. The result indicated that higher amount of sulphur is responsible for increasing oil content irrespective of treatment of FYM application. Application of SOB in T_7 and T_8 treatments along with FYM significantly increased the oil content in seeds compared to the treatments received S and FYM only. Anandham *et al*. (2007) [23] reported that the inoculation of SOB promotes yield and oil content in oilseed crops.

3.5. Protein content

Highest amount of protein in seeds was found in T_8 (22.8%) treated plot and lowest was found in control plot (19.7%). The increase in protein content under the treatments which received FYM, sulphur and S-oxidizing bacteria might be attributed to the increased availability of S that involved in an increased conversion of primary fatty acid metabolites to the end product of fatty acid as described by Tripathi *et al*. (2010)[24]. The result shows that minimum increase in protein content upon application of sulphur was found to be 6.97 percent. Again, higher order of available N is mineralized from FYM with higher dose (T_8) which helped to produce more protein and made potential deficiency of carbohydrates vis-à-vis acetyl co-enzyme A, precursor of fatty acid resulting in low oil content (T_8). The results of the present investigation are at par with earlier works (Shukla *et al*. 2002) [22]; Singh and Pal, 2011) [25].

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