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Effect of Sulphur and Biofertilizer in Nutrient Uptake by Sesame and Microbial Population in Red and Lateritic Soil of West Bengal

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ABSTRACT

The study was conducted in red and lateritic soils of West Bengal during *pre-kharif* season of 2016 on sandy loam soil of Agricultural Farm, Palli Siksha Bhavana, (Institute of Agriculture), Visva-Bharati, Sriniketan, West Bangal. The experiment was laid out in Randomized Block Design (RBD) with three replications using four levels of sulphur (0, 15, 30 and 45 kg ha^{-1}) and single and dual inoculation of bio fertilizers to study the nutrient uptake by sesame and soil fertility status along with microbial population before and after harvest of crop. The results showed highest value of different nutrients uptake *viz.,* Nitrogen, Phoshorus, Potasium and Sulphur with higher dose of fertilizer along with *Azotobacter and PSB*. The number of nitrogen fixing bacteria i.e. *Azotobector* and Phosphorus Solubilizng Bacteria (PSB) in soil increased due to inoculation of seed with biofertilizer. The seed inoculation exerted significant effect on number of nitrogen fixing bacteria and PSB in soil. The study suggested that the combined application of organic and inorganic fertilizer in sesame cultivation in red and laritic soils will exerts significant yield through important implications in nutrient uptake by sesame for its improved nutrition and improved productivity of soil.

Key words: Nitrogen fixing bacteria, Nutrient uptake, Phosphorus Solubilizng Bacteria (PSB), Sesame.

INTRODUCTION

Red and lateritic soils cover an area of about 91 million hectares in India. Basically these soils are well drained and acidic with lower cation exchange capacity and organic matter concentration and have mixed or kaolinitic clay mineralogy enriched with sesquioxides (Sehgal *et al.,* 1998). Red and lateritic soils occupy an area of about 28,000 sq km in West Bengal, which is about 28 per cent of the total geographic area of the state. Occurrence of these red soils in the state are mainly found in districts namely Birbhum, Bankura, Burdwan, Midnapore and in some parts of Malda and West Dinajpur. In some parts of Birbhum, Bankura, Burdwan, Midnapore, laterites and lateritic soils are also available (Panda *et al.,* 1991). In fact the red, lateritic and associated soils of Eastern India are acidic in soil reaction, light textured, low in organic matter and phosphorus and are often deficient in sulphur and micronutrients like Zn, B and Mo (Panda *et al.,* 1991). It has been reported that external supply of sulphur plays an important role in the primary and secondary plant metabolism as a component of proteins, glucosinolates and other compounds that related to several parameters determining the nutritive quality of crops (Ceccotti, 1996). The response of oilseeds to sulphur is increasing due to increasing of cropping intensity (Ghosh *et al.*, 2002). It is required for the synthesis of proteins, vitamins and chlorophyll and also sulphur containing amino acids such as cysteine and methionine which are essential components of proteins (Tisdale *et al.,* 1999). At the same time it was also reported that the application of sulphur significantly increased the uptake of Nitrogen (N) in straw and grain (Badruddin, 1999). Sulphur has long been recognized as one of the essential elements for plant growth particularly for oilseed crops (Pavani *et al*., 2013). In oilseeds, sulphur plays a significant role in the quantity, quality and development of seeds (Dhingra *et al*., 1988). Therefore, oil seed crops require higher quantity of sulphur for proper growth, development and higher yields (Salwa *et al.,* 2010). Deficiency of sulphur is known to hamper N metabolism in plants as well as synthesis of sulphur containing amino acids and thus exerts adverse effects on both seed and oil yield. Sulphur (S) is also essential for the growth and development, plays a key role in plant metabolism, indispensible for the synthesis of essential oils, chlorophyll formation (Singh *et al.,* 2000), required for development of cells and it increases cold resistance and drought hardness (Patel and Shelke, 1995) and constituent of a number of organic compounds, oil storage organs particularly oil glands (Jaggi *et al.,* 2000).

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Nitrogen is another most essential plant nutrient for plant growth and crop yield. The ability to fix nitrogen is a vital physiological characteristic of *Azotobacter*. *Azotobacter*cells are not usually present on the root surface but are abundant in the rhizosphere and protect the roots from other pathogens present in the soil. Reddy and Sudhakarababu (1996) indicated that nitrogen fixing bacteria can be used to decrease the use of N fertilizer to 50 per cent. Phosphorous is another important primary plant nutrient which helps root formation, plant growth and development and thereby better yield. It involves in many biochemical functions in the plant physiology systems. It is essential parts of skeleton of plasma membrane, nucleic acid, many coenzymes, organic molecules and phosphorylated compounds in plant system (Thakur and Patel, 2004). With this background the study aims to find out the effect of both sulphur and biofertilizer in nutrients uptake by sesame and also availability of nitrogen fixing bacteria *i.e Azotobacter* and Phosphorus Solubilizng Bacteria (PSB) in red and lateritic soil of West Bengal.

MATERIALS AND METHODS

The study was carried out to examine the effect of sulphur and bio fertilizers on nutrient intake by sesame and impact on microbial population in red and lateritic soil of West Bengal during pre-kharif season of 2016. Analysis revealed that the soil of the experimental plot was sandy-loam in texture which contains high percentage of sand and low percentage of clay. The soil was slightly acidic with low organic carbon, very low in available nitrogen (115.52 kg/ ha), high in available phosphorus (50.40 kg/ha), low in available potassium concentration (38.48 kg/ha) and available sulphur (12.6 kg/ha). The experiment was carried out in randomized block design (RBD) with three replications and total thirteen treatments. As per the treatments specification, fertilizers were applied in the form of urea, diammonium phosphate (DAP), murate of potash (MOP) for the source of nitrogen, phosphorus and potassium respectively. A general recommended dose of N: P_2O_5: K_2O for sesame was applied for each plot at the rate of 60:40:40 kg ha^{-1} as urea, DAP and MOP. As per treatment sulphur was applied @ 0, 30, 45 and 60 kg ha^{-1} from zinc sulphate (15% S). Phosphorus, potassium and sulphur was applied as basal dose and nitrogen as split doses.The fertilizer was weighted separately as per need of the treatment for individual plots. Required quantity of fertilizer as per treatment was applied uniformly in the plots through broadcast method of application. Seed were soaked in clean water for better germination. The soaked seeds were treated with bio fertilizers like PSB and *Azotobacter* as per treatment and dried in the shade before sowing. Seeds were treated with biofertilizer @ 60 kg ha^{-1}. Sesame was sown on 17th Feb, 2016 at 30 cm apart row spacing by making shallow furrows with the help of tines in 5 cm soil depth. The seed rate was 4 kg ha^{-1}. After sowing, seeds were covered with loose soil for compaction of soil and better germination. The observation for the nutrient uptake and microbial population in soil were taken at various stages of experiment. The nutrient availability in soil of initial soil analysis data and initial microbiological population count and method followed for the analysis are given below in Table 1.

RESULTS AND DISCUSSION

Concentration of nutrients (NPKS) in plant and seed

Nitrogen concentration (%) in the crop

The results obtained from the present study revealed significant difference on concentration of nitrogen with various treatments at harvest stage (Table 2). A perusal of the results highlights that the concentration of nitrogen in seed was higher than the nitrogen concentration in stalk of sesame. Analysis indicates that the nitrogen concentration range lies between 1.62 to 2.26 (%) for seed. In depth investigation shows that the application of sulphur @ 45 kg ha^{-1} + PSB gave the highest concentration of nitrogen (2.26%) in seed and followed by application of sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (2.13%) which gave at par result. The minimum nitrogen concentration was observed in control which was valued 1.62% in sesame seed after harvest. Investigation indicates that the nitrogen concentration ranged revising 0.38 to 0.56 (%) by stover of sesame. Highest concentration of nitrogen by stalk obtained from treatment sulphur @ 45kg ha^{-1} + *Azotobacter* (0.56%) which gave at par by the application of sulphur @ 45kg ha^{-1} + PSB (0.54%). The minimum nitrogen concentration was observed in control 0.38% by plant of sesame after harvest.

Phosphorus concentration (%) in the crop

The results obtained from the Table 2 show a significant difference on concentration of phosphorus (%) by the crop

Table 1: Initial soil analysis and methods followed.

Particulars	Initial values	Methods followed
Available nutrients		
Available nitrogen (kg ha^{-1})	115.52	Alkaline permanganate method (Subbaiah and Asija, 1959)
Available phosphorus (kg ha^{-1})	50.40	Bray's No.1 method (Bray and Kurtz, 1945)
Available potassium (kg ha^{-1})	38.48	Flame photometer (Borchani *et al.*, 2010)
Available sulphur (kg ha^{-1})	12.6	Turbid metric method (Borchani *et al.*, 2010)
Microbiological population count		
Nitrogen Fixing Bacteria (nos. g^{-1})	4.25×10^6	Jensen's Agar medium (Saren *et al.*, 2004)
Phosphorus SolubilizngBacteria (nos. g^{-1})	3.75×10^6	Pikovskaya's medium

Table 2: Concentration of nutrients (NPK) in sesame.

Treatments	Nitrogen concentration		Phosphorus concentration		Potassium concentration	
	Seed	Stalk	Seed	Stalk	Seed	Stalk
Control	1.62	0.38	0.68	0.82	0.54	1.44
S @ 0 kg ha^{-1} + PSB	1.89	0.27	0.83	0.85	0.61	1.30
S @ 0 kg ha^{-1} + *Azotobacter*	1.97	0.27	0.84	0.70	0.30	1.35
S @ 0 kg ha^{-1} + PSB + *Azotobacter*	2.01	0.36	0.90	0.74	0.45	1.00
S @ 15 kg ha^{-1} + PSB	1.91	0.49	1.10	0.97	0.49	1.41
S @ 15 kg ha^{-1} + *Azotobacter*	2.04	0.38	0.86	0.71	0.59	1.30
S @ 15 kg ha^{-1} + PSB + *Azotobacter*	1.99	0.42	1.21	0.84	0.39	1.64
S @ 30 kg ha^{-1} + PSB	1.96	0.44	1.26	1.08	0.20	1.36
S @ 30 kg ha^{-1} + *Azotobacter*	1.79	0.53	1.19	0.92	0.44	1.36
S @ 30 kg ha^{-1} + PSB + *Azotobacter*	2.05	0.40	1.11	1.14	0.55	1.43
S @ 45 kg ha^{-1} + PSB	2.26	0.54	1.38	1.20	0.69	1.69
S @ 45 kg ha^{-1} + *Azotobacter*	1.93	0.56	1.37	0.91	0.64	1.11
S @ 45 kg ha^{-1} + PSB + *Azotobacter*	2.13	0.44	1.39	0.93	0.63	1.31
Sem (±)	0.05	0.007	0.07	0.014	0.019	0.09
CD 5%	0.15	0.021	0.19	0.040	0.056	0.28
CV %	4.59	2.98	10.33	2.63	6.69	11.98
RBD(0.05)	S	S	S	S	S	S

after harvest with difference treatment. Table 2 clearly depicts that there was no progressively increase or decrease in concentration of phosphorus (%) in the seed and stalk of sesame. The results indicates that the phosphorus concentration range lies between 0.68 to 1.39 (%) in seed and application of sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* gave the highest concentration of phosphorus (1.39%) in seed and followed by application of sulphur @ 45 kg ha^{-1} + PSB (1.38%) and application of sulphur @ 45 kg ha^{-1} + *Azotobacter* (1.37%) and they were at par. The minimum concentration was observed in control 0.68 per cent in sesame seed after harvest.

Obsevation indicates that the phosphorus concentration ranged revising 0.82 to 1.20 (%) by stover of sesame. Highest concentration of phosphorus by stalk obtained from treatment sulphur @ 45 kg ha^{-1} + PSB (1.20%) which were at par by the application of sulphur @ 30 kg ha^{-1} + PSB + *Azotobacter* (1.14%). The minimum phosphorus concentration was observed in control 0.82% by plant of sesame after harvest.

Potassium concentration (%) in the crop

The results of the study presented in the Table 2 show concentration of potassium (%) in seed was lower than the stalk concentration of sesame. Perusal of the Table 2 indicates the potassium concentration range lies between 0.54 to 0.69 (%) in seed and application of sulphur (@ 45 kg ha^{-1}) + PSB gave the highest concentration of potassium (0.69%) in seed and followed by application of sulphur @ 45 kg ha^{-1} + *Azotobacter* (0.64%) and application of sulphur @ 45kg ha^{-1} + PSB + *Azotobacter* (0.63%) and they were at par. The minimum phosphorus concentration was observed in control 0.54 per cent in sesame seed after harvest. Table also depicts that the concentration of potasium ranges between 1.44 to 1.69 per cent by stover of sesame. Highest concentration of potassium by stalk obtained is obtained when treatment is done with sulphur @ 45kg ha^{-1} + PSB (1.69%) which were at par by the application of sulphur @ 15 kg ha^{-1} + PSB + *Azotobacter* (1.16%). In control phosphorus concentration was minimum (1.44%) by plant of sesame after harvest.

Sulphur concentration (%) in the crop

The perusal of the Table 3 indicates the sulphur concentration range lies between 0.68 to 1.18 per cent by seed at harvest stage. Analysis showed that the application of sulphur @ 45 kg ha^{-1} + *Azotobacter* gave the highest concentration of sulphur (1.18%) in seed and followed by application of sulphur @ 45 kg ha^{-1} + PSB (1.17%), application of sulphur @ 45kg ha^{-1} + PSB + *Azotobacter* (1.12%) and they were at par. The concentration was minimum in control (0.68%) in sesame seed after harvest.

Present study highlights that the sulphur concentration in stover at different stage of plant growth significantly increasing up to harvest stage. At 30 DAS highest concentration of sulphur in stalk obtained from treatment sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (0.75%) which followed by the application of sulphur @ 45 kg ha^{-1} + *Azotobacter* (0.68%) and application of sulphur @ 45 kg ha^{-1} + PSB (0.66%). At 60 DAS highest concentration of sulphur by stalk observed in treatment sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (0.92%) which gave at par the application of sulphur @ 45 kg ha^{-1} + *Azotobacter* (0.88%). At harvest stage highest concentration of sulphur in stalk obtained from treatment sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (1.02%) which was followed by the application of sulphur @ 45 kg ha^{-1} + *Azotobacter* (0.91%) and application of sulphur @ 45 kg ha^{-1} + PSB (0.89%). The

Table 3: Concentration of sulphur in sesame.

Treatments	Sulphur concentration (%)			
	30 Days	60 Days	Harvest	
	Stalk	Stalk	Seed	Stalk
Control	0.39	0.48	0.68	0.54
S @ 0 kg ha^{-1} + PSB	0.41	0.45	0.74	0.55
S @ 0 kg ha^{-1} + *Azotobacter*	0.47	0.57	0.71	0.60
S @ 0 kg ha^{-1} + PSB + *Azotobacter*	0.45	0.49	0.67	0.57
S @ 15 kg ha^{-1} + PSB	0.50	0.52	0.92	0.65
S @ 15 kg ha^{-1} + *Azotobacter*	0.56	0.63	0.95	0.79
S @ 15 kg ha^{-1} + PSB + *Azotobacter*	0.48	0.54	0.91	0.58
S @ 30 kg ha^{-1} + PSB	0.55	0.66	0.98	0.78
S @ 30 kg ha^{-1} + *Azotobacter*	0.58	0.61	1.01	0.80
S @ 30 kg ha^{-1} + PSB + *Azotobacter*	0.64	0.69	1.03	0.86
S @ 45 kg ha^{-1} + PSB	0.66	0.70	1.17	0.89
S @ 45 kg ha^{-1} + *Azotobacter*	0.68	0.88	1.18	0.91
S @ 45 kg ha^{-1} + PSB + *Azotobacter*	0.75	0.92	1.12	1.02
Sem (±)	0.05	0.017	0.034	0.007
CD 5%	0.14	0.04	0.10	0.02
CV %	14.60	5.08	6.42	1.60
RBD(0.05)	S	S	S	S

Table 4: Uptake of nutrients (NPK) by crop.

Treatments	Nitrogen uptake (kg ha^{-1})		Phosphorus uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})	
	Seed	Stalk	Seed	Stalk	Seed	Stalk
Control	6.26	1.77	2.14	3.92	1.79	6.88
S @ 0 kg ha^{-1} + PSB	20.03	2.76	4.24	8.49	3.13	16.98
S @ 0 kg ha^{-1} + *Azotobacter*	21.35	3.05	3.74	7.94	2.99	14.63
S @ 0 kg ha^{-1} + PSB + *Azotobacter*	28.04	4.57	5.93	9.25	3.14	17.12
S @ 15 kg ha^{-1} + PSB	22.22	5.79	6.25	11.48	2.79	16.85
S @ 15 kg ha^{-1} + *Azotobacter*	27.24	5.72	5.78	10.86	3.97	19.75
S @ 15 kg ha^{-1} + PSB + *Azotobacter*	26.07	6.52	8.36	13.93	2.72	24.95
S @ 30 kg ha^{-1} + PSB	23.98	5.69	7.60	14.02	3.21	17.61
S @ 30 kg ha^{-1} + *Azotobacter*	28.34	7.86	8.86	13.72	3.26	20.12
S @ 30 kg ha^{-1} + PSB + *Azotobacter*	33.24	5.96	9.13	17.20	4.53	21.15
S @ 45 kg ha^{-1} + PSB	24.89	7.84	8.02	17.58	4.01	16.36
S @ 45 kg ha^{-1} + *Azotobacter*	27.52	9.66	9.58	15.60	2.80	18.95
S @ 45 kg ha^{-1} + PSB + *Azotobacter*	32.91	8.85	10.99	18.57	4.98	25.99
Sem (±)	1.88	0.487	0.603	1.021	0.28	1.54
CD 5%	5.49	1.422	1.760	2.979	0.82	4.50
CV %	13.15	14.44	14.98	14.14	14.60	14.64
RBD(0.05)	S	S	S	S	S	S

lowest sulphur concentration in stover was observed in control (0.39, 0.48 and 0.54%) at 30, 60 DAS and harvest stage, respectively by plant of sesame after harvest. It was also found that sulphur concentration in stover and seed increased by increasing level of sulphur application due to rapid absorption and translocation of sulphur by plant with adequate sulphur from the soil (Shrivastava *et al.*, 2000) leading to improved sulphur concentration and uptakeby the crop.

Uptake of Nutrients (NPKS) by Crop after Harvest

Nitrogen uptake by the crop (kg ha^{-1})

The results obtained from the present investigation revealed a significant difference on uptake of nitrogen (kg ha^{-1}) by the crop in harvest stage (Table 4). Perusal of table depicts that uptake of nitrogen (kg ha^{-1}) by the seed is higher than uptake by the stalk of sesame. In depth analysis of the table indicates the nitrogen uptake range lies between 6.26 to 33.24 kg ha^{-1} by seed and 1.77 to 9.66 kg ha^{-1} by stalk.

Table clearly shows that the application of sulphur @ 30 kg ha^{-1} + PSB + *Azotobacter*gave the highest uptake of nitrogen (33.24 kg ha^{-1}) by seed and followed by application of sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (32.91 kg ha^{-1}). Highest uptake of nitrogen by stalk was obtained from treatment sulphur @ 45 kg ha^{-1} + *Azotobacter* (9.66 kg ha^{-1}) which was followed by application of sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (8.85 kg ha^{-1}). The minimum uptake of nitrogen was observed in control by seed 6.26 kg ha^{-1} and by stalk 1.77 kg ha^{-1} of sesame after harvest. The increased response of nitrogen uptake by both seed and stalk of sesame over control was observed (6.26 and 1.77 kg ha^{-1}, respectively) by 5.31 and 5.46 fold, respectively. Increased uptake of N by crop due to S may be result of assimilation pattern N and S inplant (Dayanand and Shivra,2002).

Phosphorus uptake by the crop (kg ha^{-1})

Results obtained from the present investigation indicated a significant difference on uptake of phosphorus (kg ha^{-1}) by the crop up to harvest stage (Table 4). Perusal of results highlights that uptake of phosphorus (kg ha^{-1}) by the seed was lower than the uptake by stalk of sesame. Results showed phosphorus uptake range lies between 2.14 to 10.99 kg ha^{-1} and 3.92 to 18.57 kg ha^{-1} by seed and stalk respectively. Observations on phosphorus uptake depicted that highest phosphorus uptake by seed gave treatment application of sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (10.99 kg ha^{-1}) followed by application of sulphur @ 45 kg ha^{-1} + *Azotobacter* (9.58 kg ha^{-1}) and sulphur @ 30 kg ha^{-1} + PSB + *Azotobacter* (9.13 kg ha^{-1}), they were at par. Treatment sulphur @ 45kg ha^{-1} + PSB + *Azotobacter* (18.57 kg ha^{-1}) gave highest uptake of phosphorus by stalk which was at par with application of sulphur @ 45 kg ha^{-1} + PSB (17.58 kg ha^{-1}) and sulphur @ 30 kg ha^{-1} + PSB + *Azotobacter* (17.20 kg ha^{-1}). The lowest uptake was observed in control by seed 2.14 kg ha^{-1} and by stalk 3.92 kg ha^{-1} of sesame after harvest. The increased response of phosphorus uptake by both seed and stalk of sesame over control was 5.14 and 4.7 fold respectively. Beneficial role of sulphurin mobilizing soil P and its use by crops was also reported by Saren *et al.* (1991).

Potassium uptake by the crop (kg ha^{-1})

Results obtained from the present investigation indicated a significant difference on uptake of potassium (kg ha^{-1}) by the crop up to harvest stage (Table 4). Perusal of results highlights that the uptake of potassium (kg ha^{-1}) by seed was lower than uptake by stalk of sesame. Results showed potassium uptake range lies between 1.79 to 4.98 kg ha^{-1} and 6.88 to 25.99 kg ha^{-1} by seed and stalk respectively. Observations on potassium uptake by the crop depicted that treatment application of sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (4.98 kg ha^{-1}) gave highest potassium uptake by seed followed by application sulphur @ 30 kg ha^{-1} + PSB + *Azotobacter* (4.53 kg ha^{-1}) and sulphur @ 45 kg ha^{-1} + PSB (4.01 kg ha^{-1}) and, they were at par. Treatment sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (25.99 kg ha^{-1}) gave highest uptake of potassium by stalk which was at per with application of sulphur @ 15kg ha^{-1} + PSB + *Azotobacter* (25.95 kg ha^{-1}). The lowest uptake was observed in control by seed which valued 1.79 kg ha^{-1} and by stalk which valued 6.88 kg ha^{-1} of sesame after harvest. The sulphur interacted synergistically in increasing potassium uptake by the crop which corroborates the study of Malewar *et al.* (2001).

The findings of combined use of bio fertilizers and chemical fertilizers in sesame helps in maintaining stability of crop production, besides improving soil physical conditions corroborates the the study of Deshmukh *et al.* (2002) and Vaghani *et al.* (2010). The use of nitrogen fixing bacteria increases dry matter production and yields in sesame (Sonia *et al.,* 2012). Further, combined application of organic and inorganic fertilizer during *kharif* season in sesame exerts significant yield. Thus, understanding the factors associated in uptake of nitrogen, phosphorus and potassium and their utilization by sesame in soils of low nutrient status has important implications for its improved nutrition and productivity which corroborates the study of Khaled *et al.* (2012) Purushottam (2005) and Jaishankar and Wahab (2005) where they indicated that higher concentrations (%) of oil and protein in sesame seeds proved the effect of both organic and N-fixing bacteria application.

Sulphur uptake by the crop (kg ha^{-1})

Uptake of sulphur by sesame increased significantly with increasing levels of sulphur application (Fig 1). Observed results indicating that sulphur uptake (kg ha^{-1}) by seed was lower than plant. It is clear from the observations that progressively higher fertility level lead to significant increase in total sulphur uptake by seed (1.72 to 8.95 kg ha^{-1}) and by plant (3.69 to 18.17 kg ha^{-1}). Results highlight the maximum uptake of sulphur by seed for treatment sulphur @ 45kg ha^{-1} along with co-inoculation of PSB + *Azotobacter* (8.95 kg ha^{-1}) which gave at par result with treatment sulphur @ 30 kg ha^{-1} + PSB + *Azotobacter* (8.43 kg ha^{-1}) andsulphur @ 45 kg ha^{-1} + *Azotobacter* (8.28 kg ha^{-1}). Sulphur uptake by plant was observe highest with application of sulphur @ 45 kg ha^{-1} with combined inoculation of seed PSB + *Azotobacter* (18.17 kg ha^{-1}) followed by sulphur @ 45 kg ha^{-1} + *Azotobacter* (15.11 kg ha^{-1}) and sulphur @ 45 kg ha^{-1} + PSB (13.01 kg ha^{-1}). Whereas, in control lowest sulphur uptake by seed 1.72 kg ha^{-1} and by plant 3.69 kg ha^{-1} was observed which may be due to fact of non-availability of external supply of sulphur fertilizer through any source.

The result showed in Fig 1, compared with uninoculated control all the treatments increased the mean sulphur uptake by seed and plant by 1.9 to 5.2 and 1.5 to 4.9 fold. It was also found that treatment sulphur @ 45 kg ha^{-1} along with dual inoculation of PSB and *Azotobacter* and sulphur @ 45 kg ha^{-1} along with single inoculation of *Azotobacter* increased sulphur uptake by 141.9, 107.2 and 124.3 per cent and 123.8, 147.2 and 107.5 per cent by seed and 238.4, 168 and 152.7 per cent and 181.4, 122.9 and 110.2 per cent by plant over only PSB inoculation, only Azotobacter inoculation

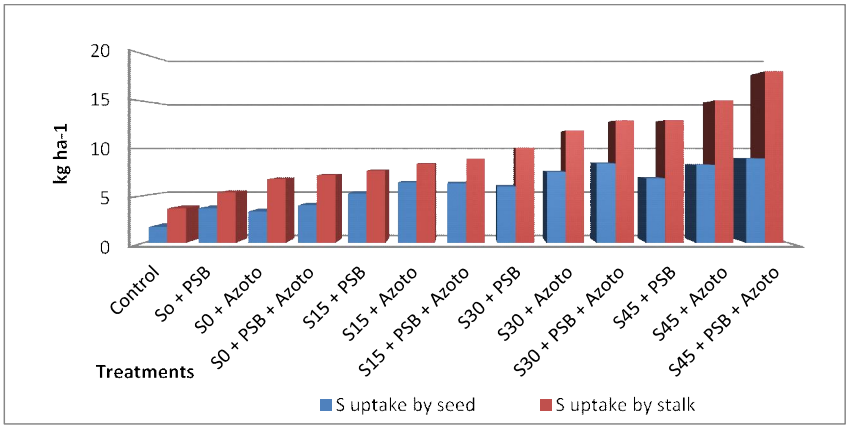

Fig 1: Effect of treatments on sulphur (S) uptake by seed and stalk at harvest stage.

and dual inoculation of PSB + *Azotobacter*, respectively. Increasing trend of sulphur uptake was due to the application of graded level of sulphur through Zinc sulphate with inoculation of bio fertilizers. The result implies that in an oil seed crops like sesame, sulphur uptake is higher which corroborates the findings of Purushottam (2005). The above results revealed that with the increase in S dose the uptake of sulphur was also increased due to high S concentration and high grain yield. These results are in agreement with those of Ganeshamurthy (1996) who reported that sulphur significantly increased the S uptake. Similar result was documented by Chand *et al*. (1997) in mustard.

Counting of microbial population in soil before and after harvest of crop

Number of nitrogen fixing bacteria

Analysis of nitrogen fixing bacteria in soil is presented in Table 5. This analysis was carried out at 30, 60 DAS and harvest stage which shows difference on the number of nitrogen fixing bacteria with advancement of the crop. Nitrogen fixing bacteria depend largely on the concentrations of different exchangeable bases and also on some micronutrients (Brown, 1975). The perusal of the table depicts number of nitrogen fixing bacteria i.e. *Azotobector* in soil is increased due to inoculation of biofertilizer with seed. The seed inoculation exerted significant effect on number of nitrogen fixing bacteria in soil. At 30 DAS analysis shows that the application of sulphur @ 30 kg ha^{-1} + PSB + *Azotobacter* gave the highest number of *Azotobacter* (8.43) followed by application of sulphur @ 45 kg ha^{-1} + PSB+ *Azotobacter* (5.97) and they were at par whereas minimum concentration was observed in control (1.27). Study at 60 DAS highlights the number of *Azotobacter* was highest with the application of sulphur @ 30 kg ha^{-1} + PSB + *Azotobacter* (29.58) and at par with treatment sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (25.77). The lowest number of *Azotobacter* was observed in control (4.17). At harvest stage the number of *Azotobacter* observed highest in treatment sulphur @ 30 kg ha^{-1} + PSB + *Azotobacter* (22.02) which followed by treatment sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (19.48). It may be concluded that application of *Azotobacter* along with fertilizer gave highest response in number at different growing stage of the crop and it also gave highest yield and other produce of sesame.

Table 5: Effect of treatments on number of Azotobacter.

Treatments	*Azotobacter* (No. × 10^6)		
	30 Days	60 Days	Harvest
Control	2.13	4.17	2.58
S @ 0 kg ha^{-1} + PSB	1.53	7.94	5.85
S @ 0 kg ha^{-1} + *Azotobacter*	2.67	9.79	3.85
S @ 0 kg ha^{-1} + PSB + *Azotobacter*	4.50	12.06	6.94
S @ 15 kg ha^{-1} + PSB	2.47	9.78	11.33
S @ 15 kg ha^{-1} + *Azotobacter*	3.90	13.75	9.38
S @ 15 kg ha^{-1} + PSB + *Azotobacter*	3.53	15.62	12.82
S @ 30 kg ha^{-1} + PSB	3.60	13.00	9.36
S @ 30 kg ha^{-1} + *Azotobacter*	8.43	23.41	16.51
S @ 30 kg ha^{-1} + PSB + *Azotobacter*	5.27	19.58	18.02
S @ 45 kg ha^{-1} + PSB	3.55	15.52	8.76
S @ 45 kg ha^{-1} + *Azotobacter*	4.87	19.87	14.11
S @ 45 kg ha^{-1} + PSB + *Azotobacter*	5.97	25.77	19.48
Sem (±)	0.240	0.743	0.594
CD 5%	0.700	2.168	1.734
CV %	10.31	8.35	9.35
RBD(0.05)	S	S	S

Phosphate solubilizing bacteria (PSB)

An analysis of Phosphate Solubilizing Bacteria in soil is presented in Table 6. Analysis at 30, 60 DAS and harvest stage showed significant difference on the number of phosphate solubilizing bacteria with advancement of the crop. The results indicate inoculation of seeds with bio fertilizer increased the number of phosphate solubilizing bacteria i.e. PSB in soil. Analysis shows that the application of sulphur @ 30 kg ha^{-1} + *Azotobacter* gave the highest number of PSB (5.13) followed by application of sulphur @ 45 kg ha^{-1} + PSB+ *Azotobacter* (4.85) at 30 DAS. The results at 60 DAS highlights the number of PSB was highest with

Table 6: Effect of treatments on number of PSB.

Treatments	PSB (No. × 10^6)		
	30 Days	60 Days	Harvest
Control	1.80	5.85	3.87
S @ 0 kg ha^{-1} + PSB	2.80	13.87	8.00
S @ 0 kg ha^{-1} + *Azotobacter*	2.27	10.71	6.73
S @ 0 kg ha^{-1} + PSB + *Azotobacter*	3.02	13.87	8.83
S @ 15 kg ha^{-1} + PSB	3.31	26.80	21.80
S @ 15 kg ha^{-1} + *Azotobacter*	3.28	24.94	19.20
S @ 15 kg ha^{-1} + PSB + *Azotobacter*	4.87	25.69	19.63
S @ 30 kg ha^{-1} + PSB	4.37	22.71	16.77
S @ 30 kg ha^{-1} + *Azotobacter*	5.13	18.22	21.42
S @ 30 kg ha^{-1} + PSB + *Azotobacter*	4.52	19.13	24.56
S @ 45 kg ha^{-1} + PSB	4.18	18.63	11.53
S @ 45 kg ha^{-1} + *Azotobacter*	3.95	27.10	22.70
S @ 45 kg ha^{-1} + PSB + *Azotobacter*	4.85	30.91	25.62
Sem (±)	0.305	0.792	0.699
CD 5%	0.892	2.312	2.040
CV %	14.23	6.36	7.26
RBD(0.05)	S	S	S

the application of sulphur @ 30 kg ha^{-1} + PSB + *Azotobacter* (31.13) and at per with treatment sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (30.91). Highest number of PSB was observed in treatment sulphur @ 30 kg ha^{-1} + PSB + *Azotobacter* (22.02) which followed by treatment sulphur @ 45 kg ha^{-1} + PSB + *Azotobacter* (27.56) at harvest stage. The findings clearly indicate that the number of PSB count increased with the increase in sulphur dose.

Thus the study found that the population of phosphate solubilizer in soil was significantly increased due to seed inoculation of PSB over uninoculated treatments. These results are in agreement with the findings of Kundu and Gaur (1980) in potato. Based on these findings, the study suggesting that use of nitrogenous and phosphoric bio-fertilizers in sesame cultivation will lead to better results which also corroborates with the findings of Borchani *et al.* (2010), Haruna (2011) and Shelke *et al.* (2014).

CONCLUSION

The study showed highest value of different nutrients uptake *viz.,* Nitrogen, Phoshorus, Potasium and Sulphur uptake with higher dose of fertilizer along with *Azotobacter* and *PSB*. The number of nitrogen fixing bacteria i.e. *Azotobector* and Phosphorus Solubilizng Bacteria (PSB) in soil increased due to inoculation of seed with biofertilizer. The seed inoculation exerted significant effect on number of nitrogen fixing bacteria and PSB in soil. The study suggested that the combined application organic and inorganic fertilizer in sesame cultivation in red and laritic soils will exerts significant yield through important implications in nutrient uptake by sesame for its improved nutrition and improved productivity of soil.

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