INTERNATIONAL JOURNAL OF PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES

IJPAES

Volume-7, Issue-1 Jan-Mar-2017 Coden: IJPAJX-CAS-USA, Copyrights@2015ISSN-2231-4490

Received: 4th Nov-2016 ***Revised: 24th Dec-2016*** ***Accepted: 25th Jan-2017***

DOI: 10.21276/Ijpaes [***http://dx.doi.org/10.21276/ijpaes***](http://dx.doi.org/10.21276/ijpaes) ***Research Article***

INTEGRATED NUTRIENT MANAGEMENT IN SESAME (*Sesamum indicum*) IN RED AND LATERITIC SOILS OF WEST BENGAL

Gayatri Sahu, Nitin Chatterjee, Manisanker Bera, Goutam Kumar Ghosh*, Suchhanda Mondal, P. K. Biswas and M.C. Kundu

Department of Soil Science and Agricultural Chemistry, Palli Siksha Bhavana, Institute of Agriculture, Visva- Bharati University, Sriniketan – 731 236, West Bengal, India

ABSTRACT: A field experiment was conducted on sesame during summer season of 2015 in red and lateritic soils of West Bengal at the Agricultural Farm of Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan to study the effect of combined application of macro- and micronutrient fertilizers and biofertilizers i.e. Integrated Nutrient Management (INM) on yield, nutrient uptake, soil fertility status along with microbial population in Sesame. The experiment was laid out in randomized block design. Highest grain yield (7.9 q ha^{-1}), stover yield (24.5 q ha^{-1}), biological yield (32.4 q ha^{-1}) and harvest index (28.8%) of sesame was registered where higher doses of sulphur along with other inorganic fertilizers ($N_{40}P_{40}K_{40}S_{45}Zn_{21}Mo_{2.0}$) were applied. The uptake of NPK by sesame increased with integrated application of *Azospirillium* and combined application of micronutrients with macronutrients ($N_{40}P_{40}K_{40}$ $Zn_{10.5}$ $Mo_1B_{1.0}S_{30}$+*Azospirillium*). Highest S uptake, oil content, oil yield, protein content and protein yield of sesame was associated with sulphur @ 45kg ha^{-1} along with macronutrients and micronutrients. Higher population of *Azospirillium* was registered in post harvest soil treated with *Azospirillium* along with sulphur, micro and macronutrients treated plots.

Key words: Sesame, Integrated Nutrient Management, Macronutrients, Micronutrients, Sulphur, *Azospirillium*, Yield, Oil content, Protein content

*Corresponding author: Goutam Kumar Ghosh, Palli Siksha Bhavana, Institute of Agriculture, Visva-Bharati, Sriniketan – 731 236, West Bengal, India E-mail: ghoshgk@rediffmail.com

INTRODUCTION

The post green revolution scenario of Indian agriculture encompasses many problems such as stagnation or even decline in production and productivity growth rates of major crops, deterioration of soil fertility, decline in factor productivity, low diversity of production systems and increasing cost of production. These constraints have cropped-up partially as a result of continuous cropping without proper nutrient management and indiscriminate use of agrochemicals on soil and crops. Indiscriminate use of high analysis chemical fertilizers resulted in the deficiency of nutrients other than the applied and disturbs the natural equilibrium of nutrient elements in soils [1]. The problems of micronutrients also generally crops up with the use of high analysis chemical fertilizers having one or two nutrient elements [2]. The decline in productivity of intensive cropping systems over the years was associated with deficiencies of secondary and micronutrients [3]. Sustainability of crop production is not a viable proposition either through use of organic manures or chemical fertilizers alone [4]. Use of chemical fertilizers alone increase the crop yields in the initial year adversely affected the sustainability at a later stage.

Furthermore, the chemical fertilizers are in short supply, derived from non-renewable sources of energy and are costly. Under these constraints, bioinoculants are the route to alternative strategy and many workers reported the beneficial effects of integrating biofertilizers on crop growth, yield and maintenance of soil fertility [5]. *Azospirillium*, an associative diazotroph have been identified as potential microbial inoculants for increasing the productivity of various non legume crops. Biofertilizer helps in nitrogen fixation, synthesize and secrete many amino acids which influence seed germination, plant growth and yield [6].

Oilseed crops play the second important role in the Indian agricultural economy next to food grains in terms of area and production. The Indian climate is suitable for the cultivation of oilseed crops; therefore, large varieties of oilseeds are cultivated here. Among the oilseed crops, sesame (*Sesamum indicum* L.) is well known and is one of the oldest crops in the world [7]. It is known as 'the queen of oils' due to its high nutritional, medicinal, cosmetic and cooking qualities [8]. Oleic and linoleic acids are the predominant fatty acids of sesame oil [9] that have many dietary and health benefits for humans. India ranks first in area, production and export of sesame in the world. Sesame ranks third in terms of total oilseed area and fourth in terms of total oilseed production in India. It is one of the important oilseed crops in West Bengal and mainly grown in marginal land with minimum care. The area, production and productivity of sesame are higher in summer season than those of post-*kharif* and *kharif* seasons [10]. Lower productivity of sesame is due to use of sub-optimal rate of fertilizer, poor management and cultivation of sesame in marginal and sub-marginal lands where deficiency of macronutrients such as nitrogen, phosphorus, potassium and micronutrient is predominant.

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 [11]. The response of oilseeds to sulphur is increasing due to increasing of cropping intensity [12]. It is required for the synthesis of proteins, vitamins and chlorophyll and also S containing amino acids such as cystine, cysteine and methionine which are essential components of proteins [13]. S-application significantly increased the uptake of N in straw and grain [14] thereby increased grain yield. Nitrogen which is most essential plant nutrient for plant growth and crop yield. Reddy and Sudhakarababu [15] indicated that an *Azospirillum* application can be used to decrease the use of N fertilizer to 50%. El-Habbasha *et al.* [16] illustrated that the effect of partial replacement of chemical fertilizer with N-fixing bacteria did not have a significant influence on oil percentage in sesame. Phosphorous is an important primary plant nutrient which helps root formation and plant growth and thereby better yield. Boron also plays a vital role in oil synthesis. Integrated use of organic manures and chemical fertilizers in sesame helps maintaining stability in crop production, besides improving soil physical conditions [17,18].

MATERIALS AND METHODS

A field experiment was conducted on sesame during summer season of 2015 in red and lateritic soils of West Bengal at the Agricultural Farm of Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan. The experimental farm was situated at 23°39′ N latitude and 87°42′ E longitude with an average altitude of 58.9 m above the mean sea level under sub humid semi-arid region of West Bengal. The soil was acidic (pH 4.35), low in organic carbon (0.32%), available nitrogen (160 kg ha^{-1}), available phosphorus (15.92kg ha^{-1}), available potassium (72 kg ha^{-1}) and available sulphur (11.23 kg ha^{-1}). The experiment was laid out in randomized block design with 15 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. Magnesium sulphate (26.63% S) was used for the source of sulphur. In the cases of micronutrients Boric acid (17% B), Zinc Sulphate Heptahydrate (21% Zn), Ammonium molybdate (54% Mo) are used for the source of boron, zinc and molybdenum. The sesame seed was inoculated properly with the culture of *Azospirillium*. Oil extraction was done by Soxhlet's extraction method. The available nutrient status of soil, total uptake of nutrients, grain yield, stover yield, oil content and oil yield, protein content and protein yield was calculated. The soil samples were analyzed following standard procedures. Available sulphur in the soil was extracted using 0.15% $CaCl_2$ solution. The total sulphur in the soil was extracted by perchloric acid ($HClO_4$) digestion. Sulfur content in the digest of plant and soil extract was determined using turbidimetric method of Chesnin and Yien [19]. The amount of seed nitrogen content was estimated as per expressed the concentration in percentage. Crude protein was determined by multiplying percentage of nitrogen content in seeds of sesame with a factor of 6.25. The data collected from the experiment at different growth stages was subjected to statistical analysis as described by Gomez and Gomez [20].

RESULTS AND DISCUSSION

Sesame seed yield was affected significantly by integrated application of fertilizer in different treatments over control (Table 1). Combined application of inorganic nutrients along with micronutrients and sulphur has a great role to increase the seed yield of sesame as compared to only inorganically treated nutrients. The seed yield varied between 4.85 to 7.92q ha^{-1}. The highest grain yield (7.92q ha^{-1}) was observed in T_{13} ($N_{40}P_{40}K_{40}$ S_{45} Zn_{21} $Mo_{2.0}$) followed by T_{15} which were treated by both micronutrients (Zn, B and Mo) and sulphur along with macronutrients (NPK) and lowest seed yield (4.85 q ha^{-1}) was recorded in control. It is interesting to note that *Azospirillium* treated plots recorded higher yield than only NPK and NPK with micronutrients. Integrated nutrient management are reported to be the best option to increase the yield of the crops and maintaining soil health [5,17,18].

Table 1: Effect of INM treatments on sesame yield

Treatments	2014-2015			
	Seed Yield	Stover Yield	Biological Yield	Harvest Index (%)
	q ha^{-1}			
T_1- Control	4.85	15.93	20.79	23.34
T_2- $N_{40}P_{40}K_{40}$	5.26	16.60	21.86	24.06
T_3- $N_{40}P_{40}K_{60}$	5.24	17.23	22.47	23.32
T_4- $N_{40}P_{40}K_{80}$	5.86	17.10	22.96	25.52
T_5- $N_{40}P_{40}K_{40}$ Mo_{1kg}	5.97	17.20	23.17	25.77
T_6- $N_{40}P_{40}K_{40}$ $Bo_{0.5}$	6.25	17.47	23.72	26.35
T_7- $N_{40}P_{40}K_{40}$ Zn_5	6.34	18.00	24.34	26.05
T_8- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$	6.37	18.80	25.17	25.31
T_9- $N_{40}P_{40}K_{40}$ Zn_{21}	6.53	19.50	26.03	25.09
T_{10}- $N_{40}P_{40}K_{40}$ + *Azospirillium*	6.84	21.57	28.40	24.08
T_{11}- $N_{40}P_{40}K_{40}$ S_{15}	6.93	22.37	29.30	26.17
T_{12}- $N_{40}P_{40}K_{40}$ S_{30} $Zn_{10.5}$ $Mo_{1.0}$	7.17	22.83	30.01	26.24
T_{13}- $N_{40}P_{40}K_{40}$ S_{45} Zn_{21} $Mo_{2.0}$	7.92	24.50	32.42	28.82
T_{14}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ $Mo_1B_{0.5}$ S_{30}	7.55	23.07	30.61	26.27
T_{15}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ Mo_1 $B_{1.0}S_{30}$ +*Azospirillium*	7.77	23.27	31.05	26.31
SEm(±)	0.064	0.227	0.243	0.271
CD(P=0.05)	0.199	0.702	0.749	0.836
CV%	1.96	2.27	1.82	2.15
RBD(0.05)	S	S	S	S

The results clearly indicate that integrated use of N P K, along with S, B, Mo, Zn and *Azospirillum* in various combinations or alone performed better with regards to seed yield, stover yield, biological yield of sesame. It is interesting to note that application of either B, or Mo or Zn along with NPK boosted the yield of sesame significantly. This may be due to supply of nutrients from diversified sources and prolonged availability of nutrients to the growing plants. The beneficial role of free living nitrogen fixing microorganisms for enhancing plant growth through their ability in nitrogen fixation as well as the effect of their metabolites secretion on the crop may also be attributed for the same. These results are in agreement with Jaishankar and Wahab [21], Imayavaramban *et al.* [22] and Verma *et al.* [18].

Like seed yield, stover yield was significantly increased by different treatments under study. In case of stover yield the ranges varied between 15.93 to 24.50q ha^{-1}. Like grain yield the highest yield was also found in T_{13} i.e. 24.50 qha^{-1} followed by T_{15} i.e. 23.27 q ha^{-1}. Lowest stover yield was found in control i.e.15.93 q ha^{-1}. It was also found that *Azospirillium* treated plots recorded higher yield than only NPK and NPK with micronutrients treated plots. Here also combined application of macro and micronutrients along with sulphur has a great role to increase the stover yield of sesame.

Depending upon stover yield and seed yield the biological yield was summed up. The biological yield was found highest in T_{13} i.e. 32.42q ha^{-1} followed by T_{15} i.e. 31.05 q ha^{-1} and lowest value was observed in control i.e. 20.79 q ha^{-1}. Harvest index was also calculated depending upon the seed yield and biological yield. The ranges of harvest index was observed in case of sesame from 23.34-28.82%. The highest harvest index was found in T_{13} and lowest value was observed in T_3. Improvement of yield due to combined application of macro and micronutrients along with sulphur. In case of T_{13} integrated use of fertilizer was done by combined application of micro and macronutrients with higher dose of sulphur helps to get higher yield in case of sesame.

Content (%) of nutrients (NPKS) in stover and seed

Content (%) of nutrients (NPKS) in seed of sesame

Analysis of the data about content (%) of nutrients (NPKS) in seed of sesame is shown in Table 2. The effect of treatments on nitrogen content in seeds varied significantly. Nitrogen content in seed ranged between 1.49 to 2.30%. The highest N content was observed in T_{13} i.e. 2.30% followed by T_{12} i.e. 2.28% due to integrated application of micronutrients with macronutrients along with sulphur and lowest value was observed in control plot. Phosphorus content in sesame seed varied from 0.55 to 0.94%. The highest P concentration was found in T_{15} i.e. 0.94% followed by T_{13} i.e.0.85% due to combined application of biofertilizer (*Azospirillium*) with inorganic fertilizer along with micronutrients in $T_{15.}$ Minimum result was obtained in plots receiving no fertilizers (control).

Table 2: Content (%) of nutrients (NPKS) in seed of sesame

Treatments	2014-2015			
	N	**P**	K	S
	(%)			
T_1- Control	1.49	0.55	0.41	0.17
T_2- $N_{40}P_{40}K_{40}$	1.77	0.58	0.47	0.19
T_3- $N_{40}P_{40}K_{60}$	1.66	0.79	0.50	0.20
T_4- $N_{40}P_{40}K_{80}$	1.87	0.62	0.56	0.21
T_5- $N_{40}P_{40}K_{40}$ Mo_{1kg}	1.94	0.59	0.46	0.28
T_6- $N_{40}P_{40}K_{40}$ $Bo_{0.5}$	1.74	0.51	0.45	0.22
T_7- $N_{40}P_{40}K_{40}$ Zn_5	1.81	0.45	0.43	0.26
T_8- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$	1.89	0.62	0.44	0.32
T_9- $N_{40}P_{40}K_{40}$ Zn_{21}	2.15	0.57	0.45	0.24
T_{10}- $N_{40}P_{40}K_{40}$ + *Azospirillium*	2.13	0.60	0.48	0.50
T_{11}- $N_{40}P_{40}K_{40}$ S_{15}	2.17	0.67	0.46	0.83
T_{12}- $N_{40}P_{40}K_{40}$ S_{30} $Zn_{10.5}$ $Mo_{1.0}$	2.28	0.73	0.48	1.52
T_{13}- $N_{40}P_{40}K_{40}$ S_{45} Zn_{21} $Mo_{2.0}$	2.30	0.85	0.49	1.55
T_{14}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ $Mo_1B_{0.5}$ S_{30}	2.20	0.70	0.47	1.53
T_{15}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ Mo_1 $B_{1.0}S_{30}$ +*Azospirillium*	2.24	0.94	0.48	1.53
SEm(±)	0.045	0.033	0.010	0.174
CD(P=0.05)	0.139	0.104	0.032	0.536
CV%	4.49	10.22	4.26	85.61
RBD(0.05)	S	S	S	S

The effect of treatments on Potasssium content in seed varied from 0.41 to 0.56%. The highest content was found in T_4 followed by T_3 due to application of higher dose of potassic fertilizer. The level of potassium @80kg ha^{-1} gave significantly higher content than potassium @60kg ha^{-1}. Minimum result was obtained in plots receiving no fertilizers (control). Sulphur content in seed ranged between 0.17-1.55%. The highest content was found in case of T_{13} which was treated by sulphur source i.e.@45kg ha^{-1} along with micro and macronutrients followed by T_{14} and T_{15} i.e. 1.53% and lowest value was observed in control plot. Application of micronutrients also significantly improve the sulphur content in seed.

Content (%) of nutrients (NPKS) in stover of sesame

Analysis of the data about content (%) of nutrients (NPKS) in stover of sesame is shown in Table 3.

Nitrogen content in stover is lower than seed content. Nitrogen content in stover varied from 0.90% to 1.29%. The highest concentration in stover was observed in T_{15} i.e. 1.29% followed by T_{14} i.e. 1.25%. The minimum value got in plots receiving where there no fertilizer were applied (control). No treatment effect was found to be significant.

Phosphorus content in stover varied from 0.20 to 0.62%. The highest P concentration was found in T_7 i.e. 0.62% followed by T_{14} and T_{15}. Like nitrogen phosphorus content in stover is lower as compared to phosphorus content in seed. Lowest value was observed in control plot. Micronutrients has a great impact to increase the phosphorus content.

Potassium content in stover varied between between 0.36 to 0.81%. The highest content was found in T_4 i.e. 0.81% due to application of higher dose of potassic fertilizer @80kg ha^{-1} followed by T_{12} i.e. 0.80%. Potassium content in stover is higher as compared to potassium content in seed. Here also lowest value observed in control plots.

Sulphur content in stover ranged between 0.23 to 0.80%. The highest content was found in T_{13} i.e. 0.80% followed by T_{15} i.e. 0.72%. Lowest value was observed in control. Sulphur content in stover is lower as compared to sulphur content in seed. Application of micronutrients also significantly improve the sulphur content in stover. Sulphur content in stover also increased by application of biofertilizer.

Table 3: Content (%) of nutrients (NPKS) in stover of sesame

Treatments	2014-2015			
	N	P	K	S
	(%)			
T_1- Control	0.90	0.20	0.36	0.23
T_2- $N_{40}P_{40}K_{40}$	1.08	0.30	0.52	0.31
T_3- $N_{40}P_{40}K_{60}$	1.21	0.36	0.53	0.33
T_4- $N_{40}P_{40}K_{80}$	1.10	0.51	0.81	0.55
T_5- $N_{40}P_{40}K_{40}$ Mo_{1kg}	1.12	0.37	0.60	0.58
T_6- $N_{40}P_{40}K_{40}$ $Bo_{0.5}$	1.08	0.35	0.61	0.62
T_7- $N_{40}P_{40}K_{40}$ Zn_5	1.02	0.62	0.61	0.59
T_8- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$	1.16	0.30	0.57	0.56
T_9- $N_{40}P_{40}K_{40}$ Zn_{21}	1.16	0.35	0.56	0.53
T_{10}- $N_{40}P_{40}K_{40}$ + *Azospirillium*	1.22	0.39	0.62	0.59
T_{11}- $N_{40}P_{40}K_{40}$ S_{15}	1.02	0.46	0.61	0.64
T_{12}- $N_{40}P_{40}K_{40}$ S_{30} $Zn_{10.5}$ $Mo_{1.0}$	1.21	0.52	0.80	0.67
T_{13}- $N_{40}P_{40}K_{40}$ S_{45} Zn_{21} $Mo_{2.0}$	1.23	0.43	0.78	0.80
T_{14}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ $Mo_1B_{0.5}$ S_{30}	1.25	0.60	0.72	0.68
T_{15}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ Mo_1 $B_{1.0}S_{30}$ +*Azospirillium*	1.29	0.60	0.77	0.72
SEm(±)	0.058	0.020	0.013	0.014
CD(P=0.05)	0.181	0.062	0.041	0.045
CV%	10.15	9.40	4.04	5.75
RBD(0.05)	NS	S	S	S

Uptake of nutrients (NPKS) by sesame

The uptake of nutrients (NPKS) by sesame is presented in Table 4. N uptake in sesame increased with integration with *Azospirillium* with inorganic fertilizers and combined application of micronutrients with macronutrients. Different level of sulfur caused significant variation for NPKS uptake by plant of sesame. Nitrogen uptake is higher in case of stover than seed uptake. Uptake of N in seed ranges between 7.25 to 18.18 kg ha^{-1}. The highest N content was observed in T_{13} due to application of sulphur along with micronutrients followed by T_{15} i.e. 17.41 $kgha^{-1}$ and lowest value was observed in control plot. Similarly uptake of N by stover ranges between 14.24 to 30.20 kg ha^{-1}. The highest concentration of N in stover was also observed in T_{13} followed by T_{15} i.e. 29.98 kg ha^{-1} and lowest value was observed in control plot. Based on uptake by stover and seed, total uptake of N by sesame was calculated. Total uptake of N ranged between 21.49 to 48.37 kg ha^{-1} The highest uptake was observed in T_{13} followed by T_{15} i.e. 45.43kg N ha^{-1} and lowest value was observed in control plot. It was observed that highest value of N uptake was found in combined application of macro and micronutrients along with sulphur treated plots. Increased sulphur application resulted in increased of nitrogen uptake.

Phosphorus uptake in sesame was lower as compared to nitrogen. Like nitrogen, the uptake of seed is lower than stover. It was also influenced by combined application of inorganic fertilizers and biofertilizers. Almost all the INM treatments gave significantly higher P uptake by sesame over control. Phosphorus uptake in seed ranged between 2.70 to 7.28 $kgha^{-1}$. The highest P uptake was found in T_{15} due to combined application of biofertilizer (*Azospirillium*) along with inorganic fertilizer followed by T_{13} i.e. 6.71 kg Pha^{-1}. Similarly in case of stover uptake of P ranges between 3.22 to 14.03 kg ha^{-1}. The highest P uptake was found in T_{15} followed by T_{14} .The total uptake of P was ranged between 5.93 to 21.30 $kgha^{-1}$. The highest uptake was found in T_{15} followed by T_{14} i.e. 19.07 $kgha^{-1}$. From the above data it was found that micronutrient impacts a great role to increase the phosphorus uptake in sesame.

Table-4: Update of nutrients (NPKS) by sesame

Treatments	2014-15											
	Nutrient uptake(kg/ha)											
	N			P			K			S		
	Seed	Stover	Total	Seed	Stover	Total	Seed	Stover	Total	Seed	Stover	Total
T_1- Control	7.25	14.24	21.49	2.7	3.22	5.93	2.4	5.68	8.08	0.84	3.63	4.47
T_2- $N_{40}P_{40}K_{40}$	9.34	17.97	27.31	3.07	4.96	8.03	2.49	13.67	16.16	1	5.15	6.15
T_3- $N_{40}P_{40}K_{60}$	8.7	20.92	29.62	4.16	6.21	10.37	2.63	14.35	16.98	1.07	5.7	6.77
T_4- $N_{40}P_{40}K_{80}$	10.94	18.8	29.75	3.64	8.65	12.29	2.71	14.33	17.03	1.24	9.4	10.63
T_5- $N_{40}P_{40}K_{40}$ Mo_{1kg}	11.59	19.24	30.83	3.5	6.39	9.89	2.74	11.12	13.86	1.66	10.03	11.69
T_6- $N_{40}P_{40}K_{40}$ $Bo_{0.5}$	10.86	18.92	29.77	3.19	6.14	9.34	2.83	14.13	16.96	1.36	10.89	12.25
T_7- $N_{40}P_{40}K_{40}$ Zn_5	11.48	18.42	29.9	2.86	11.23	14.1	4.36	12.84	17.2	1.63	10.56	12.18
T_8- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$	12	21.76	33.76	3.92	5.67	9.59	3.25	10.8	14.06	2.03	10.59	12.62
T_9- $N_{40}P_{40}K_{40}$ Zn_{21}	14.03	22.55	36.58	3.68	6.76	10.44	2.93	10.9	13.83	1.57	10.33	11.9
T_{10}- $N_{40}P_{40}K_{40}$ + *Azospirillium*	14.54	26.38	40.92	4.09	8.45	12.54	3.25	13.33	16.58	3.39	12.65	16.03
T_{11}- $N_{40}P_{40}K_{40}$ S_{15}	15.02	22.75	37.76	4.68	10.21	14.88	3.16	9.16	12.32	5.76	14.4	20.15
T_{12}- $N_{40}P_{40}K_{40}$ S_{30} $Zn_{10.5}$ $Mo_{1.0}$	16.33	27.71	44.04	5.26	11.94	17.19	3.45	18.25	21.7	10.9	15.19	26.09
T_{13}- $N_{40}P_{40}K_{40}$ S_{45} Zn_{21} $Mo_{2.0}$	18.18	30.2	48.37	6.71	10.65	17.36	3.49	9.41	12.9	12.27	19.69	31.96
T_{14}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ $Mo_1B_{0.5}$ S_{30}	16.62	28.81	45.43	5.29	13.77	19.07	3.52	16.53	20.05	11.57	15.6	27.17
T_{15}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ $Mo_1B_{1.0}S_{30}$ + *Azospirillium*	17.41	29.98	47.39	7.28	14.03	21.3	3.7	17.82	21.51	11.92	16.79	28.71
SEm(±)	0.308	1.128	1.12	0.218	0.399	0.394	0.083	0.328	0.335	0.099	0.509	0.536
CD(P=0.05)	0.951	3.477	3.452	0.673	1.23	1.216	0.256	1.012	1.035	0.308	1.57	1.652
CV%	4.68	9.81	6.19	10.04	9.16	6.04	5.22	5.03	4.13	4.31	8.79	6.61
RBD(0.05)	S	NS	S	S	S	S	S	S	S	S	S	S

Potassium uptake by sesame was found significantly higher in almost all INM treatments as compared to control. The potassium uptake in stover was higher than seed. The uptake of K by seed ranged between 2.40 to 4.36 $kgha^{-1}$. The highest uptake was found in T_7 followed by T_{15} 3.70 $kgha^{-1}$. Potassium uptake by stover ranged between 5.68 to 18.25 $kgha^{-1}$. The highest uptake was found in T_{12} followed by T_{15} i.e. 17.82 kg K ha^{-1}. Similarly the range of total uptake of K varied between 8.08 to 21.70 $kgha^{-1}$. In this case also highest yield was also found in T_{12} followed by T_{15} i.e. 21.51 $kgha^{-1}$. In this case micronutrients also plays an important role to increase the K uptake.

Sulphur uptake by sesame was influenced by the application of sulphur and also micronutrients. Sulphur uptake was higher in case of stover than seed. In case of seed uptake the uptake of sulphur is higher in case of micronutrients treated plots along with sulphur and macronutrients as compared to all other treatments. Sulphur has a great role to increase the uptake in sesame as sesame is a oilseed crop. The result corroborates the findings of Purushottam [23]. The sulphur uptake in case of seed varied between 0.84 to 12.27 $kgha^{-1}$.The highest uptake was found in case of T_{13} which was treated by sulphur source i.e. @45kg ha^{-1} along with micro and macronutrients followed by T_{15} i.e 11.92 $kgha^{-1}$and lowest value was observed in control plot. In case of stover, the S uptake ranged between 3.63 to 19.69 $kgha^{-1}$.The highest uptake of S was also found in T_{13} followed by T_{15} i.e. 16.79 $kgha^{-1}$. Lowest value was observed in control. In case of total uptake S ranges varied between 4.47 to 31.96 kg ha^{-1}. In this case also highest yield was also observed in T_{13} followed by T_{15} i.e. 28.71 kg ha^{-1} and lowest value was observed in control plot. It was observed that T_{13} gave higher yield as compared to all other treatments due to application of high doses of sulphur i.e. @45kg ha^{-1} along with micro and macronutrients. Next to this T_{15} gave higher yield due to application of *Azospirillium* along with all inorganic fertilizer including sulphur, micro and macro nutrients.

Crude protein content and Protein yield of sesame

The data related to protein content of sesame presented in table 5 indicated that the trend in protein content was similar to that of nitrogen uptake by sesame. It was observed that the range of protein content ranged between 9.31 to 14.38%. The highest value of protein content in sesame 14.38% was associated with T_{13} followed by T_{12} i.e.

14.25% and lowest value i.e 9.31% was associated with control plot. The highest value was due to application of high doses of sulphur i.e. @45kg ha^{-1}. Dwivedi and Bapat observed that not only the total quantity of protein was improved by sulphur addition but at the same time the quality of protein was also improved. They observed that relative proportion of all sulphur containing amino acids, viz., methionine, cystine and cysteine increased significantly. This indicates that synthesis of these amino acids is impeded without supply of a prime element i.e., sulphur and stimulated rapid metabolism at a faster rate with successive higher levels applied.

Table 5: Crude protein content and protein yield of sesame

T Treatments	2014-15	
	Protein content (%)	Protein Yield(kg/ha)
T_1- Control	9.31	45.16
T_2- $N_{40}P_{40}K_{40}$	11.06	58.23
T_3- $N_{40}P_{40}K_{60}$	10.38	54.40
T_4- $N_{40}P_{40}K_{80}$	11.69	68.52
T_5- $N_{40}P_{40}K_{40}$ Mo_{1kg}	12.13	72.42
T_6- $N_{40}P_{40}K_{40}$ $Bo_{0.5}$	10.88	68.02
T_7- $N_{40}P_{40}K_{40}$ Zn_5	11.31	71.69
T_8- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$	11.81	75.14
T_9- $N_{40}P_{40}K_{40}$ Zn_{21}	13.44	87.85
T_{10}- $N_{40}P_{40}K_{40}$ + *Azospirillium*	13.31	90.95
T_{11}- $N_{40}P_{40}K_{40}$ S_{15}	13.56	94.04
T_{12}- $N_{40}P_{40}K_{40}$ S_{30} $Zn_{10.5}$ $Mo_{1.0}$	14.25	102.24
T_{13}- $N_{40}P_{40}K_{40}$ S_{45} Zn_{21} $Mo_{2.0}$	14.38	113.84
T_{14}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ $Mo_1B_{0.5}$ S_{30}	13.75	103.76
T_{15}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ Mo_1 $B_{1.0}S_{30}$ +*Azospirillium*	14.00	108.85
SEm(±)	0.261	1.974
CD(P=0.05)	0.807	6.084
CV%	4.16	4.78
RBD(0.05)	S	S

Protein yield was calculated depending upon the protein content and seed yield of lentil. The highest protein yield was obtained in T_{13} i.e. 113.84kgha^{-1} followed by T_{15} i.e. 108.85 kgha^{-1} but in case of protein content T_{12}. As the seed yield of T_{13} was more than $T_{12,}$ the protein yield was more in $T_{13.}$ It was observed that the plot which was treated by high sulphur dose, gave higher protein yield as compared to other treatments. Lowest yield was obtained in case of control plot.

Oil content and oil yield of sesame

The data related to oil content of sesame presented in Table 6. indicated that oil content of sesame varied from 41.13 to 56.67%. The increase in oil content due to nitrogen and sulphur application along with biofertilizer was statistically significant. It was observed that highest oil content was obtained in T_{15} i.e. 56.67% followed by T_{13} i.e. 56.23% and lowest value was obtained in control. It was also observed that sulphur application along with biofertilizer along with micronutrients gave significantly higher oil content than other treatments.

Table 6: Oil content and oil yield of sesame

Treatments	**2014-15**	
	Oil content (%)	**Oil Yield(kg/ha)**
T_1- Control	41.13	2.0
T_2- $N_{40}P_{40}K_{40}$	47.47	2.5
T_3- $N_{40}P_{40}K_{60}$	48.20	2.5
T_4- $N_{40}P_{40}K_{80}$	47.20	2.8
T_5- $N_{40}P_{40}K_{40}$ Mo_{1kg}	48.30	2.9
T_6- $N_{40}P_{40}K_{40}$ $Bo_{0.5}$	51.03	3.2
T_7- $N_{40}P_{40}K_{40}$ Zn_5	53.50	3.4
T_8- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$	51.53	3.3
T_9- $N_{40}P_{40}K_{40}$ Zn_{21}	53.77	3.5
T_{10}- $N_{40}P_{40}K_{40}$ + *Azospirillium*	53.83	3.7
T_{11}- $N_{40}P_{40}K_{40}$ S_{15}	54.77	3.8
T_{12}- $N_{40}P_{40}K_{40}$ S_{30} $Zn_{10.5}$ $Mo_{1.0}$	55.97	4.0
T_{13}- $N_{40}P_{40}K_{40}$ S_{45} Zn_{21} $Mo_{2.0}$	56.23	4.5
T_{14}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ $Mo_1B_{0.5}$ S_{30}	55.03	4.2
T_{15}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ Mo_1 $B_{1.0}S_{30}$ +*Azospirillium*	56.67	4.4
SEm(±)	1.009	0.081
CD(P=0.05)	3.111	0.251
CV%	3.83	4.75
RBD(0.05)	S	S

Data analysed about the oil yield of sesame presented in Table 6. The value oil yield varied from 2.0 q ha^{-1} to 4.5q ha^{-1}.The minimum value was recorded in control plot. The highest oil yield was observed in T_{13} i.e. 4.5 q ha^{-1} followed by T_{15} i.e. 4.4 q ha^{-1}. The highest value was observed due to application of high doses of sulphur i.e. @45kg ha^{-1}. Increased oil content and oil yield due to application of nitrogen and sulphur was also reported by Das and Das [24]. The acetic thiolinase, a sulphur based enzyme in the presence of S convert acetyl Co-A to melonyl Co-A, rapidly resulting in higher oil content in seed crops [25].

Microbial population in soil after harvesting of sesame

Analysis of the data of microbial population in soil after harvesting of sesame is presented in Table 7. The microbial population mainly includes the *Azospirillium* population.

Table 7: Microbial population in soil after harvesting of sesame

Treatments	2014-15
	***Azospirillium* (No.× 10^6cfu g^{-1})**
T_1- Control	2.44
T_2- $N_{40}P_{40}K_{40}$	2.85
T_3- $N_{40}P_{40}K_{60}$	2.84
T_4- $N_{40}P_{40}K_{80}$	2.94
T_5- $N_{40}P_{40}K_{40}$ Mo_{1kg}	3.01
T_6- $N_{40}P_{40}K_{40}$ $Bo_{0.5}$	3.01
T_7- $N_{40}P_{40}K_{40}$ Zn_5	2.85
T_8- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$	3.36
T_9- $N_{40}P_{40}K_{40}$ Zn_{21}	3.22
T_{10}- $N_{40}P_{40}K_{40}$ + *Azospirillium*	7.48
T_{11}- $N_{40}P_{40}K_{40}$ S_{15}	3.25
T_{12}- $N_{40}P_{40}K_{40}$ S_{30} $Zn_{10.5}$ $Mo_{1.0}$	3.77
T_{13}- $N_{40}P_{40}K_{40}$ S_{45} Zn_{21} $Mo_{2.0}$	2.93
T_{14}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ $Mo_1B_{0.5}$ S_{30}	3.00
T_{15}- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$ Mo_1 $B_{1.0}S_{30}$ +*Azospirillium*	9.36
SEm(±)	0.221
CD(P=0.05)	0.681
CV%	11.56
RBD(0.05)	S

The effect of INM treatments on population of *Azospirillium* in soil after harvest of sesame is presented in Table 7. Application of *Azospirillium* along with NPK did not show any significant difference in case of growth and yield attributes in sesame but application of *Azospirillium* along with sulphur, micro and macronutrients i.e. T_{15} recorded significant difference in case of growth parameters, yield attributes and uptake of nutrients. In case of seed, stover, biological yield and oil yield T_{15} gave comparatively higher yield than all other treatments except T_{13} which was treated by high dose of sulphur i.e. @45kg ha^{-1}. In case of oil content T_{15} gave the highest yield. In case of biological uptake of nitrogen and phosphorus, the best result was obtained from T_{15}. The highest population of *Azospirillum* was observed in T_{15} followed by T_{10} and lowest population was observed in control. Integrated nutrient management involving the use of 50% recommended dose through chemical fertilizer + 50% N through FYM or vermicompost along with *Azospirillum* was found most effective for achieving higher growth and yield attributes, seed, oil and protein yield and higher gross and net return of sesame.

CONCLUSION

Integrated Nutrient Management is one of the important issues for sustainable crop production. The result of the study revealed that integrated application of NPK with sulphur, boron, molybdenum, zinc along with biofertilizer recorded higher grain yield, total biological yield, oil content as well as oil yield, crude protein content as well as protein yield, nutrient accumulation as well as uptake and maintained soil fertility. Combined application of sulphur, boron, molybdenum, zinc increased the use efficiency of N, P and K.

Integrated nutrient applications are more beneficial when the rate of the nutrient application is below the normal rate. It also improved the crop yields, quality of the produce as well as improve the soil fertility, thus the overall profit of the farmers. Thus, it may be recommended for the farmers of red and lateritic belt of West Bengal.

REFERENCES

[1] Singh B, Singh Y, Sekhon G S 1995. Fertilizer N use efficiency and nitrate pollution of groundwater in developing countries. Journal of Contaminant Hydrology*;* 20: 167-184.

[2] Takkar P N, Chhibba I M, and Mehta S K 1989. Twenty years of coordinated research on Micronutrients in Soil and Plants, 1967-87, Bulletin 1, Indian Institute of Soil Science, Bhopal.

[3] Swarup A and Ganeshamurthy A N 1998. Emerging nutrient deficiencies under intensive cropping systems and remedial measures for sustainable high productivity. Fertilizer News; 43(7), 37-40 and 43-50

[4] Singh S P, Dhayani B P, Shahi U P, Kumar Ashok, Singh R R, Kumar Y, Kumar S and Baliyan Vikash 2009. Impact of Integrated Nutrient Management on yield and nutrient uptake in rice (*Oryza sativa*)-Wheat (*Triticum aestivum*) under rice-wheat cropping system In sandy loam soil. Indian Journal of Agril. Sc.*;* 79: 65-69

[5] Pattanayak S K, Mohanty R K and Sethy A K 2001. Response of okra to *Azotobactor*, *Azospirillium* and FYM. Second North Eastern Regional Conference on Biofertilizers, Assam Agricultural University, Jorhat, Assam.

[6] Sardana V 1997. Agronomic Evaluation of Bioinoculants to supplement inorganic fertilizers for sustained crop production- A critical review. Agricultural Research*;* 18, 69-95

[7] Were BA, Onkware AO, Gudu S, Welander M, Carlsson AS. 2006. Seed oil content and fatty acid composition in east African sesame (*Sesamum indicum* L.) accessions evaluated over 3 years. Field Crop Res. 97:254–260.

[8] Sabannavar S J, Lakshman H C 2008. Interactions between *azotobacter*, *pseudomonas* and arbuscular mycorrhizal fungi on two varieties of (Sesamum indicum L.). J Agron Crop Sci.194:470–478.

[9] Arslan Ç, Uzun B U, Ülger S C, İlhan Çağırgan M I 2007. Determination of oil content and fatty acid composition of sesame mutants suited for intensive management conditions. J Am Oil Chem Soc. 84:917–920.

[10] Anonymous. 2006. Package of Organic Practices for Brinjal, Rice, Sesame and Taro. Development Research Communication and Services Centre. Available from http://www.drcsc.org.

[11] Ceccotti S P. 1996. Plant nutrition sulphur-A review of nutrient balance, environment impact and fertilizers. Fertilizer research: an international journal on fertilizer use; 43: 117-125.

[12] Chattopaddhyay, S and Ghosh, G K. 2012**.** Response of Rapeseed *(Brassica juncea* L.) to various Sources and Levels of Sulphur in Red and Lateritic Soils of West Bengal, India. International Journal of Plant, Animal and Environmental Sciences 2(4): 50 -59.

[13] Tisdale P P, Poongothai S, Savithri R K, Bijujoseph O P 1999. Influence of gypsum and green leaf manure application on rice. Journal of the Indian Society of Soil Science*;* 47(1), 96-99.

[14] Badruddin M. 1999. The effect of sulphur deficiency on ion accumulation with special reference to 15N and 35S transport and metabolism in chickpea. Ph.D Thesis, University of Dhaka, Bangladesh.

[15] Reddy B N, Sudhakarababu S N 1996. Production potential and utilization and economics of fertilizer management in summer sunflower based crop. Ind J Agri Sci.; 66:16–19.

[16] El Habbasha SF, Abd El Salam MS, Kabesh MO 2007. Response of two sesame varieties (Sesamum indicum L.) to partial replacement of chemical fertilizer by bio-organic fertilizers. Res J Agr Biol Sci. 3:563–571.

[17] Deshmukh M R, Jain H C, Duhoon S S, Goswami U 2002. Integrated nutrient management in sesame for Kymore plateau zone of M.P. Journal of Oilseeds Research*;* 19(1): 73-75.

[18] Verma S, Saxena R, Singh H V 2012. Integrated nutrient management in sesame (*Sesamum indicum* L.). Bioinfolet. 9(4), 576-579.

[19] Chesnin L and Yien CH. 1951. Tubidimetric determination of available sulphate. Proc. Soil Sci. Soc. Am., 15:149-151.

[20] Gomez, K.A., Gomez, A.A. 1984. Statistical Procedures for Agricultural Research. A Wiley-Interscience Publication, New york, pp. 130–139.

[21] Jaishankar S, Wahab K. 2005. Effect of integrated nutrient management on the growth, yield components and yield of sesame. Sesame and Safflower Newsletter. 20: 732

[22] Imayavaramban V, Thanunathan K, Singaravel R, Manickam G. 2002. Studies on the influence of integrated nutrient management on growth, yield parameters and seed yield of sesame (*Sesamum indicum* L.). Crop Research. 24(2): 309-313.

[23] Purushottam G 2005. Integrated nutrient management in sesame (*Sesamum indicum* L.) and its residual effect on succeeding chickpea (*Cicer arietinum* L.). M.Sc.(Ag.) in Agronomy Thesis submitted to the University of Agricultural Sciences, Dharwad, Karnataka.

[24] Das K N and Das K. 1995. Effect of sulphur and nitrogen fertilizer on growth and yield of toria *(Brassica campestris sub sp. oleifera var. toria).* Indian Journal of Agronomy. 40: 329-331

[25] Krishnamurthy V V and Mathan K K. 1996. Effect of sulphur on yield of groundnut. Madras. Agric. J. 83: 640-642.

INTERNATIONAL JOURNAL OF
PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES

ISSN 2231-4490

International Journal of Plant, Animal and Environmental Sciences