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Effect of integrated nutrient management on lentil-sesame-rice cropping system in red and Lateritic Soils of West Bengal

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Abstract
Integrated Nutrient Management is one of the important issues for sustainable crop production. A field experiment was conducted during 2014-15 at the Agricultural Farm of Palli Siksha Bhavana (Institute of Agriculture), Visva- Bharati, Sriniketan to study the effect of combined application of organic and inorganic fertilizers on yield, nutrient uptake, and quality content along with microbial population in Lentil-Sesame-Rice cropping system. Highest yield, nutrient uptake and quality content were obtained in integrated application of organic and inorganic fertilizer treated plots. Micronutrients have a great impact on soil health in sustainable agriculture by improving growth, yield and fertility status of soils. Sulphur has a major role in case of yield, uptake and oil content of sesame.

Keywords: Integrated Nutrient Management, macro and micronutrients, sulphur, Farm Yard Manure, biofertilizer, yield, uptake, oil and protein content

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. 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 [43]. The problems of micronutrients also generally crops up with the use of high analysis chemical fertilizers having one or two nutrient elements [46]. The decline in productivity of intensive cropping systems over the years was associated with deficiencies of secondary and micronutrients [45]. 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 [32]. *Azospirillium*, an associative diazotroph, and *Azotobacter*, a heterotrophic free living diazotroph have been identified as potential microbial inoculants for increasing the productivity of various non legume crops. These organisms besides N_2 fixation synthesize and secrete many amino acids which influence seed germination, plant growth and yield [39]. FYM is a key fertilizer in organic and sustainable soil management. It contains many of the elements that are needed for plant growth and development. Lentil, sesame and rice, crops are grown in sequence in some areas of West Bengal. The Lentil is grown mainly as *rabi* crop, sesame as pre-*kharif* and rice is grown mostly as *kharif* crop. This cropping system could be practiced in Red and Lateritic belt of West Bengal with limited assured irrigation facility. Since the yield level of lentil, sesame and rice crops are sub-optimal and keeping all other points so far in mind an integrated nutrient management approach was followed under lentil-sesame-rice cropping system in the red and lateritic belt of West Bengal.

Pulses form an integral part of the vegetarian diet and the cheapest source of protein for the resource of poor farmers of the Indian sub-continent. Lentil (*Lens culinaris* Medikus) is an important grain legume in Asia. It occupies an important position in this region. India is the world's major lentil producing country, followed by Canada and Turkey, which collectively account for 68% of global production [15]. It is an important source of protein and several essential micronutrients. It synthesizes N in symbiosis with *Rhizobium* and enriches the soil. It improves the fertility status of soil through atmospheric N fixation.

Out of total pulses, lentil ranks fourth in acreage and fifth in production and third in productivity in West Bengal. However, there is a great possibility to increase lentil production by cultivating HYV with balanced fertilization including micronutrient. Micronutrients play an important role in increasing yield of pulses through their effect on the plant itself and on the Nitrogen fixing by symbiotic process. Deficiencies of these nutrients have been very pronounced under multiple cropping systems due to excess removal by HYV of crops and hence their exogenous supplies are urgently required.

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 [49]. 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 [2]. But the productivity of sesame in general is much lower than its potential yield. Lower productivity of 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. It is reported that 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 [8, 22]. Sulphur application significantly increased the uptake of Nitrogen in straw and grain [4, 13], thereby increased grain yield. In oilseeds, sulphur plays a significant role in the quality and development of seeds. The *Azospirillum* application can be used to decrease the use of N fertilizer to 50% [36]. The effect of partial replacement of chemical fertilizer with N-fixing bacteria did not have a significant influence on oil percentage in sesame [17]. Boron plays a vital role in oil synthesis. Further, combined application of organics and inorganics during *kharif* season in sesame exerts significant yield. Understanding the factors involved in the 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.

Rice is one of the most important food crop and a primary food source for more than one third of world's population [33]. In India, West Bengal is one of the leading states for rice cultivation. Rice is a nutritional staple food which provides instant energy as its most important component is carbohydrate (starch). The use of nitrogen fertilizers increases the percentage content of some amino acids. The main rice growing season in the country is the '*Kharif*'. Nitrogen and Sulphur are both involved in plant protein synthesis, a process that may determines yield of crops. As a result, the requirement of N by plants increases when N is fertilized with S, as their metabolism is coupled in the synthesis of S-containing amino acids, membrane lipids, enzymes and coenzymes [1]. Indian farmers apply N, P and K fertilizers widely, it is found that application of micronutrients such as B, Zn, and Mo is not a usual practices. A marked higher incidence of micronutrient deficiency is found in crop due to intensive cropping, loss of fertile top soil and losses of nutrient through leaching [35, 44, 42]. Zinc is one of the most important micronutrient essential for plant growth especially for rice grown under submerged condition. Application of Zn along with NPK fertilizer increases the grain yield dramatically in most cases [42, 12].

Materials and Methods

A field experiment was conducted during 2014-15 to study the Integrated Nutrient Management of Lentil (*Lens culinaris* Medikus)-Sesame (*Sesamum indicum*)-Rice (*Oryza sativa*) cropping system in red and lateritic soil 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}), 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% Z), Ammonium molybdate (54% Mo) are used for the source of boron, zinc and molybdenum. All the plots are treated with FYM (5tonnes per ha) except T_1 whereas T_1 was treated as control plot where RDF was followed accordingly in cropping system. The seed was inoculated properly with the culture of *Rhizobium*, *Azotobactor* and *Azospirillium* in this cropping system. The available nutrient status of soil, Total uptake of nutrients, yield, oil and protein content along with microbial population 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. The amount of seed nitrogen content was estimated as per Jackson and 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 [16].

Results and Discussion

Effect of INM on yield

Analysis of data about effect of treatments on the yield of lentil is presented in Table 1. The table consists the seed, stalk and harvest index of lentil. Seed yield was affected significantly by integrated application of fertilizer in different treatments over control. Combined application of inorganic nutrients along with organic nutrients increased seed yield as compared to only inorganically treated nutrients. The highest seed yield (6.98 q ha^{-1}) was observed in T_{15} and lowest value (4.09 q ha^{-1}) was observed in control. Seed inoculation of *Rhizobium* + PSB @ 60 g kg^{-1} seed recorded significantly higher seed yield as compared to uninoculated control except micronutrient treated plots. Dual application of biofertilizer gave more yield than single application of biofertilizers [30, 6].

Table 1: Effect of INM treatments on Lentil yield

Treatments	Seed Yield	Stalk Yield	Harvest Index
	(qha^{-1})		(%)
T_1- Control(RDF:: 30:40:20)	4.09	16.10	20.26
T_2-$N_{15}P_{20}K_0$ + FYM	4.48	16.56	21.29
T_3-$N_{15}P_{40}K_0$+ FYM	5.17	17.17	23.13
T_4-$N_{15}P_{20}K_{20}$+ FYM	5.31	17.23	23.55
T_5-$N_{15}P_{40}K_{20}$+ FYM	5.42	17.75	23.38
T_6-$N_{15}P_{20}K_{40}$+ FYM	5.94	18.03	24.78
T_7-$N_{15}P_{40}K_{40}$+ FYM	5.96	17.89	24.92
T_8-$N_{15}P_{20}K_{60}$+ FYM	6.23	18.04	25.65
T_9-$N_{15}P_{40}K_{60}$+ FYM	6.34	18.32	25.73
T_{10}-$N_{15}P_{20}K_{20}$+*Rhizobium*+ FYM	6.43	18.27	26.03
T_{11}-$N_{15}P_{20}K_{20}$+*Rhizobium*+PSB+ FYM	6.50	18.67	25.80
T_{12}-$N_{15}P_{40}K_0Zn_{10.5}S_{8.5}Mo_{1.0}$+ FYM	6.57	19.22	25.47
T_{13}-$N_{15}P_{40}K_0Zn_{21}S_{17}Mo_{2.0}$+ FYM	6.68	19.28	25.73
T_{14}-$N_{15}P_{40}K_0Zn_{10.5}S_{8.5}Mo_{1.0}B_{0.5}$+ FYM	6.86	19.20	26.33
T_{15}-$N_{15}P_{40}K_0Zn_{10.5}S_{8.5}Mo_{1.0}B_{1.0}$+ FYM	6.98	19.53	26.35
SEm(±)	0.081	0.107	0.311
CD(P=0.05)	0.251	0.331	0.959

Improvement of yield due to combined application of inorganic fertilizer and biofertilizer might be attributed to controlled release of nutrients in soil through mineralization of biofertilizer which might have facilitated better crop growth [37]. In case of T_{15} ($N_{15}P_{40}K_0Zn_{10.5}S_{8.5}Mo_{1.0}B_{1.0}$+ FYM) i.e. integrated use of fertilizer was done by combined application of micro and macronutrients with FYM. So it was observed that micronutrients play a greater role to increase the yield of crop rather than macronutrients. Like seed yield, stalk yield was significantly affected by different treatments under consideration. In case of stalk yield, highest yield (19.53 q ha^{-1}) was recorded in T_{15} followed by T_{13} 19.28 q ha^{-1}. The stalk yield of T_{12} and T_{14} treatments were almost same. Lowest stalk yield (16.10 q ha^{-1}) was found in control which was treated with recommended dose of fertilizer (RDF). In this case also combined application of micronutrients along with macronutrients and sulphur gave higher yield as compared to all other treatments. The ranges of harvest index observed in case of lentil ranges from 20.26-26.35. The highest harvest index (26.35) was found in T_{15} followed by T_{14} (26.33) and lowest value was observed in control.

Sesame seed yield was affected significantly by integrated application of fertilizer in different treatments over control (Table 2). Combined application of inorganic nutrients along with micronutrients, sulphur and FYM 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} 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.

Table 2: Effect of INM treatments on sesame yield

Treatment Details	Seed Yield	Stover Yield	Harvest Index (%)
	(qha^{-1})		
T_1- Control(RDF::60:40:40)	4.85	15.93	23.34
T_2- $N_{40}P_{40}K_{40}$ + FYM	5.26	16.60	24.06
T_3- $N_{40}P_{40}K_{60}$+ FYM	5.24	17.23	23.32
T_4- $N_{40}P_{40}K_{80}$+ FYM	5.86	17.10	25.52
T_5- $N_{40}P_{40}K_{40}$ Mo_{1kg}+ FYM	5.97	17.20	25.77
T_6- $N_{40}P_{40}K_{40}$ $Bo_{0.5}$+ FYM	6.25	17.47	26.35
T_7- $N_{40}P_{40}K_{40}$ Zn_5+ FYM	6.34	18.00	26.05
T_8- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$+ FYM	6.37	18.80	25.31
T_9- $N_{40}P_{40}K_{40}$ Zn_{21}+ FYM	6.53	19.50	25.09
T_{10}-$N_{40}P_{40}K_{40}$+*Azospirillium*+ FYM	6.84	21.57	24.08
T_{11}- $N_{40}P_{40}K_{40}$ S_{15} + FYM	6.93	22.37	26.17
T_{12}-$N_{40}P_{40}K_{40}S_{30}$+FYM (Residual effect of Zn, Mo)	7.17	22.83	26.24
T_{13}-$N_{40}P_{40}K_{40}$ S_{45} + FYM (Residual effect of Zn, Mo)	7.92	24.50	28.82
T_{14}-$N_{40}P_{40}K_{40}S_{30}$+ FYM (Residual effect of Zn, Mo and B)	7.55	23.07	26.27
T_{15}-$N_{40}P_{40}K_{40}S_{30}$+*Azospirillium*+FYM (Residual effect of Zn, Mo and B)	7.77	23.27	26.31
SEm(±)	0.064	0.227	0.271
CD(P=0.05)	0.199	0.702	0.836

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 [31, 10, 48]. The results clearly indicate that integrated use of FYM, 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, and 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 [48, 21, 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. The ranges of harvest index were 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.

Table 3: Effect of INM treatments on rice yield

Treatments	Grain Yield (qha^{-1})	Straw Yield (qha^{-1})	Harvest Index (%)
T_1- Control(RDF:: 80:40:60)	35.20	27.00	56.55
T_2- $N_{80}P_{20}K_0$	44.53	49.73	47.12
T_3- $N_{80}P_{40}K_0$	46.47	50.27	48.16
T_4- $N_{80}P_{20}K_{20}$	47.20	58.60	44.68
T_5- $N_{80}P_{40}K_{20}$ (Residual effect of Mo)	48.53	59.47	44.87
T_6- $N_{80}P_{20}K_{40}$ (Residual effect of B)	49.27	45.87	52.42
T_7- $N_{80}P_{40}K_{40}$ (Residual effect of Zn)	50.40	45.80	52.51
T_8- $N_{80}P_{20}K_{60}$(Residual effect of Zn)	49.33	53.47	48.56
T_9- $N_{80}P_{40}K_{60}$(Residual effect of Zn)	50.20	63.40	44.57
T_{10}- $N_{80}P_{20}K_{20}$+*Azotobacter*	51.27	73.07	41.10
T_{11}- $N_{80}P_{20}K_{20}$ +*Azotobacter* +*Azospirillum*	53.60	74.87	47.71
T_{12}- $N_{80}P_{40}K_0S_{10}$(Residual effect of Zn, Mo)	53.67	72.60	47.24
T_{13}- $N_{80}P_{40}K_0S_{20}$(Residual effect of Zn, Mo)	55.33	78.80	41.31
T_{14}- $N_{80}P_{40}K_0S_{10}$(Residual effect of Zn, Mo, B)	56.87	90.53	38.60
T_{15}- $N_{80}P_{40}K_0S_{10}$ (Residual effect of Zn, Mo, B)	57.93	93.47	38.28
SEm(±)	3.178	4.983	3.895
CD(P=0.05)	9.794	15.353	12.001

Analysis of data about effect of treatments on the yield of rice is presented in Table 3. The table consists the grain, straw yield of rice along with harvest index. Grain yield was affected significantly by integrated application of fertilizer in different treatments over control. Combined application of inorganic and organic nutrients increased grain yield as compared to only inorganically treated nutrients. So combined application of macro and micronutrients along with sulphur has a great role to increase the grain yield of rice. The grain yield varied between 35.20 to 57.93 qha^{-1}. The highest grain yield was observed in T_{15} i.e 57.93 q ha^{-1} followed by T_{14} i.e 56.87 qha^{-1} which were treated by both micronutrients and sulphur along with macronutrients (NPK) and lowest value was observed in control i.e. 35.20 q ha^{-1}. It is interesting to note that micronutrients like B, Mo and Zn has exerted their profound effect in conjunction with NPK on yield and yield attributing parameters of rice. It was also found that *Azotobactor* and *Azospirillium* treated plots recorded higher yield than only NPK treated plots. Improvement in yield due to combined application of INM treatments are mainly due to balanced supply of nutrients which might have facilitated better crop growth [37]. Like grain yield, straw yield was significantly increased affected by different treatments under study. Straw yield of rice varied between 27.00 to 93.47 q ha^{-1}. Like grain yield the highest straw yield was also found in T_{15} i.e. 93.47 q ha^{-1} followed by T_{14} i.e. 90.53 q ha^{-1}. Lowest straw yield was found in control i.e. 27.00 q ha^{-1}. It was also found that *Azotobactor* and *Azospirillium* treated plots recorded higher yield than only NPK treated plots. Here also combined application of macro and micronutrients along with sulphur has a great role to increase the straw yield of rice. The harvest index observed in case of rice ranged from 38.28-56.55%. The highest harvest index was found in control and lowest value was observed in T_{10}. Improvement of yield takes place due to combined application of macro and micronutrients along with sulphur. In case of T_{15} integrated use of fertilizer was done by combined application of micro and macronutrients along with sulphur helps to get higher yield in case of rice. Several authors reported the beneficial effects of *Azospirillum* inoculation in increasing rice yield [23, 20, 14]. Investigations showed that *Azospirillum* inoculation increased rice yield significantly by 1.6–10.5 g per plant (32–81% increase) in greenhouse conditions [28, 26]. However, under field conditions the estimated yield increase was approximately 1.8 t ha^{-1} (22% increases) [5]. Rice yields in field trials increased by 0.4–0.9 t ha^{-1}(7–20% increase) due to *Azotobacter* application [50].

Effect of INM on nutrient uptake

Nutrient uptake in lentil

Results indicate that N uptake in lentil increased with integration of micronutrients with macronutrients along with sulphur. Nitrogen uptake is higher in stalk than seed because yield of stalk was more than that of seed. Uptake of N by seed ranges between 6.94 to 19.33 kg ha^{-1}. The highest N uptake was observed in T_{15} due to integrated application of micronutrients with macronutrients along with sulphur and FYM followed by T_{13} and lowest value was observed in control plot. The uptake of N by stalk ranges between 18.03 to 25.56 kg ha^{-1}.The highest uptakes was observed in T_{12} and lowest value was observed in control plot. Depending upon the stalk uptake and seed uptake total uptake of lentil was summed up. The total N uptake ranged between 24.97to 44.09 kg ha^{-1}. The highest value of total N uptake was observed in T_{15} (i.e. 44.09 kgha^{-1}) followed by T_{12} and T_{13}, lowest value was observed in control plot. The higher N uptake with biofertilizers and organic manure might be attributed to solubilisation of native nutrients, chelating of complex form of intermediate organic molecules produced during decomposition of added organic manures, their mobilization and accumulation of different nutrients in plant parts [29]. Seed inoculation of *Rhizobium* + PSB @ 60 g kg^{-1} seed recorded significantly higher nitrogen uptake in stalk as compared to uninoculated control except micronutrients treated plots [24].

Phosphorus uptake in lentil was lower as compared to nitrogen and potassium uptake. Like nitrogen the uptake by stalk is higher than seed. It was also influenced by combined application of inorganic fertilizers along with biofertilizers. Almost all the INM treatments gave significantly higher P uptake by lentil over control. Phosphorus uptake by seed ranges between 2.56 to 5.28 kg ha^{-1}.The highest uptake was found in T_{11} (i.e. 5.28 kg P ha^{-1}) due to dual application of biofertilizer (*Rhizobium* and PSB) along with inorganic fertilizer followed by T_{15}. Similarly in case of stalk uptake of P ranges between 5.19 to 8.92 kg ha^{-1}. The highest uptake was found in T_{11} followed by T_{10} (i.e. 8.58 kg P ha^{-1}). It was also observed that the total uptake of P ranges between 7.76-14.20 $kgha^{-1}$. The highest uptake of P was found in case of T_{11} followed by T_{10} (i.e. 13.57 kg P ha^{-1}). In all three cases lowest value was observed in control plot. Seed inoculation increased phosphorus uptake in grain significantly. Seed inoculation of *Rhizobium* + PSB @ 60 g kg^{-1} seed recorded significantly higher phosphorus uptake in grain as compared to other treatments. This might be due to higher dry matter production. The above findings, in general reveal that phosphorus uptake by stalk, grain and total uptake increased by application of biofertilizers inoculation.

Potassium uptake was found significantly higher in almost all INM treatments as compared to control. In case of potassium the uptake by stalk was more than seed. The uptake of K in seed ranged between 4.70 to 8.75 kg ha^{-1}. The highest uptake was found in T_{10} due to application of biofertilizer along with inorganic fertilizer but in this case *Rhizobium* inoculated treatment (T_{10}) gave higher yield than *Rhizobium* and PSB inoculated treatment (T_{11}). Potassium uptake by stalk ranged between 19.48 to 26.89 kg ha^{-1}. The highest K uptake was found in T_{11} followed by T_{15} (i.e. 25.84 kg ha^{-1}). Similarly the range of total uptake varied between 24.18 to 34.88 kg ha^{-1}. In this case also highest yield was found in T_{11} followed by T_{15}. In all three cases lowest value was observed in control plots. The increased uptake by K in lentil may be ascribed to the release of K from the K bearing minerals by complexing agents and organic acids produced during decomposition of organic sources.

Sulphur uptake by lentil was also similar with all cases of nutrient uptake. It was observed that the sulphur uptake was also higher in case of stalk than seed and also the uptake of sulphur is higher in case of micronutrients treated plots along with sulphur and macronutrients as compared to all other treatments. The sulphur uptake in case of seed varied between 0.56 to 3.05 kg ha^{-1}. The highest S uptake was found in case of T_{13} which was treated by sulphur sources @17kg S ha^{-1} along with micro and macronutrients followed by biofertilizers inoculated treatment i.e. T_{11} and lowest value was observed in control plot. In case of stalk, the S uptake ranged between 8.77-20.72 kg ha^{-1}. The highest S uptake was found in T_{15}. Lowest S uptake was observed in T_2 instead of control, it may be due to variability in research plot. In case of total uptake S ranges varied between 9.40-23.14 kg ha^{-1}. In this case highest yield was also observed in T_{15} followed by T_{13} and lowest value was observed in control plot. Uptake of sulphur was more in case of integrated use of biofertilizers along with inorganic fertilizer as compared to control [47].

Table 4: Uptake of nutrients (NPKS) by lentil

Treatment Details	Nutrient uptake(kg/ha)											
	N			P			K			S		
	Seed	Stalk	Total	Seed	Stalk	Total	Seed	Stalk	Total	Seed	Stalk	Total
T_1- Control (RDF:: 30:40:20)	6.94	18.03	24.97	2.56	5.19	7.76	4.70	19.48	24.18	0.56	8.84	9.40
T_2-$N_{15}P_{20}K_0$ + FYM	10.08	20.09	30.17	3.00	5.78	8.78	5.39	21.48	26.86	0.97	8.77	9.74
T_3-$N_{15}P_{40}K_0$+ FYM	11.39	22.12	33.50	3.77	6.73	10.50	6.31	21.37	27.69	1.26	9.96	11.22
T_4-$N_{15}P_{20}K_{20}$+ FYM	12.19	18.64	30.83	3.53	6.70	10.23	6.10	21.56	27.66	1.10	12.25	13.35
T_5-$N_{15}P_{40}K_{20}$+ FYM	12.34	22.21	34.54	4.02	7.67	11.69	6.95	22.66	29.60	1.23	12.25	13.48
T_6-$N_{15}P_{20}K_{40}$+ FYM	14.01	22.54	36.56	4.34	6.73	11.06	7.75	23.45	31.20	1.47	12.62	14.09
T_7-$N_{15}P_{40}K_{40}$+ FYM	13.84	22.36	36.21	4.22	6.48	10.70	7.70	23.83	31.54	1.68	13.32	15.00
T_8-$N_{15}P_{20}K_{60}$+ FYM	14.41	22.23	36.63	4.61	6.68	11.29	7.61	23.04	30.65	1.25	12.07	13.32
T_9-$N_{15}P_{40}K_{60}$+ FYM	14.33	18.81	33.14	4.49	6.92	11.42	8.51	23.62	32.14	1.48	13.85	15.33
T_{10}-$N_{15}P_{20}K_{20}$+*Rhizobium*+ FYM	15.43	23.53	38.96	4.99	8.58	13.57	8.75	24.11	32.86	2.66	10.28	12.94
T_{11}-$N_{15}P_{20}K_{20}$+*Rhizobium*+PSB+ FYM	15.79	22.59	38.37	5.28	8.92	14.20	7.99	26.89	34.88	2.79	11.92	14.71
T_{12}-$N_{15}P_{40}K_0Zn_{10.5}S_{8.5}Mo_{1.0}$+ FYM	17.76	25.56	43.32	4.86	6.84	11.69	6.91	24.44	31.35	2.45	13.48	15.93
T_{13}-$N_{15}P_{40}K_0Zn_{21}S_{17}Mo_{2.0}$+ FYM	19.19	24.10	43.29	4.94	7.55	12.50	8.63	24.81	33.44	3.05	13.44	16.49
T_{14}-$N_{15}P_{40}K_0Zn_{10.5}S_{8.5}Mo_{1.0}B_{0.5}$+ FYM	18.84	21.84	40.69	4.99	6.96	11.95	8.32	24.02	32.33	2.25	12.50	14.75
T_{15}-$N_{15}P_{40}K_0Zn_{10.5}S_{8.5}Mo_{1.0}B_{1.0}$+ FYM	19.33	24.76	44.09	5.23	7.23	12.46	8.45	25.84	34.29	2.42	20.72	23.14
SEm (±)	0.315	1.037	1.144	0.128	0.440	0.452	0.118	0.334	0.308	0.113	0.506	0.550
CD (P=0.05)	0.972	3.197	3.526	0.395	1.356	1.394	0.364	1.029	0.950	0.348	1.561	1.695

Nutrient uptake in sesame

Analysis of the data about uptake of nutrients (NPKS) by sesame is shown in Table 5. 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 we found that micronutrient impacts a great role to increase the phosphorus uptake in sesame.

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 kg ha^{-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 micronutrient 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 oil seed crop [34]. The sulphur uptake in case of seed varied between 0.84 to12.27 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 to19.69 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.

Table 5: Uptake of nutrients (NPKS) by sesame

Treatment details	Nutrient uptake(kg/ha)											
	N			P			K			S		
	Seed	Stalk	Total	Seed	Stalk	Total	Seed	Stalk	Total	Seed	Stalk	Total
T_1- Control(RDF::60:40:40)	7.25	14.24	21.49	2.70	3.22	5.93	2.40	5.68	8.08	0.84	3.63	4.47
T_2- $N_{40}P_{40}K_{40}$ + FYM	9.34	17.97	27.31	3.07	4.96	8.03	2.49	13.67	16.16	1.00	5.15	6.15
T_3- $N_{40}P_{40}K_{60}$+ FYM	8.70	20.92	29.62	4.16	6.21	10.37	2.63	14.35	16.98	1.07	5.70	6.77
T_4- $N_{40}P_{40}K_{80}$+ FYM	10.94	18.80	29.75	3.64	8.65	12.29	2.71	14.33	17.03	1.24	9.40	10.63
T_5- $N_{40}P_{40}K_{40}$ Mo_{1kg}+ FYM	11.59	19.24	30.83	3.50	6.39	9.89	2.74	11.12	13.86	1.66	10.03	11.69
T_6- $N_{40}P_{40}K_{40}$ $Bo_{0.5}$+ FYM	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+ FYM	11.48	18.42	29.90	2.86	11.23	14.10	4.36	12.84	17.20	1.63	10.56	12.18
T_8- $N_{40}P_{40}K_{40}$ $Zn_{10.5}$+ FYM	12.00	21.76	33.76	3.92	5.67	9.59	3.25	10.80	14.06	2.03	10.59	12.62
T_9- $N_{40}P_{40}K_{40}$ Zn_{21}+ FYM	14.03	22.55	36.58	3.68	6.76	10.44	2.93	10.90	13.83	1.57	10.33	11.90
T_{10}-$N_{40}P_{40}K_{40}$+*Azospirillium*+ FYM	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} + FYM	15.02	22.75	37.76	4.68	10.21	14.88	3.16	9.16	12.32	5.76	14.40	20.15
T_{12}-$N_{40}P_{40}K_{40}S_{30}$+FYM (Residual effect of Zn, Mo)	16.33	27.71	44.04	5.26	11.94	17.19	3.45	18.25	21.70	10.90	15.19	26.09
T_{13}-$N_{40}P_{40}K_{40}$ S_{45} + FYM (Residual effect of Zn, Mo)	18.18	30.20	48.37	6.71	10.65	17.36	3.49	9.41	12.90	12.27	19.69	31.96
T_{14}-$N_{40}P_{40}K_{40}S_{30}$+ FYM (Residual effect of Zn, Mo and B)	16.62	28.81	45.43	5.29	13.77	19.07	3.52	16.53	20.05	11.57	15.60	27.17
T_{15}-$N_{40}P_{40}K_{40}S_{30}$+*Azospirillium*+FYM (Residual effect of Zn, Mo and B)	17.41	29.98	47.39	7.28	14.03	21.30	3.70	17.82	21.51	11.92	16.79	28.71
SEm (±)	0.308	1.128	1.120	0.21	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	0.67	1.230	1.216	0.256	1.012	1.035	0.308	1.570	1.652

Uptake of nutrients (N, P, K and S) by rice

Analysis of the data about total uptake (NPKS) of rice is shown in Table 6. From Table 6, it was observed that total N content in grain was more than that of straw because the straw yield of rice was more than the yield of grain. It was observed that N uptake in rice grain increased by integrated application of micronutrients with macronutrients along with sulphur. Uptake of N by grain ranges between 75.70 to 149.61 kg N ha^{-1}. The highest N uptake was observed in T_{14} which was treated by sulphur along with macro and micronutrients followed by T_{11} i.e. 147.21 kg ha^{-1} and lowest value was observed in control plot. Similarly uptake of N by straw ranges between 27.05 to 122.65 kg ha^{-1}. The highest value was observed in T_{10} followed by T_{14} i.e. 119.71 kg ha^{-1} and lowest value was observed in control plot. Depending upon the N uptake by straw and grain, the total uptake of N by rice was summed up. The highest total uptake was observed in T_{14} i.e. 269.31kg ha^{-1}followed by T_{10} i.e. 255.22 kg ha^{-1}, lowest value was observed in control plot.

Phosphorus uptake by rice was lower as compared to both nitrogen and potassium. Like nitrogen, the uptake by grain is higher than straw. It was also influenced by combined application of macronutrients with micronutrients along with sulphur. Almost all the INM treatments gave significantly higher P uptake in rice over control. Phosphorus uptake by grain ranges between 7.12 to 34.03 kg ha^{-1}. The highest P uptake in grain was found in T_{15} followed by T_{14} 32.81 kg ha^{-1} and lowest value was observed in control plot. Similarly in case of straw uptake of P ranges between 5.16 to 33.14kgha^{-1}. The highest P uptake was found in T_{15} followed by T_{14} i.e. 30.04kg ha^{-1} and lowest value was observed in control plot. Based on the P uptake by straw and grain, the total uptake by rice was summed up. The highest total P uptake was observed in T_{15} i.e. 67.17 kg N ha^{-1} followed by T_{14} i.e. 62.85 kg N ha^{-1}, lowest value was observed in control plot. Findings reveal that phosphorus uptake by straw, grain and total uptake increased by application of micronutrients with inorganic nutrients. So micronutrients have a major role to increase the P uptake in rice.

Potassium uptake by rice straw and grain was found significantly higher in almost all INM treatments as compared to control. In case of potassium uptake in straw was higher than grain. The uptake of K in grain ranged between 6.06 to 14.48 kg ha^{-1}. The highest uptake of K was recorded in T_9 followed by T_8 i.e. 13.41 kg ha^{-1} due to application of higher dose of potashic fertilizer @60kg ha^{-1} in case of T_8 and T_9. Potassium uptake by straw ranged between 21.91 to 116.84 kg ha^{-1}. The highest uptake was registered in T_{14} followed by T_{15} i.e. 115.34 kg ha^{-1} due to application of micronutrients. Similarly the range of total uptake varied between 27.97 to 129.38 kg ha^{-1}. The highest total uptake was recorded in T_{14} followed by T_{15} i.e. 127.32 kg ha^{-1}

From Table 6, it was observed that sulphur uptake by rice was higher in case of straw than grain. The uptake of sulphur was higher in case of micronutrients treated plots along with sulphur and macronutrients as compared to all other treatments. The sulphur uptake in case of grain varied between 2.93 to 15.95 kg ha^{-1}. The highest uptake was found in case of T_{13} which was treated by sulphur source i.e. @20kg ha^{-1} along with micro and macronutrients followed by T_{15} i.e 13.59 kg ha^{-1} and lowest value was observed in control plot. In case of straw, the S uptake ranged between 5.39 to 23.53 kg ha^{-1}. The highest uptake was found in T_{15} followed by T_{14} i.e. 22.67 kg ha^{-1}, which was treated with micronutrients along with sulphur and macronutrients. Lowest value was observed in control. In case of total uptake S ranges varied between 8.33 to 38.13 kg ha^{-1}. In this case highest yield was also observed in T_{13} followed by T_{15} i.e. 37.12 kg ha^{-1} and lowest value was observed in control plot. It is interesting to note that T_{13} gave higher sulphur uptake as compared to all other treatments due to application of high doses of sulphur i.e. @20kg ha^{-1} along with micro and macronutrients. Next to the micronutrients treated plots biofertilizer inoculated plots gave higher yield as compared to other treatments. Application of nitrogenous fertilizer gave a positive impact in case of uptake of sulphur.

Table 6: Uptake of nutrients (NPKS) by sesame

Treatment details	Nutrient uptake(kg/ha)											
	N			P			K			S		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Seed	Stalk	Total
T_1- Control(RDF:: 80:40:60)	75.70	27.05	102.75	7.12	5.16	12.28	6.06	21.91	27.97	2.93	5.39	8.33
T_2- $N_{80}P_{20}K_0$	99.16	52.65	151.81	11.37	10.05	21.41	8.12	67.27	75.39	4.48	10.61	15.09
T_3- $N_{80}P_{40}K_0$	108.41	93.30	201.70	12.24	11.53	23.77	9.41	68.45	77.85	7.32	10.55	17.86
T_4- $N_{80}P_{20}K_{20}$	114.48	81.07	195.54	12.14	12.36	24.51	10.26	82.38	92.64	9.39	12.81	22.20
T_5- $N_{80}P_{40}K_{20}$ (Residual effect of Mo)	118.01	80.57	198.58	13.40	14.96	28.36	11.30	84.52	95.81	10.60	14.12	24.72
T_6- $N_{80}P_{20}K_{40}$ (Residual effect of B)	119.18	48.38	167.56	15.07	10.32	25.38	12.45	65.28	77.73	10.26	9.28	19.54
T_7- $N_{80}P_{40}K_{40}$ (Residual effect of Zn)	115.30	53.08	168.38	17.68	12.09	29.77	13.22	66.24	79.47	9.56	10.09	19.65
T_8- $N_{80}P_{20}K_{60}$(Residual effect of Zn)	118.00	57.90	175.90	19.05	12.01	31.06	13.41	83.29	96.69	9.98	12.43	22.41
T_9- $N_{80}P_{40}K_{60}$(Residual effect of Zn)	116.95	81.22	198.17	19.91	14.05	33.96	14.48	102.53	117.01	11.26	15.22	26.48
T_{10}- $N_{80}P_{20}K_{20}$+*Azotobacter*	132.57	122.65	255.22	21.89	19.43	41.32	10.50	103.86	114.35	11.75	17.55	29.30
T_{11}- $N_{80}P_{20}K_{20}$ +*Azotobacter* +*Azospirillum*	147.21	92.22	239.43	27.32	20.88	48.21	11.29	91.37	102.65	12.66	19.47	32.13
T_{12}- $N_{80}P_{40}K_0S_{10}$(Residual effect of Zn, Mo)	136.01	76.16	212.17	24.60	15.60	40.20	11.28	72.34	83.62	11.41	17.80	29.21
T_{13}- $N_{80}P_{40}K_0S_{20}$(Residual effect of Zn, Mo)	142.68	84.14	226.82	27.89	21.24	49.13	12.60	87.54	100.14	15.95	22.17	38.13
T_{14}- $N_{80}P_{40}K_0S_{10}$(Residual effect of Zn, Mo, B)	149.61	119.71	269.31	32.81	30.04	62.85	12.53	116.84	129.38	13.07	22.67	35.74
T_{15}- $N_{80}P_{40}K_0S_{10}$ (Residual effect of Zn, Mo, B)	146.09	99.30	245.39	34.03	33.14	67.17	11.97	115.34	127.32	13.59	23.53	37.12
SEm (±)	8.531	6.969	9.061	1.430	1.351	1.657	0.948	7.083	6.745	0.761	1.424	1.529
CD(P=0.05)	26.285	21.475	27.918	4.408	4.164	5.106	2.920	21.825	20.784	2.345	4.389	4.713

Effect of INM on quality content

Crude protein content of lentil

The data related to crude protein content and protein yield of lentil presented in table 7 indicated that the trend in protein content was similar to that of nitrogen uptake by lentil. It was observed that the range of protein content ranged between 10.62 to 17.96%. The highest value of protein content in lentil 17.96% was associated with T_{13} followed by T_{15} i.e. 17.31% and lowest value i.e. 10.62% was associated with control plot. T_{13} gave highest yield due to application of sulphur@17kgha^{-1} along with micro and macronutrients. So sulphur plays a major role to increase the protein content along with nitrogen. After micronutrient and sulphur treated plots higher protein value was observed in biofertilizers inoculated treatments. Thus biofertilizers has played a great role to increase the protein content because it adds nitrogen in soil and other growth promoting substances.

Crude protein and oil content of sesame

The data related to protein and oil content of sesame presented in table 7 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}. It is also 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 [11]. 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.

The 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. Increased oil content is due to application of nitrogen and sulphur [9, 19]. 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].

Table 7: Effect of INM on quality content

Treatments	Protein content (%)			Oil content in Sseame (%)
	Lentil	Sesame	Rice	
T_1	10.62	9.31	14.00	41.13
T_2	14.12	11.06	14.58	47.47
T_3	13.77	10.38	13.42	48.20
T_4	14.35	11.69	15.17	47.20
T_5	14.23	12.13	15.17	48.30
T_6	14.54	10.88	15.05	51.03
T_7	14.58	11.31	14.23	53.50
T_8	14.47	11.81	14.93	51.53
T_9	14.12	13.44	14.58	53.77
T_{10}	15.00	13.31	16.10	53.83
T_{11}	15.19	13.56	17.15	54.77
T_{12}	16.92	14.25	15.87	55.97
T_{13}	17.96	14.38	16.10	56.23
T_{14}	17.17	13.75	16.45	55.03
T_{15}	17.31	14.00	16.75	56.67
SEm (±)	0.352	0.261	0.338	1.009
CD(P=0.05)	1.084	0.807	1.044	3.111

Crude protein content of rice

It was observed that the range of protein content ranged between 14.00 to 17.15%. The highest value of protein content in rice 17.15% was associated with T_{11} followed by T_{15} i.e. 16.75% and lowest value i.e14.00% was associated with control plot. The highest value was due to dual application of *Azotobacter* and *Azospirillium* along with all inorganic fertilizer including NPK [38]. Next to T_{11} higher protein content was observed in micronutrient along with sulphur and macronutrient treated plot i.e.T_{15}. Significant increase in N uptake and protein content of the rice plant with increasing N rates [27, 41]. Furthermore, many authors reported that the application of combined N and S was found to increase substantially the shoot and grain N content of field crops [40, 3]. The significant positive interaction between N and S in this experiment could be due *Azotobacter* to the metabolic coupling between N and S assimilations in the synthesis of S-containing amino acids and proteins, in which the N assimilation is down-regulated if the assimilation of S slows down.

Conclusion

Integrated Nutrient Management is one of the important issues for sustainable crop production. Integrated use of inorganic and organic sources of nutrients is essential for maintaining soil health and optimizing crop productivity. Both the fertilizers and manures are the kingpins of improved technology. The result of the study revealed that integrated application of NPK with sulphur, boron, molybdenum, zinc along with FYM and biofertilizers 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. The conjunctive use of inorganic fertilizers along with FYM, biofertilizers and micronutrients gave highest availability of N, P, K, S and Zn at post harvest soil of crop as compared to other treatment combinations. This also exerted greater residual effect on the growth attributes, yield components and seed yield of succeeding crop through improvement in soil fertility. 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 improves 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.

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