International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2020; 8(1): 275-278

Received: 07-11-2019
Accepted: 09-12-2019

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Increasing the production potential and quality of soybean through integrated nutrient management practices in vertisols

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Abstract
A field experiment was conducted in 2016-17 and 2017-18 at the Research Farm of Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra) to evaluate the yield response of soybean to various integrated nutrient management treatments. The treatments consisted of integrated nutrient management *viz.*, S_1 - RDF (30:75:30 NPK kg ha^{-1}), S_2 - 50% RDN + 50% RDN through vermicompost, S_3 - 50% RDN + 50% RDN through FYM, S_4 - 50% RDN + 50% RDN through compost and S_5 - 50% RDN + 50% RDN through soybean straw + *Trichoderma viride* @ 1 kg ha^{-1} to soybean and replicated four times in randomized block design. The study revealed that, soybean seed yield, straw yield, oil yield, protein yield, GMR, NMR and B:C ratio were significantly enhanced with application of RDF (30:75:30 NPK kg ha^{-1}) through chemical fertilizers. However, the application of 50% RDN + 50% RDN through vermicompost also improved all parameters equally. So, it could be concluded that application of 50% RDN + 50% RDN through vermicompost have feasibility of replacing at least 50% nitrogen through field application of vermicompost.

Keywords: Production potential, quality, soybean, integrated nutrient management practices, vertisols

1. Introduction
Soybean (*Glycine max*) known as 'golden bean' rich in protein (40%) and moderate in cholesterol free oil (20%) holds good promise in *kharif season.* Soybean is grown extensively in Madhya Pradesh, Maharashtra, Rajasthan and in some parts of Kamataka, Uttar Pradesh, Tamil Nadu and Andhra Pradesh as a pure and/or intercrop. Soybean being a potentially crop can play a greater role in boosting oil seed production in the country. Besides residual effect on soil fertility, soybean has great potential as an exceptionally nutritive and very rich protein food. It can supply the much needed protein to human diets. This legume is making a straight way in Indian Agriculture to meet the protein and oil requirements. It is outstanding in its nutritive value with enhanced protein and oil content and is also rich in vitamins, minerals, salts and other essential amino acids. In addition to this soybean protein has five per cent lysine, which is deficit in most of the cereals. Enriching the cereal flour with soybean improves the nutritive quality.
Continuous use of chemical fertilizers is leading to the crop yield stagnation and resulted in imbalance of nutrients in the soil which has adverse effects on soil health, Use of organic manures alone or in combination with chemical fertilizers will help to improve physico-chemical properties of the soils, efficient utilization of applied fertilizers for improving seed yield and seed quality. Like other leguminous crops, requirement of nitrogen is subsequently fulfilled from symbiotic nitrogen fixation through Rhizobium. Organic manures provide substrate for the growth of microorganisms and maintain a favorable nutritional balance and soil physical properties. It is recognized that combined source of organic matter and chemical fertilizers play a key role in increasing the productivity of soil.
Productivity of soybean is also reducing because of uncontrollable climatic factors like erratic rainfall, distribution pattern and controllable edaphic factor of low organic matter status owing to imbalanced use of both macro and micro nutrient through inorganic fertilizers. Soybean utilizes high quantities of nutrient from soil and if balanced fertilization is not done, it may lead to mining of soil nutrients. Therefore, it is necessary to integrate various sources of both organic and inorganic in nature to maintain soil fertility for sustainable production of soybean.

The importance of integrated nutrient management in soybean has been realized and hence an attempt was proposed for study under the climatic conditions of Vidharbha region.

2. Materials and Methods

The field experiment was conducted at Agronomy Research Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during *kharif* seasons of 2016-17 and 2017- 2018. The soil of the experimental plot was clayey in texture, having pH value of 8.6 and organic carbon content was 0.52%. Available nitrogen, phosphorus and potassium were 216.50, 16.86 and 367.22 kg ha^{-1}, respectively. The treatments consisted of integrated nutrient management *viz*., S_1 - RDF (30:75:30) NPK kg ha^{-1}, S_2 - 50% RDN + 50% RDN through vermicompost, S_3 - 50% RDN + 50% RDN through FYM, S_4 - 50% RDN + 50% RDN through compost and S_5 - 50% RDN + 50% RDN through soybean straw + *Trichoderma viride* @ 1 kg ha^{-1} to soybean and replicated four times in randomized block design. Nitrogen was applied through urea, vermicompost, compost, FYM and soybean straw. In treatment S_1 100% nitrogen was applied through urea, while in INM treatments i.e S_2, S_3, S_4 and S_5, the 50% nitrogen was applied through Urea and remaining 50% nitrogen through different organic sources *viz.* vermicompost, compost, FYM, and soybean straw. Remaining P & K were given through inorganic sources as per RDF.

Observations were recorded on yield, quality and economics of soybean. Seed and straw yield was recorded in kilogram per net plot, and from this yield per hectare was calculated. For getting protein content of soybean, first the seed samples were analyzed for nitrogen content (per cent) by Micro-Kjeldahl method and then, the nitrogen content was multiplied with the factor 6.25 and protein yield per hectare was worked out by multiplying the percentage of seed protein content by seed yield **(**kg ha^{-1}**)** of respective treatments. Seed and straw yield ($kgha^{-1}$) of soybean was converted into money value (Rs) with the prevailing market prices and treatment wise gross monetary returns per hectare were calculated. Net monetary returns were calculated by subtracting the cost of cultivation from gross monetary returns. The B:C was calculated by taking the ratio of gross monetary returns to the cost of cultivation.

3. Results and discussion

i. Seed and straw yield (kg ha^{-1}) of soybean

Data in respect of seed yield and straw yield of soybean are presented in Table-1. During the year 2016-17 and 2017-18, significantly highest soybean seed yield (2125 and 2103 kg ha^{-1}) and straw yield (2708 and 2681 kg ha^{-1}), respectively was recorded with treatment of RDF (30:75:30 NPK kg ha^{-1}) (S_1). However, this treatment was found statistically at par with treatment of 50% RDN + 50% RDN through vermicompost (S_2). Conversely, performance of treatment 50% RDN + 50% N through Soy. Straw (S_5) was found to be significantly lowest.

Table 1: Seed yield, straw yield, oil content, oil yield, protein content and protein yield of soybean influenced by different treatments during 2016-17 and 2017-18

Treatments	2016-17		2017-18		2016-17		2017-18		2016-17		2017-18	
	Seed yield ($kgha^{-1}$)	Straw yield ($kgha^{-1}$)	Seed yield ($kgha^{-1}$)	Straw yield ($kgha^{-1}$)	Oil content (%)	Oil yield ($kgha^{-1}$)	Oil Content (%)	Oil yield ($kgha^{-1}$)	Protein Content (%)	Protein yield (kgha-1)	Protein Content (%)	Protein yield (kgha-1)
S_1- RDF (30:75:30 NPK kg ha^{-1})	2125	2708	2103	2681	19.88	422.29	19.40	408.18	37.34	792.76	37.03	777.44
S_2- 50% RDN + 50% RDN through VC	2058	2640	2042	2625	19.50	400.65	19.08	389.45	36.00	741.83	35.69	729.09
S_3- 50% RDN + 50% RDN through FYM	1712	2343	1698	2327	18.75	320.65	17.80	302.28	35.25	602.89	35.13	595.81
S_4- 50% RDN + 50% RDN through compost	1904	2470	1897	2446	19.50	371.66	18.60	353.61	35.75	680.47	35.56	674.43
S_5- 50% RDN + 50% RDN through Soy Straw + *T. viride*	1616	2220	1602	2202	18.75	303.05	16.95	272.46	33.88	548.11	33.56	537.85
SE(m)±	57	76	57	75	0.41	12.21	0.59	17.79	0.61	23.63	0.50	17.59
CD (P= 0.05)	177	234	175	231	NS	37.61	NS	54.81	1.89	72.82	1.54	54.19
GM	1883	2476	1868	2456	19.28	363.66	18.37	345.20	35.64	673.21	35.39	662.92

Performance of treatment RDF (30:75:30 NPK kg ha^{-1}) in respect of seed and straw yield of soybean was superior might be due to availability of inorganic nutrient element as per recommendations (RDF) resulted in favorable increase in plant growth and performance and the accumulation of seed and straw weight. Among the INM treatments, most significant results were delivered by the treatment of 50% RDN + 50% N through vermicompost, being statistically similar with that of treatment RDF (30:75:30 NPK kg ha^{-1}), this was might be due to slow and steady available nutrients during entire crop growth besides inorganic forms in similarity with trend exhibited in seed yield. Similar results were observed earlier by Bachhav *et al*. (2012) [2], Sunderiya (2014) [13], Aziz *et al.* (2016) [1], Verma *et al*. (2017) [14] and Jagdeesh *et al*. (2018) [6].

ii. Oil content (%) and oil yield (kg ha^{-1}) of soybean

During 2016-17 and 2017-18, the data pertaining to oil content (Table 1) did not show any significant differences among treatments. Halvankar *et al.* (1999) [5] also reported that the oil content in soybean was not altered due to fertility levels. Numerically maximum oil content in seed was observed with treatment application of RDF (S_1) (19.88 and 19.40%) while treatment 50% RDN + 50% RDN through soybean straw + *T. virride* (S_5) (18.75 and 16.95%) recorded minimum oil content during both the years of investigation.

Oil yield was significantly influenced by various treatments due to significant differences among treatments in respect of seed yield. During individual years, application of chemical fertilizer RDF (S_1) recorded maximum oil yield (422.29 and 408.18 $kgha^{-1}$) as compared to remaining treatments and it was observed statistically on par with treatment 50% RDN + 50% RDN through vermicompost (S_2) (400.65 and 389.45 kgha^{-1}), however, in second year, the same best treatment RDF (S_1) also found statistically identical with treatment 50% RDN + 50% RDN through compost (S_4) (353.61 kgha^{-1}). The lowest oil yield (303.05 and 294.13 kgha^{-1}) was noticed with treatment 50% RDN + 50% RDN through soybean straw + *T. viride* (S_5). Increases in oil content and oil yield might be attributed to balanced nutrition and supply of organic and inorganic nutrients seems to be involved in an increased conversion of primary fatty acid metabolites to end products of fatty acid which increased the oil content in seeds and resulted in higher oil yield. Similar results were reported by Kumavat *et al.* (2000) [8] and Kolpe and Bodake (2017) [7].

iii. Protein content (%) and protein yield (kg ha^{-1}) of soybean

The data on protein content and protein yield of soybean seed as affected by different treatments are presented in Table 1. The data pertaining to protein content showed significant differences among treatments. During both years, maximum value of protein content in seed was observed with treatment of application of RDF (S_1) (37.34 and 37.03%) and being statistically comparable with 50% RDN + 50% RDN through vermicompost (S_2) (36.00 and 35.69%) and 50% RDN + 50% RDN through compost (S_4) (35.75 and 35.56%). However, treatment 50% RDN + 50% N through soybean straw + *T. viride* (S_5) recorded minimum values of protein content (33.88 and 33.56%).

Protein yield was significantly influenced by various treatments due to significant differences among treatments in respect of seed yield. During both the years of investigation, the treatment where nutrients were supplied directly in the available form i.e. RDF (S_1), recorded significantly highest protein yield (792.76 and 777.44 kg ha^{-1} respectively) as compared to remaining treatments, being statistically on par with 50% RDN + 50% RDN through vermicompost (S_2) (741.83 and 729.09 kg ha^{-1}). Among the organic and inorganic nitrogen substitution treatments, 50% RDN + 50% RDN through vermicompost (S_2) recorded maximum protein yield, while in first year it was found comparable with treatment 50% RDN + 50% RDN through compost (S_5) (680.47 kg ha^{-1}) but during second year this treatment i.e. (S_2) found superior over rest of the nitrogen substitution treatments.

As nitrogen is a basic constituent of protein and with the increase in rate of nitrogen application from organic manures and inorganic fertilizers, the nitrogen availability increased which resulted in enhanced protein content in seeds and protein yield. Similar results were reported by Kumavat *et al.* (2000) [8] and Kolpe and Bodake (2017) [7].

iii. Economic studies of soybean

a. Gross monetary returns (Rs. ha^{-1})

Data presented in Table. 2. indicate the pronounced treatment differences due to various nutrient management practices. During the years 2016-17 and 2017-18, significantly highest GMR (67048 and 70560 Rs. ha^{-1} resp.) were recorded with treatment S_1 (RDF alone) and found statistically similar with treatment 50% RDN + 50% RDN through vermicompost (S_2) (64963 and 68552 Rs. ha^{-1}). However, it was followed by other nitrogen substitution treatments in the decreasing order of treatments S_4>S_3>S_5, with respective GMR values of 60148, 54334 and 51312 ₹ ha^{-1}, respectively in first year and 63699, 57292 and 54066 ₹ ha^{-1}, respectively in second year of investigation. The resultant increased in GMR with different treatments was due to increased production of soybean with it. Similar results were reported by Narayana (2003) [10] and Kolpe and Bodake (2017) [7].

b. Net monetary returns (Rs ha^{-1})

Net monetary returns were found significantly affected by various nutrient management treatments, as observed while perusing the data presented in Table. 2. During the years 2016-17 and 2017-18, the treatment S_1 (RDF alone) recorded significantly highest NMR of 39291 and 42247 Rs. ha^{-1} over remaining treatments.

Table 2: Cost of cultivation (COC), Gross monetary returns (GMR), Net monetary returns (NMR), and Benefit: Cost (B:C) ratio of soybean as influenced by various treatments

Treatments	2016-17				2017-18			
	GMR (Rs ha^{-1})	COC (Rs ha^{-1})	NMR (Rs ha^{-1})	B:C	GMR (Rs ha^{-1})	COC (Rs ha^{-1})	NMR (Rs ha^{-1})	B:C
S_1- RDF (30:75:30 NPK kg ha^{-1})	67048	27757	39291	2.42	70560	28313	42247	2.49
S_2- 50% RDN + 50% RDN through VC	64963	32355	32608	2.01	68552	32903	35649	2.08
S_3- 50% RDN + 50% RDN through FYM	54334	34298	20036	1.58	57292	34839	22453	1.64
S_4- 50% RDN + 50% RDN through compost	60148	32413	27735	1.86	63699	32947	30752	1.93
S_5- 50% RDN + 50% RDN through Soy Straw + *T. viride*	51312	31864	10448	1.61	54066	32406	21660	1.67
SE(m)±	1811	--	1811	--	1906	--	1906	--
CD (P= 0.05)	5579	--	5579	--	5874	--	5874	--
GM	59561	31737	27823	1.89	62834	32282	30552	1.96

Among the nitrogen substitution treatments, treatment 50% RDN + 50% RDN through vermicompost (S_2) recorded maximum NMR (32608 and 35649 Rs. ha^{-1}). It was observed statistically identical with treatment 50% RDN + 50% RDN through compost (S_4) (27735 and 30752 Rs. ha^{-1}), while it was followed by treatments 50% RDN + 50% RDN through FYM (S_3) (20036 and 22453 Rs. ha^{-1}) and 50% RDN + 50% RDN through soybean straw with *T. virride* (S_5) (10448 and 21660 Rs. ha^{-1}) respectively.

Remarkable improvement in NMR due to treatment S_1 (RDF alone) could be attributed to greater productivity coupled with less cost incurred towards cultivating the soybean crop, at this treatment. The performance of treatment 50% RDN + 50% RDN through vermicompost (S_2), where vermicompost was added to replace the 50% N, found quite noteworthy, because of its better mineralization of N and other nutrients, produced statistically comparable yield with that of the superior treatment of S1, where the nutrients were supplied solely through chemicals. Similar views were expressed by Halvankar *et al.* (1994) [5], Singh *et al.* (1994) [12], Dube *et al.* (1995) [4], Malik (1996) [9], Sunderiya (2014) [13], Chaudhary *et al.* (2014) [3], Shivran and Jat (2015) [11] and Kolpe and Bodake (2017) [7].

c. Benefit to cost ratio

Benefit to cost ratio gives an appropriate indication of net benefit per rupee investment. Thus, the economic feasibility as influenced by any alterations in crop management practices is adequately indicated by the benefit to cost ratio. Therefore, benefit to cost ratio of both the years of study was computed by statistical analysis of the economic data from each treatment and presented in Table.2. It is evident from the data that, as compared to the cost incurred towards cultivation of soybean crop, almost one and half times or greater benefit was noticed in present investigation due to various nutrient management treatments.

Various nutrient management treatments differed markedly in benefit obtained from each treatment. During both the years of study, highest benefit to cost ratio of 2.42 and 2.49 was noted with treatment, where RDF (S_1) was applied through chemical fertilizers. The next best treatment in this respect was treatment S_2, where 50% RDN was replaced through application of vermicompost, by providing the benefit to cost ratio of 2.01 and 2.08 in the year 2016 and 2017 respectively. However, treatment S_4, where 50% RDN was given through compost also responded well and resulted in providing B:C ratio of 1.86 and 1.93. The other nutrient management treatments *viz*. S_3 and S_5 did not perform to a level of significance. Similar views were expressed by Singh *et al*. (1994) [12], Malik (1996) [9], Chaudhary *et al.* (2014) [3] and Kolpe and Bodake (2017) [7].

Thus, in nutshell, the results discussed above indicate the feasibility of replacing at least 50% nitrogen through field application of vermicompost.

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