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Soybean growth and yield response to integrated nutrient management under soybean-maize crop sequence in *Typic haplustert* soils of Maharashtra

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Abstract
A field experiment was conducted for two consecutive years in 2016-17 and 2017-18 at the Research Farm of Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra) to evaluate the effects of inorganic nutrients on the crop growth and yield under diversified soybean-maize cropping system. The treatments applied to monsoon season soybean were, 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. These treatments were replicated four times in randomized block design. The study revealed that, soybean growth characters, yield attributes, grain yield, straw yield and harvest index were significantly improved 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, thus giving way to conclude that application of 50% RDN through inorganics + 50% RDN through vermicompost can to be the most feasible integrated nutrient management system which possess the potential to replace the source of nitrogen through organics.

Keywords: Soybean growth, yield response, soybean-maize, *Typic haplustert*

1. Introduction
Since last decade, soybean continued to gain much popularity among the farmers of Vidarbha region of Maharashtra state (India). In view of the rapid spread of crop, studies on integrated nutrient management factor would throw much light to substantial increase in the productivity of crop. Soybean has been accredited as principle food crop since long time that produces 2-3 times more high-quality protein yield per hectare than other pulses and cholesterol free oil. It is preferred especially by vegetarians on account of its richness in protein, fat, carbohydrates, mineral salts and vitamins. The protein of meat, fish, eggs and pulses are acid producing while that of soybean are alkalizing in their effects which makes it a desirable constituent of human diet. Apart from this, soybean also builds up the soil fertility by fixing atmospheric nitrogen through nodules. Symbiotically soybean fixes 125-150 kg N ha^{-1} and leaves behind at about 30-40 kg N ha^{-1} for succeeding crop. All these qualities have made it an ideal alternative for crop rotation.

However, it has been observed and recorded by many scientists that the productivity of soybean is reducing because of mining of nutrients as it is high energy providing crop in terms of protein and oil. Crop nutrition through chemical fertilizer may satisfy the need of crop but also invite incidence of pest and diseases. Soil fertility in terms of soil health is deteriorated and hence to resist the soil inherent capacity, supply of required nutrients and develop immunity in crop to stand against biotic and abiotic stresses, it was felt necessity to substitution of chemical fertilizer partly through organic sources. Hence an attempt was proposed for study. 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. Organic manure produced due to the activity of earthworms is commonly referred to as vermicompost which is a rich source of macro and micro nutrients, vitamins and growth hormones (Tomati *et al.*, 1983; Bano *et al.*, 1987 and Bhawalker, 1991) [21, 3, 4]. Hence an attempt has been made to evaluate the best source of nutrients to soybean under soybean-maize crop sequence, keeping in view the soil health enhancement at central focus, apart from breaking the yield barriers.

2. Materials and Methods

The field experiment was carried out in the plot No. 66 at Agronomy Research Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during *kharif* (monsoon) seasons of 2016-17 and 2017- 2018. The soil of the experimental plot was clayey in texture dominated by smectite clay minerals which belongs to hyperthermic family of Typic Haplustert having swell shrink property. It was slightly alkaline in reaction (pH 8.6), low in organic carbon (0.52%), available nitrogen (216.50 kg ha^{-1}), available phosphorus (16.86 kg ha^{-1}) and high in available potassium (367.22 kg ha^{-1}). 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 which were replicated four times in randomized block design. 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 dose of P and K was given through inorganic sources as per RDF.

Plant growth parameters and yield attributes *viz*., plant height (cm), number of functional leaves $plant^{-1}$, total dry matter accumulation (g $plant^{-1}$), number of pods $plant^{-1}$, weight of seed $plant^{-1}$ (g), 100 seed weight (g), grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index (Donald and Hamblin, 1976) [7] were studied.

3. Results and Discussion

i. Growth attributes of soybean

Data in respect of soybean plant height (cm), number of functional leaves $plant^{-1}$, total dry matter accumulation $plant^{-1}$ (g), as influenced by various nutrient management treatments are presented in Table-1. It reveals that statistically maximum plant height, number of functional leaves $plant^{-1}$, total dry matter accumulation (g $plant^{-1}$) were attained with fertilizer treatment of RDF (30:75:30 NPK kg ha^{-1}) being at par with INM treatment of 50% RDN + 50% N through Vermicompost. Conversely, the lowest values in respect of these growth attributes were recorded with INM treatment of 50% RDN + 50% N through Soy. Straw. + *T. viride* @ 1 kg ha^{-1}. Similar phenomenon was recorded consecutively for two years i.e. 2016-17 and 2017-18.

The significant increase in plant height, number of functional leaves $plant^{-1}$ and dry matter accumulation $plant^{-1}$, with RDF alone i.e. (30:75:30 NPK kg ha^{-1}) might be due to the availability of required nitrogen in easily available form through chemical fertilizer within the span of its requirement. Similar type of results was also recorded earlier by Narayana (2009) [16], Imkongtoshi and Gohain (2009) [10] and Dadgale *et al*. (2011) [6]. While, in case of various integrated nitrogen management treatments *viz.*, 50 % RDN + 50 % RDN through vermicompost and 50% RDN + 50% RDN through compost, plants gets sufficient mineral nutrients through chemical fertilizers at initial stages of growth and later through organic sources, which the plants vigorously absorbed. Similar results were reported by Mathur (2000) [15], Yadav (2001) [23], Saxena *et al.* (2001) [18], Thanuathan *et al.* (2002) [20], Choudhary *et al.* (2011) [5] and Jagdeesh *et al.* (2018) [11]. However, during both the years, proportionate i.e 50% substitution of RDN with organic form, except through vermicompost, could not improved the growth attributes. This could be ascribed to the proportionately lesser amounts of active inorganic forms of nitrogen and the presence of bulky of inert organic manures and nutrient unavailable forms which might have caused hindrance in growth and accumulation of dry matter. This was also reported by Mathur (2000) [15], Ghosh *et al.* (2005) [9], Choudhary *et al.* (2011) [5], Ghosh *et al.* (2013) [8] and Jagdeesh *et al.* (2018) [11].

ii. Yield contributing characters of soybean

Yield contributing characters of soybean viz., number of pods $plant^{-1}$, weight of seeds $plant^{-1}$ (g) and 100 seed weight (g) was recorded and analyzed after harvest of soybean crop and are presented in Table-1. It is obvious from the data that treatment RDF (30:75:30 NPK kg ha^{-1}) dominated significantly and attributed towards maximum values for all these yield contributing characters of soybean plant. However, this treatment was statistically found similar with that of 50% RDN + 50% N through VC. Similar results were obtained during the subsequent years of 2017-18.

As compared to RDF, when RDN was substituted up to 50% with organic sources in INM treatments, except with vermicompost (S2), such replacement of N through organic material could not significantly impact on number of pods $plant^{-1}$, weight of seeds $plant^{-1}$ (g) and 100 seed weight (g), because of presence of bulky organic manures which might have slowly released the nutrients and could not become available as per the crop growth rate and hence could not meet the crop demand. Similar results were observed earlier by Manral and Saxena (2000) [14], Ola (2013) [17], Konthoujam *et al*., (2013) [13], Sunderiya (2014) [19], Joshi *et al*. (2016) [12], Verma *et al*. (2017) [22] and Jagdeesh *et al.* (2018) [11].

iii. Seed yield, straw yield and harvest index of soybean

Data in respect of seed yield, straw yield and harvest indez (HI) of soybean are presented in Table-2. During the year 2016-17, significantly highest soybean seed and straw yield (2125 and 2708 kg ha^{-1}, respectively) was recorded with treatment of RDF (30:75:30 NPK kg ha^{-1}). However, INM treatment of 50% RDN + 50% N through vermicompost also didn't differ significantly with that of earlier treatment, and in turn found statistically similar with that of treatment 50% RDN + 50% N through FYM. Conversely, the performance of treatment 50% RDN + 50% N through Soybean straw was found to be significantly lowest.

Performance of treatment RDF (30:75:30 NPK kg ha^{-1}) continued to be statistically significant during the year of 2017-18 and in pooled analysis with respective values of soybean seed and straw yield of 2103 & 2681 and 2114 & 2695 kg ha^{-1}, respectively. This might be due to availability of inorganic nutrient element as per recommendations (RDF) which 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}), may be due to slow and steady availability of nutrients during entire crop growth besides inorganic forms in similarity with trend exhibited in seed yield. Whereas maximum harvest index was recorded with RDF followed by treatment of 50% N through Urea + 50% N through vermicompost.

Similar results were observed earlier by Bachhav *et al*. (2012) [2], Sunderiya (2014) [19], Aziz *et al.* (2016) [1], Verma *et al*. (2017) [22] and Jagdeesh *et al*. (2018) [11].

Table 1: Growth attributes and yield contributing characters of soybean as influenced by different treatments during 2016-17 and 2017-18

Treatments	2016-17						2017-18					
	Plant height (cm)	**No. of functional leaves**	**Total dry matter (g)**	**No. of pods plant^{-1}**	**weight of seeds plant^{-1}**	**100 seed weight (g)**	**Plant height (cm)**	**No. of functional leaves**	**Total dry matter (g)**	**No. of pods plant^{-1}**	**weight of seeds plant^{-1}**	**100 seed weight (g)**
S_1- RDF (30:75:30 NPK kg ha^{-1})	64.61	10.87	33.10	74.03	13.11	13.14	60.52	10.18	32.05	65.53	12.51	13.08
S_2- 50% RDN + 50 % N VC	62.03	9.88	30.56	71.47	12.02	13.05	57.95	9.33	29.70	63.59	11.94	13.01
S_3- 50% RDN + 50 % N FYM	50.23	7.36	25.60	51.43	9.57	12.27	46.53	6.67	25.12	47.40	9.80	12.24
S_4- 50% RDN + 50 % N COMP	57.58	8.75	27.54	69.29	11.58	12.43	51.60	8.09	26.59	59.43	11.18	12.41
S_5- 50% RDN + 50 % N Soy Straw + *T. viride*	44.83	6.97	25.22	47.51	9.22	11.98	43.79	6.44	24.87	44.95	9.51	12.01
SE(m)$\pm$	2.07	0.33	1.01	2.31	0.48	0.28	1.77	0.31	0.98	1.85	0.40	0.29
CD (P= 0.05)	6.39	1.03	3.10	7.12	1.48	0.87	5.45	0.96	3.02	5.70	1.22	0.90
GM	55.85	8.76	28.40	62.74	11.10	12.57	52.07	8.14	27.67	56.18	10.99	12.55

Table 2: Seed yield (kgha^{-1}), straw yield (kgha^{-1}) and harvest index (HI) (%) of soybean as influenced by different treatments during 2016-17, 2017-18 and pooled.

Treatments	2016-17			2017-18			Pooled		
	Seed yield (kgha^{-1})	**Straw yield (kgha^{-1})**	**HI (%)**	**Seed yield (kgha^{-1})**	**Straw yield (kgha^{-1})**	**HI (%)**	**Seed yield (kgha^{-1})**	**Straw yield (kgha^{-1})**	**HI (%)**
S_1- RDF (30:75:30 NPK kg ha^{-1})	2125	2708	43.96	2103	2681	43.94	2114	2695	43.95
S_2- 50% RDN + 50 % N VC	2058	2640	43.80	2042	2625	43.75	2050	2633	43.78
S_3- 50% RDN + 50 % N FYM	1712	2343	42.23	1698	2327	42.19	1705	2335	42.21
S_4- 50% RDN + 50 % N COMP	1904	2470	43.54	1897	2446	43.69	1900	2458	43.62
S_5- 50% RDN + 50 % N Soy Straw + *T. viride*	1616	2220	42.14	1602	2202	42.12	1609	2211	42.13
SE(m)$\pm$	57	76	-	57	75	-	57	76	-
CD (P= 0.05)	177	234	-	175	231	-	176	233	-
GM	1883	2476	43.13	1868	2456	43.14	1876	2466	43.14

4. Conclusion

On the basis of experimental results, it can be concluded that for getting higher returns and maintenance of soil health, *kharif* (Monsoon season) soybean crop should be nourished either with RDF (30:75:30 NPK kg ha^{-1}) or with 50% RDN through urea + 50% RDN through vermicompost

Moreover, the application of 50% RDN + 50% RDN through vermicompost proved to be the most feasible system of integrated nutrient management, which can significantly improve the crop performance in terms of its overall growth, yield attributes, seed yield and straw yield.

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