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Research Paper

Effect of organic and inorganic nutrient sources and their integrated nutrient management on productivity, economic efficiency, available N, P, K and microbial population in soybean (*Glycine max*)–onion (*Allium cepa)* cropping sequence

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ABSTRACT

A field trial was conducted during 2010–2015 at Parbhani, Maharashtra, to study the effect of organic, inorganic and integrated nutrient management on yield, economics and soil health in soybean [*Glycine max* (L.) Merr.]–onion (*Allium cepa* (L.) cropping sequence for central plateau zone of Maharashtra. The experiment was laid out in a randomized block design (RBD) during 5 years with 3 replications and 7 treatments. Out of 7 nutrient treatments, 5 had organic sources and one each having 100% fertilizer and integrated nutrient management (50% through organic and 50% inorganic). The higher value of soybean grain yield (2.67 t/ha), onion bulb yield (23.9 t/ha), soybean-equivalent yield (9.66 t/ha), production efficiency (110.0 kg/ha/day), economic efficiency (510.7 ₹/ha/day) and sustainable yield index (0.64) in soybean–onion cropping sequence were recorded by NPK recommended dose of N:P:K with secondary and micronutrients based on the soil test ($ZnSO_4$ 10 kg + S 25 kg/ha) followed by 50% recommended dose of N:P:K combined with 50% N through FYM as compared with other treatments. The mean maximum net monetary returns (₹186.4 × 10^3/ha) and benefit: cost ratio (3.35) over 5 years experimentation were recorded by 100% recommended dose of fertilizer with secondary and micronutrients based on the soil test ($ZnSO_4$ 10 kg + S 25 kg/ha) followed by 50% NPK recommended dose combined with 50% N through FYM. Among the organic treatments, different organic sources each equivalent to 1/3 of recommended nitrogen through FYM + vermicompost + neem-cake + biofertilizer containing N and P carriers recorded the highest value of soybean grain yield (2.23 t/ha), onion bulb yield (19.3 t/ha), soybean-equivalent yield (7.83 t/ha), production efficiency (89.7 kg/ha/day), economic efficiency (377.0₹/ha/day), sustainable yield index (0.54), net monetary returns (₹137.6 × 10^3/ha), benefit: cost ratio (2.14) over other treatment of organic. Soil properties and microbial population were markedly influenced by different treatments over the 5 years of experiment.

Key words : Chemical fertilizers, Economics, Farmyard manure, Neem-cake, Onion, Organic farming, Soil fertility, Soybean, Vermicompost

Soybean is considered as a natural fertilizer factory because being a leguminous crop, it helps in fixing atmospheric nitrogen in soil and leaves about 30–40 kg N/ha for succeeding crop (Saxena and Chandel, 1992) and improves the soil fertility and productivity. Besides, it can very well fit in different cropping systems under rainfed and irrigated farming. Owing to its multiplicity of uses as food and industrial products, it is called as wonder crop. Soybean is finding its place in policy agenda of industrial, medicinal and food sector of India because of wide spectrum of its chemical composition. Therefore, soybean is frequently referred as poor man's meat to vegetarians due to its high protein content (Singh *et al*., 2005).

Onion is one of the most important and widely consumed bulb crops having short duration and quick growing habit with having various purposes such as culinary purposes, viz. vegetable, spices and medicinal. India is the second largest producer of onion after China. Onion is especially seasonal crop rainy season (*kharif*) and winter season (*rabi*) belonging to the domestic market and is being commonly used for its pungency and flavour. It is indispensable item in every kitchen, as it adds flavour to

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various vegetable preparations; hence it is called 'queen of kitchen'.

In cropping systems intensive use of fertilizer, is practiced to enhance the productivity and profitability. The imbalanced and indiscriminate use of chemical fertilizers in intensive cropping system has resulted in deterioration of soil health and decline in factor productivity (Kumar *et al.,* 2008). Continuous cropping of these crops without adequate restorative practices may pose threats to sustainability of system as high-yielding varieties draw heavy amount of plant nutrients from soil and nutrient uptake often exceeds replenishment through fertilizers causing soil fertility deterioration.

Application of organic manures alone sustain the fertility of soil but are unable to fulfil increasing demand of growing population, whereas application of mineral fertilizers alone help to get higher yields but they cannot sustain the fertility of soil on a long-term basis. Also the fertilizer-use efficiency is low in all mineral fertilizer and organic manures when used separately or alone. So to overcome all these constraints combination of organic and inorganic fertilizer level will be the solution to solve and overcome the present problem in relation to soil health and crop yields.

In this context, integrated nutrient management (INM) may be the best approach. In this approach, all the possible source of plant nutrients are applied based on economic consideration and the balance required for the crop is supplemented with chemical fertilizers. Integrated fertilizer management using chemical fertilizer and biofertilizers along with manures will facilitate restoration, enhancement and maintenance of soil productivity at high level which in turn will ensure profitable and intensive agriculture (Kumar swamy, 2003). The combined use of organic and inorganic sources of plant nutrient not only pushes the production and profitability of field crops, but also it helps in maintaining the permanent fertility status of the soil. It is highly desirable to make massive efforts to adopt organic sources as a source of plant nutrients as well as soil productivity in the developing countries. In India, there is sufficient availability of organic manures like animal dung manure [791.6 million tonnes), crop residues (603.5 million tonnes), green manure (4.50 million ha), rural compost (148.3 million tonnes), city compost (12.2 million tonnes) and biofertilzier (0.41 million tonnes) (Bhattacharya and Chakraborthy, 2005) and these may become a good substitute of chemical fertilizers to maintain physico-chemical and biological properties of the soil. An incorporation of organic manures improves the nutrient content and uptake. Although organic manures contain plant nutrients in small quantities as compared to the fertilizer, the presence of growth-promoting principles like enzyme and hormones besides plant materials make them essential for improvement of soil fertility and productivity.

Hence, present investigation was carried to study effect of organic, inorganic nutrient sources integrated nutrient management on productivity, economics and soil health in soybean –onion cropping sequence.

MATERIALS AND METHODS

A field experiment was conducted during 2010–11 to 2014–15 at All India Coordinated Research Project on Integrated Farming Systems, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (19^o 16' N, 96^o 41' E and has sub-tropical climatic conditions), Maharashtra. Parbhani is grouped under assured rainfall zone with normal rainfall is around 954.9 mm, precipitating mostly between mid-June-mid-November. The mean maximum and minimum temperature recorded 31.2^{o}C and 22.6^{o}C respectively. The soil of experimental field was clayey in texture, low in nitrogen (143.5 kg/ha), medium in phosphorus (11.5 kg/ha), rich in potash (340.5 kg/ha), low in organic carbon content 0.52% and the soil had *p*H 7.6. The available N, P, K, Zn and micronutrient in soil were estimated by using standard methods. However, microbial population in soil was estimated by serial dilution pour plate method. The experiment was laid out in a randomized block design during *the* rainy (*kharif*) and winter (*rabi*) season with 7 treatments and 3 replications on same site and randomization. The soybean variety was cv. 'MAUS 71' and of onion 'Agri Found Light Red' (AFLR). The gross and net plot sizes were 9.00 m × 6.30 m and 7. 20 m × 4.50 m respectively. The soybean crop was sown at a spacing of 45 cm × 5 cm during *kharif* season and onion was planted at a spacing of 15 cm × 10 cm during *rabi* season. The treatments consisted of T_1, 50% recommended NPK + 50% N through FYM + inorganic sources of micronutrients as per soil test; T_2, different organic sources each equivalent to one-third of recommended nitrogen through FYM + vermicompost + neem-cake; T_3, T_2 + intercropping of trap crop (*kharif*-maize, *rabi*-garlic); T_4, T_2 + agronomic practices for weed and pest control (no chemical, i.e. pesticides and herbicides); T_5, 50% N as FYM + biofertilizer for N + rockphosphate to substitute the P requirement of crops + phosphorus-solubilizing bacterial culture; T_6, T_2 + biofertilizer containing N and P carriers; and T_7, 100% NPK + secondary and micronutrient based on the soil test ($ZnSO_4$ 10 kg + S 25 kg/ha). The recommended dose for soybean was 30 : 60 : 30 N:P:K kg/ha and for onion was 100 : 50 : 50 NPK kg/ha. Full dose of NPK was applied basal in both the seasons. The nutrient contains in farmyard manure, vermicompost and neem-cake on dry-weight basis were 0.50, 0.30, 0.48, 1.20, 1.6, 1.35 and 5.40, 1.10 and 1.52 respectively. The micronutrient was applied as inorganic treatment with $ZnSO_4$ 10 kg/ha and S 25 kg/ha in *kharif* and *rabi* season. The onion seed was firstly planted in nursery with seed treatment of carbendizum 50% wettable powder @ 1 g/kg, whereas in organic treatment the seed was treated with *Trichoderma viride* and very thin neem powder was coated to the seed with jaggary solution and after age of 45 days it was transplanted into main field. The experiments were conducted under irrigated condition and irrigation was applied to soybean and onion at 60 mm of depth/ irrigation. Due to yearly variation in price of crops, the cost of cultivation and net return were calculated by taking mean price of 6 years of respective crops. The soybean grain-equivalent yield was calculated by the following equation for respective treatments:

$$\text{Soybean-equivalent yield (t/ha)} = \frac{\text{Bulb yield of onion (t/ha)} \times \text{Market rate of onion (₹/t)}}{\text{Market rate of soybean (₹/t)}}$$

The sustainability, expressed as a sustainable yield index (SYI), was calculated as per Guggari and Kalaghatagi (2004). For computing SYI, average yield, maximum yield and standard deviation (SD) over 5 cropping cycles was taken in to account.

$$\text{Sustainable yield index} = \frac{\text{Average yield} - \text{SD}}{\text{Maximum yield}}$$

The soybean seed were inoculated with *Rhizobium* + phosphorus-solubilizing bacteria and onion seedlings inoculated with *Azotobactor* + phosphorus-solubilizing bacteria before sowing as per treatment. Production efficiency in kg/ha/day was calculated by dividing total system productivity by cropping period, and economic efficiency in ₹/ha/day was worked out by dividing the average net return over the year by 365.

RESULTS AND DISCUSSION

Soybean and onion yield

The soybean grain yield and onion bulb yield were significantly influenced due to different organic, inorganic and INM treatments up to 5 years of experimentation (Table 1). The highest soybean grain yield and onion bulb yield recorded by 100% recommended fertilizer dose (RDF) with secondary and micronutrients based on the soil test ($ZnSO_4$ 10 kg + S 25 kg/ha) was significantly superior to all the treatments followed by treatment 50% RDF combined with 50% N applied through FYM and inorganic sources of micronutrients as per soil test. The organic treatment with T_2 + biofertilizer containing N and P carriers recorded soybean grain yield (2.23 t/ha) and onion bulb yield (19.3 t/ha) which was significantly superior to the remaining organic treatments. The integrated nutrient management recorded soybean grain yield and onion bulb yield which was less by 10.49% and 8.67% as compared to inorganic treatment and more by 7.17% and 13.47% over organic treatment. *Khang et al.* (2011) reported similar results. They observed the highest seed yield of soybean with application of 100% NPK + FYM followed by that of 100% NPK + lime during *kharif* season. This might be owing to greater availability of nutrient in soil which improved soil environment and higher root development leading to better absorption of moisture and nutrient.

Soybean-equivalent yield

The highest soybean grain equivalent yield recorded owing to inorganic 100% RDF with secondary and micronutrients based on the soil test ($ZnSO_4$ 10 kg + S 25 kg/ha) was significantly superior to all the treatments, followed by treatment, 50% RDF combined with 50% N applied through FYM and inorganic sources of micronutrients as per soil test (Table 1). In organic sources, the treatment with T_2 + biofertilizer containing N and P carriers recorded soybean grain equivalent yield (7.83 t/ha), which was significantly superior to rest of the organic treatments. The organic treatment 50% N as FYM + biofertilizer for N + rockphosphate to substitute the P requirement of crops + phosphrous-solubilizing bacterial culture resulted in the lowest soybean grain-equivalent yield, being 36.29% less than inorganic and 30.29% less than INM treatment. Soybean-equivalent yield of INM treatment was 10.52% more than the organic treatment and 12.71% less than inorganic treatment. Similar findings were also observed by Jagdish *et al.* (1998).

Production and economic efficiency

The highest production and economic efficiency was recorded under inorganic treatment compared to all other treatment having organic and INM package (Table 1). The 100% RDF with secondary and micronutrients based on the soil test ($ZnSO_4$ 10 kg + S 25 kg/ha) recorded significantly the highest production (110.0 kg/ha/day) and economic efficiency (₹510.7 ha/day) compared with organic treatment and integrated INM treatment. In the organic treatment, similar trend was found treatment with T_2 + biofertilizer containing N and P carriers, recording production efficiency (89.7 kg/ha/day) and economic efficiency (₹377.0/ha/day) which was significantly superior to rest of the organic treatments. The organic treatment 50% N as FYM + biofertilizer for N + rockphosphate to substitute the P requirement of crops + phosphrous-solubilizing bacterial culture recorded the lowest production efficiency and economic efficiency as compared to all the treatment.

Table 1. Effect of organic, inorganic and integrated nutrient management on grain yield of soybean, bulb yield of onion, production efficiency, economic efficiency, and sustainable yield index (SYI) in soybean–onion cropping sequence (pooled data of 5 years)

	Treatment	Soybean grain yield (t/ha)	Onion bulb yield (t/ha)	Soybean equivalent yield (t/ha)	Production efficiency (kg/ha/day)	Economic efficiency (₹/ha/day)	Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio	Sustainability yield index
T_1	50% RDF + 50% N through FYM + inorganic sources of micronutrients as per soil test	2.39	21.9	8.75	101.2	476.8	220.2	174.0	3.69	0.62
T_2	Different organic sources each equivalent to one-third of recommended nitrogen (FYM + VC + NC)	1.87	16.5	6.66	76.5	300.0	169.2	109.5	1.80	0.43
T_3	T_2 + intercropping of trap crop (*kharif*–maize, *rabi*–garlic)	1.97	17.5	7.07	81.1	318.1	178.4	116.1	1.85	0.46
T_4	T_2 + agronomic practices for weed and pest control (organic),	2.18	17.7	7.36	82.8	330.7	185.4	120.7	1.86	0.51
T_5	50% N as FYM/other organic sources + biofertilizer for N + RP to substitute the P requirement of crops + PSB	1.73	15.0	6.10	69.7	279.5	155.0	102.0	1.94	0.40
T_6	T_2 + biofertilizer containing N and P carriers	2.23	19.3	7.83	89.7	377.0	200.1	137.6	2.14	0.54
T_7	100% NPK + secondary and micronutrient based on the soil test ($ZnSO_4$ 10 kg + S 25 Kg/ha)	2.67	23.9	9.66	110.0	510.7	241.2	186.4	3.35	0.72
	SEm±	0.1	0.4	0.2	-	-	-	-	-	0.19
	CD P=(0.05)	0.3	1.0	0.5	-	-	-	-	-	0.61

RDF, Recommended dose of fertilizer; VC, vermicompost; NC, neem-cake; FYM, farmyard manure; RP, rockphosphate

Integrated nutrient management treatment, i.e. 50% RDF combined with 50% N applied through FYM and inorganic sources of micronutrients as per soil test revealed production efficiency (101.2 kg/ha/day) and economic efficiency (476.5₹/ha/day) which were superior to all organic treatments. Our findings are in close agreement with those reported by Tumbare (2002).

Economics

The mean net monetary return was maximum in 100% RDF with secondary and micronutrients based on the soil test ($ZnSO_4$ 10 kg + S 25 kg/ha), followed that recorded with 50% RDF combined with 50% N through FYM and inorganic sources of micronutrients as per soil test (Table 2). Soybean-based cropping sequence was found with high monetary benefit, as reported by Bhatia (1995) and Tumbare (2002). In organic treatment application of 1/3 N through each FYM, vermicompost, neem-cake with biofertilizer containing N and P carriers recorded the mean net monetary returns of ₹137.6 × 10^3/ha. The organic treatment resulted in 26.19% less net monetary returns than inorganic treatment and 20.92% less than the INM. While in case of benefit: cost ratio, the highest value 3.69 was recorded under treatment 50% RDF combined with 50% N applied through FYM and inorganic sources of micronutrients as per soil test, i.e. integrated nutrient management treatment compared to rest of the treatments, followed by 100% RDF with secondary and micronutrients based on the soil test ($ZnSO_4$ 10 kg + S 25 kg/ha), i.e. (3.35). The organic treatment one-third N through each FYM, vermicompost, neem-cake showed the lowest benefit: cost ratio among all the treatments. The cost of production of soybean–onion cropping sequence was higher under organic treatment than inorganic treatment due to higher cost of organic seed, sources of nutrient, manures and higher labour charges for weed management under organic farming except the cost for pest management. These results are in close conformity with those of Aulakh *et al.* (2013).

Sustainability yield index

Soybean–onion cropping system, examined over a period of five years showed that the application of 100% RDF with secondary and mi-

Table 2. Soil fertility status after completion of 5 years cycle of soybean–onion cropping sequence

	Treatment	N (kg/ha)						P (kg/ha)						K (kg/ha)					
		2010–11	2011–12	2012–13	2013–14	2014–15	Mean	2010–11	2011–12	2012–13	2013–14	2014–15	Mean	2010–11	2011–12	2012–13	2013–14	2014–15	Mean
T_1	50% RDF + 50% N through FYM + inorganic sources of micronutrients as per soil test	177.5	182.5	178.7	181.2	186.0	181.1	12.6	13.2	13.6	13.4	16.3	13.8	358.4	362.4	365.2	364.5	362.1	362.5
T_2	Different organic sources each equivalent to one-third of recommended nitrogen (FYM + VC + NC)	162.5	168.7	170.8	174.3	158.3	166.9	12.4	12.9	13.0	13.5	11.8	12.7	335.6	342.5	345.3	352.4	345.8	344.2
T_3	T_2 + intercropping of trap crop (*kharif*–maize, *rabi*–garlic)	138.5	148.6	150.7	152.6	152.3	148.5	12.6	12.7	12.9	12.4	14.7	13.0	342.5	348.7	350.8	356	357.7	351.1
T_4	T_2 + agronomic practices for weed and pest control (organic),	152.7	155.6	158.8	156.4	165.3	157.7	12.5	13.1	13.3	12.8	14.2	13.1	347.8	356.4	360.5	365.4	346.2	355.2
T_5	50% N as FYM/other organic sources + biofertilizer for N + RP to substitute the P requirement of crops + PSB	161.8	162.8	165.9	162.4	161.0	162.7	12.9	12.7	12.8	12.1	15.1	13.1	357.5	356.4	360.3	362.5	357.6	358.8
T_6	T_2 + biofertilizer containing N and P carriers	165.4	172.8	176.6	174.5	166.0	171.0	12.8	13.4	13.5	13.8	15.0	13.7	342.7	352.4	362.6	367.6	361.8	357.4
T_7	100% NPK + secondary and micronutrient based on the soil test ($ZnSO_4$ 10 kg + S 25 Kg/ha)	175.4	170.8	180.8	181.2	195	180.64	13.5	13.9	14.0	14.5	16.9	14.5	365.8	364.7	366.2	371.6	373.9	368.4
	Initial reading	143.5						11.5						340.5					

RDF, Recommended dose of fertilizer; VC, vermicompost; NC, neem-cake; FYM, farmyard manure; RP, rockphosphate

cronutrients based on the soil test ($ZnSO_4$ 10 kg + S 25 kg/ha) recorded the value 0.72 of sustainable yield index, followed by 0.61 recorded in 50% NPK recommended dose combined with 50% N through FYM and inorganic sources of micronutrients as per soil test. In organic sources, application of one-third N through each FYM, vermicompost, neem-cake with biofertilizer containing N and P carriers recorded the sustainable value 0.54. These results confirm the findings of Chitale *et al.* (2015).

Soil health

Nutrients: Fertility status of soil (Table 2) showed that 100% RDF with sulphur and zinc recorded the higher NPK balance after the harvesting of soybean–onion sequence cropping. The fertility status of soil owing to inorganic and INM package revealed positive gain of nutrient in respect of NPK content of soil. Similarly, one-third N applied each through FYM, vermicompost and neem-cake recorded the positive balance of NPK content in soil, but it was less than inorganic and INM package. From this study it is clear that the fertility of soil was improved by application inorganic, INM package and in organic the fertility of soil was maintained. The balance sheet of nutrient status of soil after harvesting of soybean–onion cropping sequence is given in Table 3. The highest soil available N, P and K in soil were recorded by 100% RDF with secondary and micronutrients based on the soil test ($ZnSO_4$ 10 kg + S 25 kg/ha) followed by 50% NPK recommended dose combined with 50% N through FYM and inorganic sources of micronutrients as per soil test. Datt *et al.* (2003) reported that the beneficial effect of organic manures on yield might be owing to additional supply of plant nutrients as well as improvement in physical, chemical and biological properties of soil. The application of one-third N each through FYM, vermicompost, neem cake with

Table 3. Balance sheet of organic carbon (%) and available NPK (Kg/ ha) after the 5 years as influenced by addition of nutrient through organic and inorganic sources under soybean–onion crop sequence

Treatment	Organic Carbon status			N status					P Status					K status				
	Organic carbon initial (%)	Organic carbon at the end (%)	Net gain (+) orloss (-)	N added	N removed	N initial status	N status at the end	Net gain (+) or loss (-)	P added	P removed	Pinitial status	P status at the end	Net gain (+) or loss (-)	K added	K removed	K initial status	K status at the end	Net gain (+) or loss (-)
T_1 50% RDF + 50% N through FYM + inorganic sources of micronutrients as per soil test	0.52	0.72	+ 0.20	130	280	143.5	178.7	+ 35.2	110	72	11.5	13.6	+2.1	80	92	340.5	365.2	+24.7
T_2 Different organic sources each equivalent to one-third of recommended nitrogen (FYM + VC + NC)	0.52	0.62	+0.10	130	240	143.5	170.8	+27.37	110	56	11.5	13.0	+1.5	80	70	340.5	345.3	+4.8
T_3 T_2 + intercropping of trap crop (*kharif*–maize, *rabi*–garlic)	0.52	0.63	+0.11	130	241	143.5	150.7	+7.28	110	57	11.5	12.9	+1.4	80	71	340.5	350.8	+10.3
T_4 T_2 + agronomic practices for weed and pest control (organic),	0.52	0.64	+0.12	130	246	143.5	158.8	+15.3	110	61	11.5	13.3	+1.8	80	73	340.5	360.5	+20
T_5 50% N as FYM/other organic sources + biofertilizer for N + RP to substitute the P requirement of crops + PSB	0.52	0.66	+0.14	65	248	143.5	165.9	+22.44	110	58	11.5	12.8	+1.3	80	72	340.5	360.3	+19.8
T_6 T_2 + biofertilizer containing N and P carriers	0.52	0.67	+0.15	130	252	143.5	176.6	+33.15	110	61	11.5	13.5	+2	80	74	340.5	362.6	+22.1
T_7 100% NPK + secondary and micronutrient based on the soil test ($ZnSO_4$ 10 kg + S 25 Kg/ha)	0.52	0.78	+0.18	130	292	143.5	180.8	+37.3	110	68	11.5	14.0	+2.5	80	90	340.5	366.2	+25.7

RDF, Recommended dose of fertilizer; VC, vermicompost; NC, neem-cake; FYM, farmyard manure; RP, rockphosphate;

biofertilizer containing N and P carriers was found best for higher soil nutrient availability and good built of soil health. Khang *et al.* (2011) concluded that application with organic sources increased nitrogen in soil and observed that, maximum net nitrogen was registered as 13.0 kg/ha by 50% RDF when combined with 50% N through FYM followed by 100% RDF obtained 12.2 kg/ha. Similarly, Yadav *et al.* (2013) reported that application of organic manure along with biofertilizers improved the soil status with respect of soil organic carbon and available N, P and K, this might be owing to higher microbial activity in organic treatments which favour the conversion of organic bound nitrogen to inorganic form

Soil properties: All the soil properties were markedly influenced due to the different organic, inorganic and INM treatments. The highest values of *p*H and electrical conductivity were recorded under treatment 100% RDF with secondary and micronutrients based on the soil test, followed by treatment 50% RDF + 50% N through FYM +10 kg $ZnSO_4$ and 25 kg of sulphur/ha. More organic carbon was recorded in 100% RDF with secondary and micronutrients based on the soil test. followed treatment one-third N each through FYM, vermicompost, neem-cake. The bulk density did not show significant effect of the different treatments.

Microbial population: The microbial population of bacterial, fungal and actinomycetes count showed significant variations due to different treatments during crop-growth period (Table 4).Treatment 1/3 N through each FYM, vermicompost, neem-cake with biofertilizer containing N and P carriers recorded higher bacterial, fungal and actinomycetes counts, being superior to rest of the organic, chemical and INM practices. The lowest bacterial count was recorded under treatment 50% NPK recommended dose combined with 50% N through FYM and inorganic sources of micronutrients as per soil test, while lowest values of fungal and actinomycetes were recorded in treatment one-third N through each FYM, vermicompost, neem-cake. This might be due to better survival and secretions of organic acids through different parts of the plants. These results are in close agreement with those of Nath *et al.* (2011) and Singh *et al.* (2011).

It was concluded that, the application of inorganic sources of nutrient100% RDF along with sulphur and zinc (25 kg sulphur and 10 kg of $ZnSO_4$/ha) recorded the highest soybean grain-equivalent yield and net monetary return (NMR) in soybean–onion cropping sequence, followed by integrated nutrient management with 50% RDF + 50% N through FYM +10 kg zinc and 25 kg of sulphur/ha. Among the organic source of nutrient, application of one-third N through each FYM, vermicompost, neem-cake with biofertilizer containing N and P carriers recorded higher soybean grain-equivalent yield and NMR.

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Table 4. Soil properties and microbial population as influenced by organic, inorganic and INM treatments after 5 years experimentation

	Treatment	Soil properties			Microbial population		
		*p*H	EC (dS/m)	Bulk density (Mg/m^3)	Bacterial count (Cfu/g soil)	Fungal count (Cfu/g soil)	Actinomycetes (cfu/g soil)
T_1	50% RDF + 50% N through FYM + inorganic sources of micronutrients as per soil test	7.93	0.35	1.26	31.00	16.00	2.47
T_2	Different organic sources each equivalent to one-third of recommended nitrogen (FYM + VC + NC)	7.82	0.33	1.22	36.33	15.00	1.39
T_3	T_2 + intercropping of trap crop (*kharif*–maize, *rabi*–garlic)	7.83	0.30	1.21	37.33	17.00	3.42
T_4	T_2 + agronomic practices for weed and pest control (organic),	7.82	0.28	1.17	32.66	16.66	2.32
T_5	50% N as FYM/other organic sources + biofertilizer for N + RP to substitute the P requirement of crops + PSB	7.84	0.30	1.15	46.32	19.00	4.26
T_6	T_2 + biofertilizer containing N and P carriers	7.78	0.26	1.13	57.00	20.00	5.88
T_7	100% NPK + secondary and micronutrient based on the soil test ($ZnSO_4$ 10 kg + S 25 Kg/ha)	7.92	0.39	1.21	32.00	16.33	3.39
	SEm±	–	–	0.05	0.70	0.26	0.13
	CD (P=0.05)	–	–	N.S.	2.16	0.79	0.45

RDF, Recommended dose of fertilizer; VC, vermicompost; NC, neem-cake; FYM, farmyard manure; RP, rockphosphate

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