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Research Paper

Long-term organic nutrient management in high value rice (*Oryza sativa*)–potato (*Solanum tuberosum*)/onion (*Allium cepa*) cropping system in Chhattisgarh

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ABSTRACT

A field experiment was conducted at Raipur, Chhattisgarh, in Inceptisols for 10 years to compare organic, integrated and chemical fertilizer nutrient inputs packages in scented rice (*Oryza sativa* L.)–potato (*Solanum tuberossum* L.) from 2003–04 to 2008–09 and from 2009–10 to 2012–13 in scented rice (*Oryza sativa* L.)–onion (*Allium cepa* L.) sequence on same field. Of the 7 nutrient treatments, 5 used organic inputs and one each having integrated (50% through chemical fertilizer and 50% through organic nutrient and 100% through chemical fertilizers) were studied in randomized block design with 3 replications. Organic transition effect in which decline in yield during the first year and again increase in yield was noticeable in rice as well as in onion under organic nutrient inputs packages. These treatments followed a steady increase and registered 33% more rice yield after 10 years over the first year, i.e. 2003–04, 40% potato yield at the end of sixth year, i.e. 2008–09 and 9% more onion bulb yield at the end of study, i.e. 2012–13 than yield obtained during 2009–10. However, bulb yield of onion achieved from organic input treatments was still lower than inorganic and integrated treatment. Rice–potato cropping system showed the maximum total productivity (13.81 t/ha) in terms of rice-equivalent yield under 100% recommended dose of fertilizer (RDF) at the end of the sixth cropping cycle during 2008–09. However when the system was changed into rice–onion, it was found the highest (13.62 t/ha) under 50% RDF + 50% N one-third each from cowdung manure + neem cake + composted crop residues closely followed by 100% chemical fertilizer dose (13.09 t/ha). The 100% N (one-third each from cowdung manure, neem cake and composed crop residue) + green manuring in rice appreciably sustained the organic carbon (5.6 g/ha) and available N (266 kg/ha) over initial value (169) and the generated the maximum total net return (126.7×10^3/ha) owing to premium price given to the produce. Organic as well as integrated nutrient approaches did not to enhance or maintain the K content of soil even after 10 years.

***Key words* :** Organic nutrient management, Rice–onion cropping system, System productivity

Organic farming is recognized as the best known alternative to the conventional agriculture which not only produces the quality products but also maintains soil health. This is based on the environment friendly crop production and involves naturally available and prepared nutrient sources and plant-protection measures. Organic farming is not new to Indian farming community. Several forms of organic farming have been successfully practiced by 80% of the farmers in diverse climate, particularly in rainfed, tribal, mountains and hill areas of the country as well as in Chhattisgarh state. Food material produced organically has got its place in food market in developed and developing countries. Nutrient management in organic farming is not a simple affair as under conventional system.

By virtue of using less quantity of chemical fertilizers and pesticides and dependency upon naturally available sources of nutrients, organic food could provide better vistas towards high remuneration with premium price in market producing safe and assorted food, being sustainable in the long term with inherent lesser cost advantage in the state. The constraints for lesser productivity like inadequate use of fertilizers; herbicides, pesticides and other chemicals could become a boon by adopting organic agriculture in this state. Although, in a few cases, a higher input costs due to the purchase of compost and other organic manure and unawareness of farmers for the market opportunities of high-priced organically produced food might be seen (Mahapatra *et al*., 2009). But the replacement of external inputs by farm-derived resources can lead to a reduction in variable input costs and premium prices of or-

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ganically produced food can make organic farming equally or often more profitable than conventional farming. The use and application of these products has to be adapted to local conditions, markets, and consumer demands. Recycling of organic wastes as manure for sustaining soil health is important in the present context. There are several reports that show balanced inorganic fertilizers and/or integrated nutrient management have sustained the soil fertility and crop yield on long-term basis (Urkurkar *et al*., 2010) but persuasive confirmation of maintaining the comparable crop yield under organic farming is not adequate. Farmers of the state have been practicing *in-situ* green manuring and using organic manures for years and sustained varietal aroma and special taste. Farmyard manure or cowdung manure is very common source of nutrients to the farmers of Chhattisgarh, which is prepared easily and contains substantial amount of plant nutrients. Therefore information needs to be generated with respect to suitable combination of different organic sources to develop the suitable nutrient-management practices for high-value organic cropping system for better quality and high-productive food as well as sustainability.

MATERIALS AND METHODS

A field experiment was conducted during 2003–04 to 2008–09 on rice–potato and from 2009–10 to 2012–13, rice–onion cropping system with same set of treatments on same site under irrigated conditions at the Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, under All India Coordinated Research Project on Integrated Farming Systems. The soil was silty clay (Inceptisols) and neutral with medium organic carbon (5.7 g/kg), low available N (169 kg/ha), medium available P (17.4 kg/ha) and K (270 kg/ha). Bulk density of the soil before starting of experiment was 1.66 Mg/cm^3 of 0–7 cm soil depth. Seven treatments, having 5 different organic nutrient inputs packages and one each of integrated and chemical fertilizer treatment, viz. T_1, integrated–50% recommended dose of fertilizer (RDF) + 50% N [one-third each from cowdung manure (CDM) + neem cake (NC) + composted crop residues (CCR)], T_2, 100% N [one-third each from CDM + NC + CCR); T_3, T_2 + green manuring in rice + intercropping of radish in potato; T_4, T_2 + deep summer ploughing, T_5, 50% N (one-third each from CDM + NC + CCR) + *Azospirillum* + phosphorus-solubilizing bacteria culture (PSB); T_6, T_2 + *Azospirillum* + PSB and T_7, 100% RDF were tested in randomized block design replicated thrice with a plot size of 10.0 m × 4.10 m. Bunds of 50 cm height were made between replications and individual plots to check the outflow of nutrients and reduce the border effect. Under the treatment T_3, green manuring was done *in-situ* with *Sesbania aculeate* (1.6 t/ha dry-weight having 2.4 to 2.5% N) in different years. Recommended dose of fertilizer (RDF) for rice crop was 80, 22.0 and 25.2 kg N, P and K/ha and for potato and onion it was 150, 35.2 and 83.3 and 100, 25.2 and 83.3 kg N, P and K/ha respectively. Nitrogen, P and K content (%) of different organic manures on dry-weight basis were 0.5, 0.37 and 0.80 in CDM; 5.0, 1.0 and 1.25 in neem cake and 0.5, 0.5 and 0.75 in CCR respectively. The full dose of P and K and half of the fertilizer N was applied basal. The remaining quantity of N was given at tillering and panicle-initiation stage to rice and at earthing of potato, i.e. 25 and 50 days after germination. Nitrogen was given in the form of urea, CDM, NC and CCR as per treatment requirement as basal dose. In organic treatments, P requirement was supplemented through rock phosphate (23% P_2O_5 grade) after adjusting the quantity of P supplied through manures. Basmati rice 'Kasturi' was grown during rainy (*kharif*) season and potato 'Kufri Chipsona' for first 2 years (2003–04 to 2004–05) and 'Kufri Badshah' for rest of the four years (i.e. 2005–06 to 2008–09). From 2009–10, onion 'Nasik Red' was taken after rice in place of potato with same set of treatments. Transplanting of rice at spacing of 20 cm × 10 cm was done from 15 to 25 July and harvested in the last week of October every year to facilitate the planting of well-sprouted seed tuber of 30–40 g potato in rows, 60 cm apart, during the first fortnight of November and transplanting of onion in rows of 30 cm apart during the last week of November. The experiment was conducted under assured irrigation facilities and need based irrigations were applied to rice and potato/onion as per recommended practice. Due to yearly variation in price of crops, the cost of cultivation and net returns of ending year, i.e. 2008–09 for rice–potato and 2012–13 for rice–onion cropping system was only presented in the study and calculated on the basis of 25% premium price to organic produce where organic manure was added. Sustainability yield index (SYI) was calculated as per the formula suggested by Wanjari *et al*. (2004).

RESULTS AND DISCUSSION

Rice yield under rice–potato and rice–onion cropping systems

Application of 100% RDF through chemical fertilizers resulted in significantly higher yield of rice (3.06, 3.85, 3.97 and 4.13 t/ha) during the first 4 years of rice–potato cropping system, i.e. from 2003–04 to 2006–07 (Table 1). Since a yield-stabilizing factor of about 5–6 years is generally required for practicing organic farming, firstly the integrated nutrient management treatment (50% RDF + 50% N through cowdung manure) showed its superiority to all other treatments irrespective of any organic nutrient management, viz. T_2 (100% organic, one-third N each from CDM + NC + CCR), (100% organic + DSP), (50% organic + *Azospirillum* + RP + PSB) and (100% organic + *Azospirillum* + PSB) and resulted higher yields (4.28 and 4.23 t/ha) of rice under rice–potato cropping system during intermediate time span, i.e. from 2007–08 and 2008–09 (Table 1). From the year 2009–10 and onwards under T_3 where 100% organic was accompanied with *in-situ* green manure resulted in the maximum yield of rice. The higher values of rice yield in this treatment might be due to greater availability of nutrients in soil and improvement of soil environment by green manure for higher root penetration leading to better absorption of moisture and nutrients and by providing beneficial micro environment by organic manures which, ultimately resulted in higher yield. Further, availability of ammonical-N through *in-situ* green manuring during initial stage, i.e. up to 60 days after transplanting (DAT) mainly due to decomposition of green manure started from 10 days after incorporation and gradually increased up to 60 DAT. Subsequent release of mineral N from 8 to 16 weeks of incubation from concentrated/bulky manures having C:N ratio of 29 to 33:1 at later stage after a series of chemical reaction in soil ensured the continuous supply of N to the crop throughout the crop growth and resulted in good yield.

Besides supplying nutrients, organic manures have also soulubilizing effect on fixed form of other nutrients and therefore, improve the productivity of soil. Surekha (2007) and Singh *et al*. (2011) also reported similar results of gradual increase in grain yield with the use of organic sources over a period of time. Application of one-third each of CDM + NC + CCR either alone or in combination with deep summer ploughing under T_4 and with *Azospirillum* + PSB also resulted in considerable yield advantages of about 17% over suboptimal dose in 50% N (CDM) + *Azospirillum* + RP + PSB, which gave the lowest yield of 3.38 t/ha. However, 100% of RDF (4.36 t/ha) and application of 50% RDF through chemical fertilizers + 50% N through cowdung manure (4.23 t/ha) both have registered comparable yield (4.36 and 4.23 t/ha respectively during 2012–13) to that of 100% N (one-third each CDM + NC + CCR) + GM in rice throughout the study.

Potato yield

In the sixth year of experimentation, the yield obtained from organic inputs treatments was improved and per cent deviation in integrated and organic nutrient management options narrowed down to that of 100% RDF treatment. The maximum tuber yield (18.12 t/ha) was obtained where 100% RDF was applied (Table 2). An integration of inorganic and organic sources has also enhanced the yield in T_1 (i.e. 50% RDF + 50% N through CDM). Among organic treatments, 100% N (one-third each CDM + NC + CCR) + green manure in rice was higher (15.66 t/ha) than others. The lowest potato tuber yield was achieved with 50% N (CDM) + *Azospirillum* + RP + PSB (T_5). Potato is one of the heavy feeder crops, thus the yields of integrated and inorganic nutrients were higher those of than the organic treatments as organic inputs release the nutrient slowly.

Onion yield

During the fourth year of growing onion, the bulb yield obtained from organic inputs treatments was still lower than that with inorganic and integrated treatment, but the per cent variation to that of 100% RDF treatment was minimized during 2012–13 compared to 2009–10 (Table 2). Even an increase in yield was observed during 2012–13 compared to previous 2011–12 under organic nutrient

Table 1. Yield of rice under rice–potato/onion cropping system under organic and inorganic input supply over the years

Treatment	Rice yield (t/ha)									
	Rice–potato cropping system						Rice–onion cropping system			
	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13
T_1, 50% RDF + 50% N (CDM)	2.92	4.10	3.47	3.50	4.28	4.23	3.64	3.92	4.45	4.23
T_2, 100% N (one-third each CDM + NC + CCR)	2.86	3.41	3.51	3.58	3.66	3.92	3.41	3.63	4.17	3.83
T_3, T_2 + green manuring in rice	2.71	3.32	3.62	3.87	4.03	4.13	3.50	3.80	4.67	4.41
T_4, T_2 + DSP	2.78	3.13	3.71	3.92	3.37	3.69	3.46	3.66	4.14	3.70
T_5, 50% N (CDM) + *Azos*.+ RP + PSB	2.44	2.74	2.81	2.99	3.58	3.41	3.05	3.09	3.44	3.38
T_6, T_2 + *Azos*. + PSB	2.25	3.22	3.45	3.49	4.03	3.99	3.43	3.66	4.33	3.90
T_7, 100% RDF	3.06	3.85	3.97	4.13	4.10	4.16	3.59	3.97	4.55	4.36
SEm±	0.12	0.06	0.19	0.02	0.05	0.04	0.06	0.12	0.10	0.14
CD (P=0.05)	0.36	0.15	0.59	0.07	0.14	0.13	0.19	0.36	0.31	0.44

CDM, cow dung manure; NC, neem cake; CCR, composted crop residues; RDF, recommended dose of fertilizer; DSP, deep summer ploughing; RP, rock phosphate; *Azos*., *Azospirillum;* PSB, phosphorous solubilizing bacteria management, particularly in 100% N (one-third each CDM + NC + CCR) + green manure in rice (T_3) over 100% RDF. The maximum bulb yield (13.15 t/ha) was obtained with treatment T_1 where integrated nutrient, ie.50% RDF + 50% N through CDM was applied followed by 100% RDF (12.22 t/ha) treatment (Table 2). Integration of inorganic and organic sources has also increased the plant height and bulb diameter under T_1 (i.e. 50% RDF + 50% N through CDM) treatment. Among the organic treatments, 100% N (one-third each CDM + NC + CCR) + green manure in rice resulted in higher (9.76 t/ha) bulb yield with bigger bulb size (5.49 cm) than other full organic treatments (Table 2). The lowest onion bulb yield (5.28 t/ha) was realized with 50% N (CDM) + *Azospirillum* + RP + PSB.

System productivity and economics

Rice–potato cropping system: The highest rice equivalent yield was obtained with inorganic followed by 50% RDF + 50% N through CDM, while 50% organic + BF + RP + PSB showed the lowest during 2008–09 (Table 3). The highest total net returns and benefit: cost ratio was also obtained with the application of 100% RDF (T_7); followed by T_3 where green manuring was done in addition to one-third each of CDM + NC + CCR. The lowest net returns and benefit: cost ratio (1.08) was recorded with the treatment T_4. The effect of organic manures combined with inorganic fertilizers on both rice and potato was prominent as compared to that of organic manure alone (Singh and Kushwah, 2006). Organic nutrient packages failed to register higher net returns, though the premium prices was given to them due to more cost of cultivation involved on weeding, arrangement and transportation of bulky manures etc.

Rice–onion cropping system: The highest rice-equivalent yield was obtained with 50% RDF + 50% N through CDM, followed by application of 100% RDF through inorganic fertilizers. Application of 100% N (one-third each CDM + NC + CCR) + green manure in rice also showed appreciable system productivity and the highest total net returns. This shows that the application of organic sources of the nutrients, integrated management of organic and inorganic and 100% chemical fertilizer had their significant role in influencing the productivity of scented rice–onion cropping sequence (Table 3). Microbes in rhizosphere of crops provide benefits to crops through better nutrient availability by way of mineralization of organic N, atmospheric N-fixation or solubilizing fixed mineral forms of P and other nutrients (Hegde *et al.,* 2007).

Sustainability

Sustainability yield index (SYI) of the rice–potato system was the highest in 100% organic N through CDM + NC + CCR either with green manuring in rice or added with *Azospirillum* + PSB in both the crops, followed by 50% N (CDM) + *Azospirillum*+ RP + PSB (0.79) and 100% N (one-third from each of CDM + NC + CCR followed by deep summer ploughing (0.78) in rice–potato cropping system. On the other hand, in rice–onion cropping system, the sustainability was higher in the application of 100% RDF through inorganic fertilizers (0.79) followed by 100% N through organic sources (0.77) and integration of both the sources, i.e. 50% RDF + 50% N through CDM (0.76). It was further noticed that sustainability of rice–potato system is more than rice–onion in this zone as indicated by higher SYI in almost all the organic-nutrient management options. This indicates the more dependency of onion in rice–onion system on

Table 2. Potato tuber yield and bulb yield of onion in rice–potato/onion cropping system under organic and inorganic inputs supply

Treatments	Rice–potato/onion cropping system									
	Tuber yield of potato (t/ha)						Bulb yield of onion (t/ha)			
	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
T_1, 50% RDF + 50% N (FYM)	9.11	14.36	19.25	20.43	15.91	17.66	12.16	10.06	11.25	13.15
T_2, 100% N (one-third each CDM + NC + CCR)	8.39	13.17	16.33	16.26	13.36	14.84	9.02	8.39	9.27	9.46
T_3, T_2 + green manuring in rice	10.50	15.81	15.82	15.95	12.62	15.66	8.78	9.46	9.76	10.76
T_4, T_2 + DSP	8.83	13.88	16.64	18.04	14.04	14.35	9.06	8.39	9.41	9.71
T_5, 50% N (CDM) + *Azos*. + RP + PSB	6.52	12.20	14.83	13.53	11.36	13.21	4.28	4.21	5.28	5.83
T_6, T_2 + *Azos*. + PSB	9.07	14.25	15.95	17.60	14.56	14.83	9.34	8.59	9.67	9.81
T_7, 100% RDF	9.80	15.66	18.58	19.93	16.98	18.10	12.98	9.58	10.67	12.22
SEm±	0.17	0.83	0.66	0.06	0.29	0.73	0.26	0.29	0.32	0.41
CD (P=0.05)	0.54	2.56	1.85	0.17	0.84	2.21	0.79	0.88	0.97	1.23

CDM, cow dung manure; NC, neem cake; CCR, composted crop residues; RDF, recommended dose of fertilizer; DSP, deep summer ploughing; RP, rock phosphate; *Azos*., *Azospirillum*, PSB, phosphorous solubilizing bacteria balanced nutrient level as compared to the potato in rice–potato system over the years (Table 4).

Physico-chemical properties of soil

Rice–potato system: Bulk density of the soil remained unaffected and was slightly higher under 100% RDF than the organic treatments. Organic carbon (OC) in soils ranged from 5.1 to 5.5 g/kg of soil under various organic and chemical nutrient treatments (Table 5). It remained higher under organic treatment with 100% N (one-third each from CDM + NC + CCR) and in 100% RDF. After completion of the sixth crop cycle during 2008–09, application of chemical fertilizer source of nutrients, i.e. 100% RDF recorded the highest N as well as P and K status. High availability of N, P and K nutrients was also found in organic treatments, i.e. under 100% N (one-third each from CDM + NC + CCR) + GM in rice. Built-up of N status of organic nutrient packages followed an increasing trend over the years. Available P content remained high in chemical source of nutrient, i.e. 100% RDF, followed by integrated nutrient supply. Amongst the various organic sources of nutrients, an application of 100% N supplied one-third each from CDM + NC + CCR + GM in rice stood the second. However, the lowest available soil phosphorus status was recorded under the sub-optimal organic treatment having 50% N through CDM + *Azospirillum* + PSB (Fig. 3). Available K content in soil ranged from 253 to 295 kg/ ha. It remained higher under 100% RDF followed by integrated treatment and was lower in 100% organic (CDM + NC + CCR) + *Azospirillum* + PSB. Amongst the sources of organic nutrients, application of 100% N (one-third each from CDM + NC + CCR) recorded higher status of available K in soil.

Rice–onion system: Bulk density of soil under various organic source of nutrient was recorded at par with each

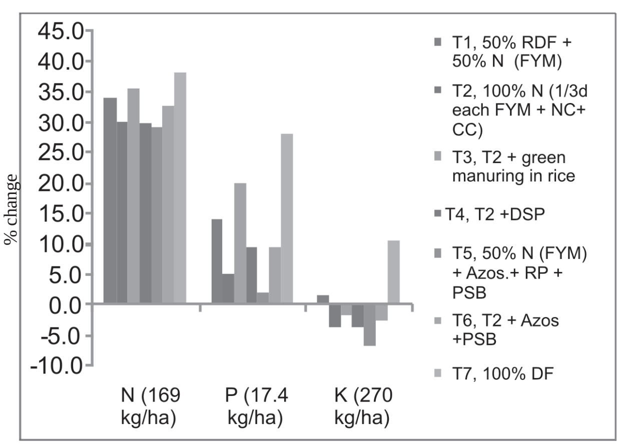

Fig. 1. Per cent change in nutrient status of the soil as affected by different nutrient- management options over initial values after 10 cropping cycles.

Table 3. Total productivity of rice–potato/onion cropping system over the years under integrated, organic and inorganic inputs supply system

Treatment	Total productivity of rice–potato cropping system (t/ha) in terms of REY						Pooled over 6 years	Total productivity of rice–onion cropping system (t/ha) in terms of REY				Pooled over 4 years
	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09		2009–10	2010–11	2011–12	2012–13	
T_1, 50% RDF + 50% N (CDM)	7.89	10.77	18.34	17.12	12.95	13.65	13.45	11.12	10.11	13.11	13.62	12.00
T_2, 100% N (1/3rd each CDM + NC + CCR)	7.44	12.35	15.76	14.42	10.94	11.84	12.12	8.96	8.79	11.30	10.59	9.91
T_3, T_2 + GM in rice	8.44	14.82	15.49	14.51	10.92	12.48	12.77	8.91	9.63	12.17	12.10	10.70
T_4, T_2 + DSP	7.59	13.01	16.14	15.94	11.24	11.34	12.54	9.04	8.82	11.38	10.64	9.97
T_5, 50% N (CDM) + *Azos.* + RP + PSB	6.00	11.43	13.93	12.01	9.56	10.45	10.57	5.68	5.68	7.50	7.55	6.60
T_6, T_2 + *Azos.* + PSB	7.10	13.36	15.41	15.22	11.98	11.89	12.49	9.18	8.95	11.76	10.91	10.20
T_7, 100% RDF	8.40	11.75	17.91	17.42	13.36	13.81	13.77	11.57	9.86	12.76	13.09	11.82
SEm±	0.28	-	0.42	0.34	0.16	0.41	0.78	0.18	0.26	0.27	0.23	0.25
CD (P=0.05)	0.85	-	1.22	1.05	0.50	1.24	2.37	0.56	0.80	0.81	0.69	0.72

Rabi, In treatment T_3, radish yield intercropping with potato is included as REY

CDM, cow dung manure; NC, neem cake; CCR, composted crop residues; RDF, recommended dose of fertilizer; DSP, deep summer ploughing; RP, rock phosphate; *Azos.*, *Azospirillum*, PSB, phosphorous solubilizing bacteria other and remained unaffected. However, it was significantly higher in 100% RDF (T_7) than the organic treatments. The organic carbon content in soil after onion harvesting ranged from 5.3 to 5.6 g/kg under various organic, integrated and inorganic treatments. It was increased significantly in the plots receiving 50% N through chemical fertilizer and 50% N from NC + CDM + CCR and in the application of 100% N (one-third each CDM + NC + CCR) + green manure in rice as compared to the treatment received sub-optimal dose of N through organic sources, i.e. in 50% N (CDM) + *Azospirillum* + rockphosphate + PSB and in 100% RDF, which failed to maintained the initial OC content (5.8 g/kg) of the soil (Table 4). Yadav *et al*. (2009) also reported higher values of OC in organic treatments and slight decrease in 100% chemical fertilizer treatment.

Available N and P contents in soil were increased after 10 years of study over the initial values irrespective of nutrient-management options. Contrarily, K content of the soil was declined from the initial values under all the nutrient-management options except under the application of inorganic source of nutrients, i.e. 100% RDF. This might be due to luxury consumption of K, firstly by potato and subsequently by the onion (Table 4; Fig. 4). It is interesting that the organic carbon and available N, P and K contents in soil of the organic and integrated nutrient management options had gradually decreased over the years up to 2008–09 and thereafter got increasing trend from 2009–10 onwards (Fig. 2, 3 and 4). This authenticates the conversion of conventional field to organic which normally takes 3–4 years. The 100% RDF treatment recorded the highest N status as well as P and K status. Higher availability of N,

Table 4. Economics and sustainability of rice–potato/onion cropping system

Treatment	Rice–potato system (2008–09)		Sustainable yield index	Rice–onion system (2012–13)		Sustainable yield index
	Net returns (× 10³ ₹/ha)	Benefit: cost ratio		Net returns (× 10³ ₹/ha)	Benefit: cost ratio	
T_1, 50% RDF + 50% N (FYM)	94.1	1.35	0.67	114.2	2.01	0.76
T_2, 100% N (one-third each CDM + NC + CCR)	97.6	1.22	0.77	101.4	1.65	0.77
T_3, T_2 + green manuring in rice	104.4	1.26	0.74	126.7	2.03	0.74
T_4, T_2 + DSP	88.3	1.08	0.77	96.7	1.50	0.77
T_5, 50% N (CDM) + *Azos*.+ RP + PSB	89.2	1.32	0.73	56.1	1.00	0.73
T_6, T_2 + *Azos*. + PSB	98.2	1.22	0.75	106.3	1.71	0.75
T_7, 100% RDF	109.3	1.94	0.79	114.2	2.19	0.79

CDM, cow dung manure; NC, neem cake; CCR, composted crop residues; RDF, recommended dose of fertilizer; DSP, deep summer ploughing; RP, rock phosphate; *Azos*., *Azospirillum*, PSB, phosphorous solubilizing bacteria

Table 5. Effect of different integrated, organic and inorganic inputs on bulk density, organic carbon (OC) and available nutrients after rice–potato and rice–onion systems at the end of *rabi* harvest

Treatment	Rice–potato systemyear 2008–09					Rice–onion systemyear 2012–13				
	Bulk density (Mg/m³)	OC (g/kg)	Available nutrient status (kg/ha)			Bulk density (Mg/m³)	OC (g/kg)	Available nutrient status (kg/ha)		
			N	P	K			N	P	K
T_1, 50% RDF + 50% N (CDM)	1.36	5.2	248	21.1	278	1.37	5.5	256	20.3	274
T_2, 100% N (one-third each CDM + NC + CCR)	1.34	5.4	230	18.7	253	1.31	5.6	242	18.4	261
T_3, T_2 + GM in rice	1.36	5.5	245	20.2	264	1.30	5.6	262	21.7	266
T_4, T2 + DSP	1.34	5.3	227	19.4	257	1.31	5.3	241	19.3	261
T_5, 50% N (CDM) + *Azos*. + RP + PSB	1.32	5.4	223	18.6	253	1.34	5.3	238	17.7	253
T_6, T_2 + PSB + *Azospirillum*	1.32	5.1	234	19.1	256	1.29	5.5	251	19.3	263
T_7, 100% RDF	1.42	5.3	275	24.5	295	1.43	5.4	273	24.2	302
Initial value	1.66	5.7	169	17.4	270	1.66	5.7	169	17.4	270
SEm±	0.04	0.15	4	6.3	5	0.02	0.01	3	1.0	4.0
CD (P=0.05)	NS	NS	11	2.0	14	0.05	0.03	8	2.9	11.0

CDM, cow dung manure; NC, neem cake; CCR, composted crop residues; RDF, recommended dose of fertilizer; DSP, deep summer ploughing; RP, rock phosphate; *Azos*., *Azospirillum*, PSB, phosphorous solubilizing bacteria

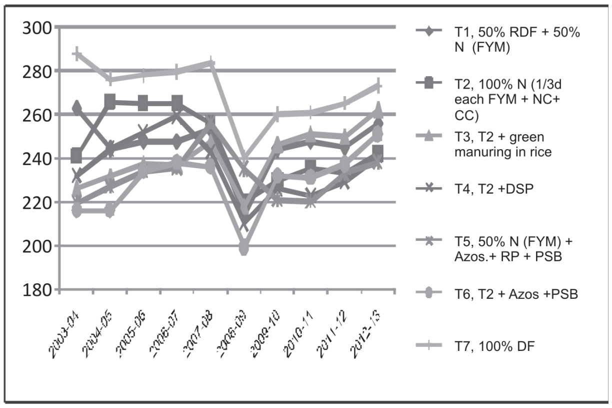

Fig. 2. Change in available nitrogen (kg/ha) in soil as affected by organic nutrient- management in rice–potato/onion system over the years.

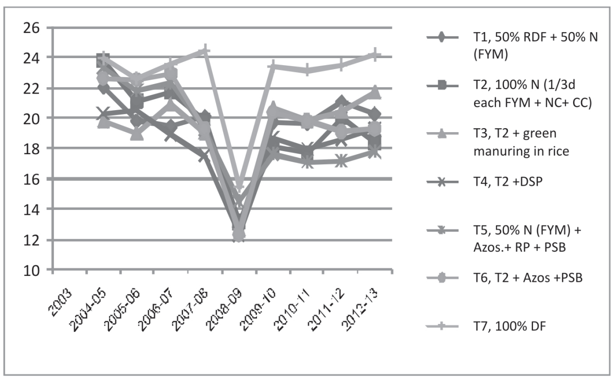

Fig. 3. Change in available P (kg/ha) in soil as affected by organic nutrient-management in rice–potato/onion system over the years.

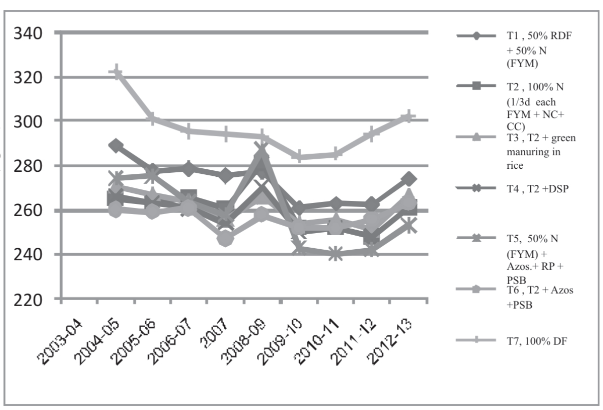

Fig. 4. Change in available K (kg/ha) in soil as affected by organic nutrient-management in rice–potato/onion system over the years.

P and K nutrients are also found in organic treatments, i.e. under T_1, 100% N (one-third each from CDM + NC + CCR) + green manure in rice and in INM in T_1 (50% RDF + 50% CDM). Available phosphorus content remained higher in inorganic source of nutrient, i.e. 100% RDF. The integrated nutrient management treatment, i.e. application of 50% RDF + 50% N supplied through CDM stood third after 100% N (one-third each from CDM + NC + CCR) + green manure in rice with regards to P content in soil. Available P remained constant with 100% N received through organic nutrient package. However, the lowest status of available soil phosphorus was recorded under sub-optimal, N i.e. 50% N through CDM + *Azospirillum* + RP + PSB + DSP. The available K content in soil ranged from 253 to 302 kg/ha and remained higher in 100% RDF followed by INM under T_1 (50% RDF + 50% CDM) and lower in 50% N only through CDM + *Azospirillum* + RP + PSB treatment. Amongst the sources of organic nutrients, application of 100% N (one-third each from CDM + NC + CCR) + green manure in rice recorded appreciably higher status of available K in soil. K content, followed a decreasing trend over the years under inorganic as well as organic treatments and was somewhat stable under integrated treatment (Fig. 4).

It can be concluded that a yield-stabilizing period of about 5–6 years is required for practicing organic farming. Yield decrease during conversion period by using organic nutrient sources has occurred but improved afterwards. Steady increase in rice productivity, build-up of organic carbon and soil N can be achieved by use of combined application of one-third each of cowdung manure + neem cake + composted crop residue for 100% N requirement either with green manuring or supplemented with *Azospirillum* + PSB. However, in potato and onion, organic treatments failed to register any noticeable increase in yield over the years as compared to integrated or full dose of chemical fertilizers and K could not be replenished only by organic sources in the soil.

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