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Changes in soil organic carbon and microbial population under organically managed rice (*Oryza sativa*)– wheat (*Triticum aestivum*)–greengram (*Vigna radiata*) cropping system

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Organic farming production system aims at promoting and enhancing agro-ecosystem health, biodiversity, biological cycles and soil biological activities. To maintain a productive organic farming system, management of soil organic matter is critical. Single source of nutrient not suffices to maintain productivity and quality in organic system, so a combination of organic amendments may be required for a successful organic cultivation (Singh *et al*. 2007). The rice–wheat production system of South Asia, occupying 10 million ha area in India, are among the most productive cropping systems in the world. However, this system has shown signs of fatigue and loss of factor productivity and evidences suggest that declining natural resources and micronutrient deficiencies may be reducing the productivity in this system. Problem of such resource degradation may be solved to some extent if organic cultivation is taken up in selected areas having this system (Prasad 2005). With such background an experiment was conducted to find out the effect of organic farming on soil organic content and microbial population under organically managed rice–wheat–greengram cropping system.

Field experiments conducted during 2003–06 at the research farm of Indian Agricultural Research Institute, New Delhi in the soil classified as sandy clay loam having 54% sand, 22.5% silt and 23.5% clay. The initial soil test values were *p*H 8.2, organic carbon 0.56%, available nitrogen 335.5 kg/ha, available P 26 kg/ha and available potassium 282.7 kg/ha. The experimental plot was kept under conversion period for three years (2000–03) before beginning of experiment as per the guidelines of International Federation for Organic Agriculture Movement (IFOAM). Different guidelines suggested by IFOAM were followed before and during the experimentation. 'Pusa Basmati 1' transplanted rice (*Oryza sativa* L.) was fallowed by irrigated 'Pusa Vishesh' wheat (*Triticum aestivum* L. emend. Fiori & Paol.) and later a crop of greengram [*Vigna radiata* (L.) wilczek] was taken in summer. Wheat was sown using zero tillage practice and biomass of greengram was incorporated in soil after picking of pods. Four bio-inoculants, viz blue green algae (BGA), *Azolla microphylla*, vermicompost and farmyard manure were applied either alone or in combination for organic crop production. BGA, vermicompost and farmyard manure were used in both rice and wheat crops but in wheat crop *Azotobacter* 0.5 kg/ha replaced *Azolla*. The treatments having bio-inoculants were compared with total control ($N_0P_0K_0$) and recommended dose of chemical fertilizer application ($N_{80}P_{40}K_{40}$). Details of the treatments are given the Tables. The same layout was used for three years. The experiment was laid out in randomized block design with three replications. *Azolla* and BGA were applied as top-dressing two days after transplanting and for their proper growth standing water (4–5 cm) was maintained in rice crop. Both *Azolla* and BGA multiplied for about 25–30 days with rice crop and later decomposed when their good mat developed. Chemical analysis of biomass of bio-inoculants (dry wt basis) indicated that *Azolla* contained 3.7% N, 0.75% P_2O_5, 4.2% K_2O; BGA contained 4.1% N, 0.88% P_2O_5, 4.7% K_2O; vermicompost had 1.65% N, 0.54% P_2O_5, 0.80% K_2O and farmyard manure contained 0.75% N, 0.17% P_2O_5 and 4.2% K_2O. Soil samples taken plot-wise at mid season (60 days after transplanting) of rice were analyzed to find out microbial population and dehydrogenase enzyme activity using the MPN technique and analyzed using keys given by DesiKachary 1959 (Kaushik 1987). Soil organic carbon content was analyzed at crop harvesting stage using Walkley and Black method (Prasad *et al.* 2006).

Grain yield of rice increased significantly over the absolute control due to application of different organic amendments applied alone or in combination and the level of increment in mean data varied between 25.6 to 44.4%, 71.7 to 107%

*Short note

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Table 1 Effect of different organic treatments on grain yield of rice and wheat (mean of three years) and organic carbon content in soil at harvesting stage of rice crop

Treatment	Grain yield (tonnes/ha)		Organic carbon content in soil (%)			
	Rice	Wheat	2003	2004	2005	2006
Azolla (A)*	2.87	2.54	0.42	0.40	0.38	0.37
BGA (B)	2.70	2.46	0.38	0.39	0.37	0.35
FYM (F)	2.69	2.24	0.42	0.41	0.39	0.36
Vermicompost (V)	2.90	2.66	0.42	0.43	0.42	0.38
A+B	3.35	3.25	0.49	0.43	0.42	0.40
A+F	3.70	3.42	0.49	0.44	0.43	0.41
A+V	4.08	3.85	0.47	0.48	0.46	0.43
B+F	3.33	3.26	0.53	0.47	0.44	0.43
B+V	3.91	3.50	0.54	0.49	0.48	0.44
F+V	3.75	3.58	0.56	0.47	0.46	0.44
A+B+F	4.05	3.66	0.51	0.59	0.56	0.57
A+F+V	4.08	3.70	0.65	0.64	0.58	0.59
B+F+V	4.10	3.82	0.67	0.69	0.64	0.64
A+B+F+V	4.19	4.35	0.72	0.75	0.78	0.82
$N_{80}P_{40}K_{30}$	4.93	4.68	0.46	0.43	0.39	0.35
N_0 P_0K_0	2.02	1.84	0.35	0.32	0.28	0.28
CD (P=0.05)	0.95	0.48	0.09	0.07	0.10	0.07

Rate of application/ha: *Azolla* 1.0 tonnes; BGA 2 kg; FYM 5.0 tonnes; Vermicompost 5.0 tonnes

Table 2 Effect of different organic inoculants on microbial population and dehydrogenase enzyme activity in soil at mid crop stage of rice

Treatment	Microbial population (CFU/gm of soil) and enzymatic activity* during 2003[a]					Microbial population (CFU/gm of soil) and enzymatic activity* during 2006				
	1*	2 *	3*	4*	5*	1*	2 *	3*	4*	5*
Azolla (A)*	307	390	36	56	122.71	332	369	31	59	131
BGA (B)	331	363	60	74	119.19	341	356	63	74	124
FYM (F)	250	301	44	63	114.08	261	322	51	61	110
Vermicompost (V)	282	393	36	27	113.96	276	365	43	48	108
A+B	300	379	25	17	134.20	287	380	32	23	121
A+F	289	390	26	33	141.78	279	364	33	42	134
A+V	192	300	23	51	118.34	195	321	32	35	113
B+F	255	393	29	47	113.85	267	386	34	55	113
B+V	235	393	32	60	127.42	243	364	37	68	127
F+V	280	387	23	55	118.65	267	368	34	57	112
A+B+F	267	383	49	71	142.34	256	376	41	78	122
A+F+V	367	440	80	93	126.74	380	402	65	98	124
B+F+V	350	401	89	91	130.58	376	378	75	86	133
A+B+F+V	311	360	34	27	127.98	301	334	61	87	125
$N_{80}P_{40}K_{30}$	197	371	44	13	107.75	164	232	49	23	101
N_0 P_0K_0	201	356	27	2	114.53	160	312	29	12	101

1*, Actinomycetes$\times 10^3$; 2*, bacteria$\times 10^3$; 3*, fungi$\times 10^3$; 4*, BGA x10^3; 5*, dehydrogenase enzyme activity

and 104.8 to 110.2% due to single, double and triple bio-inoculants application, respectively (Table 1). However, the yield increase was 134.2% when all the four organic amendments were applied altogether and this yield was *at par* with the yield recorded under recommended dose of chemical fertilizer during all the three years. Same trend was noted in wheat crop also. Positive effect of use of BGA and *Azolla* (Singh and Mandal 2000) and manuring (Hartwig and Ammon 2002) have been reported.

Soil organic carbon contents in soil were also found to be significantly enhanced due to the organic cultivation over control as well as chemical fertilizer application (Table 1).There was gradual built-up in soil organic carbon content in organic treatment having four organic amendments. On the contrary there was decline in soil organic carbon content under control treatments. The treatment having chemical fertilizer application also showed a decline in soil organic carbon but rate of decline was low as compared to control. The treatments having single bio-amendment also showed declining trend in soil organic carbon but application of 2–3 bio-inoculants showed lower decline or even slight built-up in soil organic carbon contents. Other workers also have found enhanced soil organic carbon due to manuring (Hartwig and Ammon 2002). Majumdar *et al.* (2008) reported decrease in soil organic carbon under chemical fertilization. Prasanna *et al.* (2008) reported an increase in soil organic carbon levels with increased quantity of organic residues added to the soils.

Microbial population (Actinomycetes, Bacteria, Fungi and BGA) determined at mid-season stage of rice crop, was found to be increased due to the application of organic inoculants in comparison to total control and chemical fertilizer application which accordingly resulted in notably enhancement in dehydrogenase enzyme activity (Table 2). Microbial population of actinomycetes, bacteria, fungi and BGA in a composite soil sample before starting of experimentation in June 2003 was 74, 203, 14 and 3, respectively which enhanced to 301, 334, 61 and 87, respectively, during September 2006 under the treatment of organic farming where four organic amendments were applied altogether. However, under inorganic treatment increase in microbial population was lower (164, 232, 49 and 23 respectively) as compared to organic treatment. There was gradual increase over the years in microbial population of soil due to organic farming. Changes in composition of cyanobacterial communities in rice fields due to fertilizer treatment and application of organic matter have been reported (Asari *et al.* 2008).

SUMMARY

Field experiments conducted with rice–wheat–greengram cropping system showed that combined application of four organic inoculants, viz BGA, *Azolla*, vermicompost and farmyard manure in rice and wheat gave at par grain yield with recommended dose of chemical fertilizer application. Soil microbial populations (actinomycetes, bacteria, fungi and BGA) and enzymatic activity were enhanced over the years due to the application of organic inoculants as compared to total control and recommended fertilizer application. Soil organic carbon contents were also found to be significantly enhanced due to organic cultivation over control as well as chemical fertilization.

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