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Influence of organic farming on soil microbial diversity and grain yield under rice-wheat-green gram cropping sequence

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ABSTRACT

In a long term field experiment, continuous enhancement in microbial populations of Actinomycetes, Bacteria, Fungi and BGA was recorded over the years due to the application of organic amendments with notable enhancement in dehydrogenase enzyme activity. Soil organic carbon contents were also found to be significantly increased due to organic farming over control as well as chemical fertilizer application. A significant enhancement in grain yield of rice and wheat (134%) was recorded due to the application of different organic amendments either applied alone or in combinations. The grain yield of rice (4.20 tonne ha^{-1}) and wheat (4.14 tonne ha^{-1}) obtained under combined application of four organic amendments was at par with recommended dose of chemical fertilizer.

Key words: *basmati rice, organic farming, bio-fertilizer, soil microbial activity*

Agricultural intensification in India since the 1960s has resulted in large increases in yields, although this process has led to an overall reduction in biodiversity in agricultural areas (Prasad and Nagrajan, 2004). Organic farming is a holistic farm management approach believed to encourage environmental biodiversity by excluding the input of agrochemicals and introducing specific crop management regimes for crop habitats. It aims to maintain a sustainable ecosystem, largely through replacing the use of agrochemicals by growing legumes and using crop rotations, animal manures and biological pest control exclusion of synthetic chemical inputs may contribute to increased biodiversity on organic farms. It has also a beneficial effect on biodiversity (Hole, *et al.* 2005). Due to the ill effects of chemical fertilizers and pesticides on human and environmental health, several solutions such as integrated arable farming system, low input or organic farming are being attempted on different crops in different parts of the world. 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. No one source of nutrient usually suffices to maintain productivity and quality control in organic system (Singh, 2007). Besides, the inputs used to supplement nutrient availability are often not uniformly providing the nutrient and thus presenting additional challenges in meeting the nutrient requirement of crops in organic production system.

In India, the rice-wheat production system, occupying 11 million ha area, are among the most productive cropping systems in the world. However, this system has shown signs of fatigue 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 by organic farming in some selected areas. Basmati (scented) rice is best suited for organic farming due to its lower nutritional requirement. To adopt organic farming of Basmati rice and wheat, areas need to be demarcated and reasonable price guarantee may be given (Prasad, 2005). Through organic farming, incidences of occurrences of disease and insects may be reduced; soil and grain quality improved (Stockdale, *et al.*, 2001) and fragrance (aroma) in Basmati rice may be upgraded. With such background an experiment was conducted to find out the long term effects of organic farming in rice –wheat- green gram cropping system on the soil microbial biodiversity, enzymatic activity and soil organic carbon level.

MATERIALS AND METHODS

Field experiments were conducted for seven years (2003-09) Indian Agricultural Research Institute, New Delhi, in sandy clay loam soil exhibited 54% sand, 22.5% silt and 23.5% clay. The soil of the experimental plot with pH 8.2, organic carbon 0.47%, available nitrogen 335.5 kg ha^{-1}, available P 26 g ha^{-1} and available potassium 282.7 kg ha^{-1} under rice-wheat-green gram cropping system. The experimental plot was kept under conversion period for three years (2000-2003) 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. The irrigated rice was taken in wet season (June to November) followed by wheat in dry season (November to April) and green gram in summer (April to June) season. Wheat was sown using zero tillage practice and biomass of green gram was incorporated in soil after picking of pods.

Sixteen treatments were used which included, application of Blue Green Algae (BGA) at 2.0 kg ha^{-1}, *Azolla* at 1.0 tonne ha^{-1}, Vermicompost and Farm Yard Manure(FYM) at 5.0 tonne ha^{-1} applied either alone or in combination and were compared with total control ($N_0P_0K_0$) and recommended dose of chemical fertilizer ($N_{80}P_{40}K_{40}$) in randomized block design with three replications. Details of the treatments are given in table. In wheat crop Azotobacter at 1.0 $kgha^{-1}$ replaced *Azolla*. Among the chemical fertilizers, nitrogen supplied through urea was applied in 3 equal splits (before transplanting, active tillering and pre flowering stage) and full dose of phosphorus and potassium were applied as basal. The same layout was used for three years under rice-wheat-green gram cropping system. The varieties used for scented rice, wheat and green gram were 'Pusa Basmati 1', 'HD 2687' and 'Pusa Vishal', respectively. FYM contained 1.0% N, 0.6% P_2O_5, 0.5% K_2O, Iron 140 ppm, Zinc 25 ppm, Manganese 73 ppm and Copper 3 ppm and the corresponding values for vermicompost were 1.7% N, 3.0% P_2O_5, 0.8% K_2O, Iron 175 ppm, Zinc 28 ppm, Manganese 98 ppm and Copper 6 ppm. *Azolla* and BGA biofertilizers were applied as top dressing 2 days after transplanting. Biomass of *Azolla* (on dry weight basis) contained 3.7% N, 0.75% P_2O_5, 4.2% K_2O, Iron 755 ppm, Zinc 85 ppm, Manganese 174 ppm and Copper 17 ppm while dry biomass of BGA contained 4.1% N, 0.88% P_2O_5, 4.7% K_2O, Iron 695 ppm, Zinc 74 ppm, Manganese 165 ppm and Copper 21 ppm.

Composite soil sample having a population(CFU/gm soil) of 74 x 10^3Actinomycetes, 203 x 10^3 Bacteria, 14 x 10^3 Fungi and 3 x 10^3BGA was taken before start of experiment in June 2003. Again, soil samples were taken at mid season and harvesting stage of both the crops to find out microbial population and dehydrogenase enzyme activity using the MPN technique. For the isolation of cyanobacterial strains, 1g soil was inoculated in 50ml sterilized BG-11 medium in the presence (1.5g $NaNO_3L^{-1}$) and absence of nitrogen (Stanier *et al*. 1971). The flasks were incubated at 28±2^{0}C under 3000 lux light intensity provided with cool fluorescent tubes and 16/8 hr light and dark cycle. Isolation and purification of cyanobacterial forms was carried out by repeated sub culturing followed by dilution and streak plate method. For isolation of cyanobacterial strains, enrichment cultures were grown in BG-11 medium with and without nitrogen under growth room conditions.

RESULTS AND DISCUSSION

Experimental results revelaed that the population of different microbes viz. actinomycetes, bacteria, fungi and cyanobacteria were found to be increased due to the application of organic amendments in comparison to total control and recommended fertilizer application resulted in a notable enhancement in dehydrogenase enzyme activities (Table 1). Microbial population of actinomycetes, bacteria, fungi and BGA in a composite soil sample before starting of experimentation was 74, 203, 14 and 3, respectively which enhanced to 401, 442, 71 and 98 CFU x 10^3 gm^{-1} of soil, respectively at the end under dry treatments of organic farming. Soil organic carbon (SOC) contents were also found to be significantly increased due to organic farming over control as well as chemical fertilizer application (Table 1). There was gradual built up in SOC content in organic treatment having four organic amendment. The treatments having single amendment application showed declining trend in SOC but 2 to 3 bioamendment applications showed lesser decline or even slight built

Table 1. Effect of different organic treatments on actinomycetes and bacterial population in soil at mid crop stage of rice

TrNo	Treatments	Actinomycetes population (CFU x 10^3 gm^{-1} of soil)					Bacterial population (CFU x 10^3 gm^{-1} of soil)				
		2003	2004	2005	2006	2007	2003	2004	2005	2006	2007
1	Azolla(A)*	307	310	315	332	345	390	356	378	369	400
2	BGA (B)	331	335	340	341	353	363	369	378	356	379
3	FYM (F)	250	254	257	261	279	301	312	327	322	343
4	Vermicom-post(V)	282	290	283	276	289	333	348	355	365	367
5	A+B	250	253	259	287	300	349	356	359	380	390
6	A+F	289	268	278	279	312	360	376	379	364	398
7	A+V	192	211	252	295	313	330	324	345	351	367
8	B+F	255	259	265	267	298	393	398	402	386	405
9	B+V	235	254	238	243	269	393	398	390	384	398
10	F+V	260	266	269	267	310	387	397	398	388	412
11	A+B+F	267	287	278	286	321	383	390	398	376	396
12	A+F+V	307	318	343	360	389	400	411	421	402	433
13	B+F+V	350	346	379	376	388	401	412	422	418	430
14	A+B+F+V	311	322	367	371	401	410	413	432	334	442
15	$N_{80}P_{40}K_{30}$	197	202	187	164	159	371	341	322	332	330
16	$N_0 P_0K_0$	201	165	156	160	148	356	324	314	312	302
	C.D (at 5 %)	31	46	26	36	54	38	65	58	41	37

Rate of application ha^{-1}: *Azolla* 1.0 t; BGA 2 kg; FYM 5.0 t; Vermicompost 5.0 t.

up in SOC contents. Mandal and Bandopadhyay (2008) reported a decline in soil organic carbon (SOC) control treatment while balanced fertilization with NPK maintained the SOC. Studies have shown that an increase in SOC levels is directly linked to the amount and quantity of organic residues return to the soils (Rasmussen *et al.* 1980).

Grain yield of rice and wheat increased significantly over control due to the application of different organic amendments applied either alone or

Table 2. Effect of different organic treatments on fungi and cyanobacterial population in soil at mid crop stage of rice

TrNo	Treatments	Fungi population (CFU x 10^3 gm^{-1} of soil)					Cyanobacterial population (CFU x 10^3 gm^{-1} of soil)				
		2003	2004	2005	2006	2007	2003	2004	2005	2006	2007
1	*Azolla* (A)*	36	34	36	39	42	56	53	55	59	60
2	BGA (B)	40	35	44	53	64	54	56	57	54	62
3	FYM (F)	44	45	47	51	53	63	57	60	61	60
4	Vermicompost(V)	36	38	39	43	45	47	46	43	48	50
5	A+B	35	35	34	32	37	47	48	46	49	58
6	A+F	36	34	36	33	39	43	46	48	42	50
7	A+V	33	35	37	32	41	51	46	49	48	53
8	B+F	39	38	43	44	46	47	47	49	55	56
9	B+V	32	34	35	37	42	60	61	64	68	69
10	F+V	33	34	36	34	42	55	53	56	57	59
11	A+B+F	49	45	48	47	53	71	74	77	78	82
12	A+F+V	60	65	68	65	72	73	74	79	88	89
13	B+F+V	69	65	70	75	76	81	85	83	86	88
14	A+B+F+V	44	54	56	66	71	77	83	89	87	98
15	$N_{80}P_{40}K_{30}$	44	42	46	49	46	13	23	21	23	26
16	$N_0 P_0K_0$	27	26	28	29	24	9	13	17	21	25
	C.D (at 5 %)	8	9	10	12	13	7	11	15	18	15

Table 3. Effect of different organic treatments on Dehydrogenase enzymatic activities and organic carbon content in soil at mid crop stage of rice

Tr. No	Treatments	Dehydrogenase enzymatic activities (mgm)					Organic carbon content in soil (%)				
		2003	2004	2005	2006	2007	2003	2004	2005	2006	2007
1	Azolla(A)*	123	128	129	131	135	0.42	0.40	0.38	0.37	0.33
2	BGA (B)	119	122	123	124	128	0.38	0.39	0.37	0.35	0.31
3	FYM (F)	114	115	116	117	120	0.42	0.41	0.39	0.36	0.33
4	Vermicompost(V)	114	113	117	118	121	0.42	0.43	0.42	0.38	0.35
5	A+B	134	133	131	133	136	0.49	0.43	0.42	0.40	0.38
6	A+F	142	139	136	134	141	0.49	0.44	0.43	0.41	0.37
7	A+V	128	134	140	133	138	0.47	0.48	0.46	0.43	0.41
8	B+F	114	124	128	133	139	0.53	0.47	0.44	0.43	0.39
9	B+V	127	130	134	137	140	0.54	0.49	0.48	0.44	0.40
10	F+V	129	134	134	132	136	0.56	0.47	0.46	0.44	0.42
11	A+B+F	142	143	141	142	148	0.51	0.59	0.56	0.57	0.53
12	A+F+V	137	135	145	144	147	0.65	0.64	0.58	0.59	0.56
13	B+F+V	131	134	136	139	144	0.67	0.69	0.64	0.64	0.68
14	A+B+F+V	129	136	134	145	148	0.70	0.75	0.78	0.82	0.91
15	$N_{80}P_{40}K_{30}$	108	104	103	101	98	0.46	0.43	0.39	0.35	0.31
16	$N_0P_0K_0$	115	106	104	101	97	0.35	0.32	0.28	0.27	0.24
	C.D (at 5 %)	7	9	6	8	12	0.09	0.07	0.14	0.19	0.21

in combination (Table 2). Mean data on rice grain yield of 6 seasons (2003-2008) revealed that organic amendments applied alone showed an increase of 26 to 44% over control. The yield increase was 134.1% when all the 4 organic amendments were applied altogether and it was at par with recommended dose of chemical fertilizer ($N_{80}P_{40}K_{30}$). Positive effect of use of green manuring (Mandal *et al.*, 1992), BGA and *Azolla* (Singh and Bisoyi, 1989; Singh and Mandal, 2000), incorporation of crop residues (Singh and Mandal, 2000) have also been reported. The grain yield decreased by 18% and 8% over recommended dose

Table 4. Effect of different organic treatments on rice grain yield during wet seasons (2003-08)

Tr No.	Treatments	Rice grain yield (tonne ha^{-1})						
		2003	2004	2005	2006	2007	2008	Mean
1	*Azolla*(A)*	2.87	2.54	2.43	2.36	2.29	2.06	2.43
2	BGA (B)	2.70	2.46	2.35	2.29	2.19	1.90	2.32
3	FYM (F)	2.69	2.24	2.26	2.12	2.17	2.04	2.25
4	Vermicompost(V)	2.90	2.66	2.53	2.60	2.39	2.18	2.54
5	A+B	3.35	3.25	3.03	3.16	3.02	2.68	3.08
6	A+F	3.70	3.42	3.38	3.29	3.18	2.57	3.26
7	A+V	4.08	3.85	3.67	3.57	3.43	2.64	3.54
8	B+F	3.33	3.26	3.43	3.48	3.37	2.60	3.25
9	B+V	3.91	3.50	3.47	3.52	3.48	2.82	3.45
10	F+V	3.75	3.58	3.64	3.56	3.61	3.02	3.53
11	A+B+F	4.05	3.66	3.79	3.68	3.82	3.34	3.72
12	A+F+V	4.08	3.70	3.81	3.89	3.93	3.45	3.81
13	B+F+V	4.10	3.82	3.88	3.93	3.91	3.64	3.88
14	A+B+F+V	4.19	4.35	4.38	4.16	4.48	3.68	4.20
15	N80P40K30	4.93	4.68	4.21	4.34	4.61	3.46	4.37
16	N0P0K0	2.02	1.84	1.76	1.78	1.89	1.68	1.82
	C.D (at 5 %)	0.95	0.48	0.31	0.41	0.32	0.26	0.46

Rate of application ha^{-1}: *Azolla* 1.0 t; BGA 2 kg; FYM 5.0 t; Vermicompost 5.0 t.

Table 5. Effect of different organic treatments on wheat grain yield during dry seasons (2004-09)

Treatment	Grain yield (tonne ha^{-1})					
	2004	2005	2006	2007	2008	2009
Azotobacter (A)*	2.31	2.18	2.02	2.13	1.86	1.78
BGA (B)	2.15	2.11	2.05	2.21	1.72	1.63
FYM (F)	2.45	2.24	2.31	2.41	1.90	1.96
Vermicompost(V)	2.62	2.44	2.39	2.52	2.06	2.15
A+B	2.52	2.48	2.34	2.43	2.32	2.44
A+F	2.65	2.58	2.62	2.69	2.54	2.62
A+V	2.74	2.64	2.72	2.79	2.65	2.71
B+F	2.64	2.70	2.65	2.73	2.34	2.28
B+V	2.59	2.67	2.78	2.75	2.64	2.69
F+V	2.80	2.75	2.69	2.89	2.92	3.15
A+B+F	2.68	2.74	2.82	2.97	3.32	3.46
A+F+V	3.02	2.87	3.08	3.17	3.40	3.95
B+F+V	2.84	2.90	3.01	3.26	3.74	3.86
A+B+F+V	3.26	3.04	3.35	3.57	3.82	4.14
$N_{80}P_{40}K_{30}$	4.25	4.31	4.15	4.40	4.38	4.36
$N_0 P_0K_0$(Control)	1.85	1.67	1.59	1.67	1.53	1.62
CD (P=0.05)	0.27	0.24	0.26	0.24	0.29	0.31

Rate of application ha^{-1}: *Azotobacter* 0.5 kg; BGA 2 kg; FYM 5.0 t; Vermicompost 5.0 t.

Table 6. Residual effect of different organic treatments on green gram grain yield during summer seasons (2004-09)

Treatment	Grain yield (tonne ha^{-1})					
	2004	2005	2006	2007	2008	2009
Azotobacter (A)*	0.61	0.72	0.61	0.63	0.71	0.68
BGA (B)	0.65	0.71	0.65	0.61	0.75	0.61
FYM (F)	0.65	0.74	0.65	0.64	0.75	0.65
Vermicompost(V)	0.62	0.74	0.62	0.63	0.72	0.63
A+B	0.62	0.73	0.62	0.68	0.72	0.67
A+F	0.65	0.72	0.65	0.67	0.74	0.65
A+V	0.64	0.71	0.65	0.63	0.76	0.64
B+F	0.64	0.70	0.64	0.67	0.75	0.67
B+V	0.65	0.69	0.67	0.67	0.79	0.68
F+V	0.60	0.70	0.67	0.65	0.70	0.69
A+B+F	0.68	0.74	0.68	0.64	0.69	0.70
A+F+V	0.62	0.73	0.62	0.67	0.72	0.69
B+F+V	0.64	0.70	0.64	0.67	0.74	0.70
A+B+F+V	0.68	0.79	0.75	0.74	0.77	0.78
$N_{80}P_{40}K_{30}$	0.65	0.70	0.66	0.64	0.68	0.76
$N_0 P_0K_0$	0.60	0.68	0.65	0.61	0.66	0.64
CD (P=0.05)	0.06	0.07	0.04	0.09	0.10	0.08

of chemical fertilizer during first and second year of organic farming. However, it was increased by 4.1% during the third year. These findings were in agreement with the findings on organic cultivation of rice as well as other crops in different parts of the world (Bhattacharya and Chakraborty, 2005).

Similar trend were also recorded in grain yield of wheat. It was found that there was reduction in grain yield over the years with the application of one amendment. With the application of two amendments. However, grain yield enhance the (ranging between 2.28 and 2.80 t ha^{-1}). These indicated that application of one or two amendments were not enough to sustain productivity of wheat organic system. The grain yield with three amendments showed an increasing trend in yield over the years but this level of input application was not able to give optimum yield of wheat. However, fourth year onward yield level under organic cultivation with four amendments reached at equal level of optimum yield. Singh and Singh (2005) reported increase in wheat yield due to application of FYM and vermicompost. Das *et al*. (2001) also recorded higher yield of rice and wheat with the use of organic manures. They also reported that biofertilizers have added advantage in rice and wheat production.

Grain yield of green gram also increased significantly due to the residual effect in the treatment where four organic amendments were applied together (Table 7). During six years (2003-2009) period, green gram yield was in the range of 0.68 and 0.79 t ha^{-1} with four amendments. This indicated the positive effect of inclusion of green gram crop in rice-wheat cropping sequence. Kumar *et al*. (2003) also reported similar findings.They reported positive effects on green gram yield due to biofertilizers application. Stockdale *et al*. (2001) reported important role of cover crops in enhancing productivity under organic farming.

Addition of four (blue green algae, *Azolla*, Vermicompost and farm yard manure) organic amendments can meet the nutrient requirement inorganic scented rice-wheat-green gram cropping system to provide optimum crop yield. Organic farming with organic amendments enhanced population of actinomycetes, cyancobactria, bacteria and fungi over the years. Soil organic carbon and enzymatic activity also were enhanced due to organic farming.

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