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Comparative Effect of Organic and Inorganic Nutrition on Productivity, Sustainability and Profitability of Basmati Rice-Wheat Cropping System

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Abstract

Comparison between organic nutrition with inorganic nutrition of basmati rice-wheat cropping system was studied. Organic nutrition of rice with Sesbania green manuring + 80 kg N ha^{-1} as farmyard manure + blue green algae and wheat with Leucaena green leaf manuring + 80 kg N ha^{-1} as farmyard manure + azotobactor gave highest yield of rice (4.2 t ha^{-1}) and wheat (3.7 t ha^{-1}). However, this was 10% lower in rice and 20% in wheat than that was obtained with conventional inorganic nutrition (4.6 t ha^{-1} of rice and 5.0 t ha^{-1} of wheat). Assuming 50% higher prices for organic produce as compared to inorganic produce, organic farming resulted in 27 % higher net returns of rice-wheat cropping system. Organic C, Kjeldahl N and available P contents in soil were significantly higher in organic farming as compared to inorganic farming.

Introduction

Rice-wheat cropping system (RWCS) spreading over 26 million ha area in south and east Asia (Timsinia and Connor, 2001) accounts for about one-fourth of total food grain production for the region (Abrol *et al.,* 1997). In Indo-Gangetic plains region of south Asia, scented rice (basmati) cultivation is prominent owing to its premium price in domestic as well as in international markets. The global organic food sale was estimated to be US$ 26 billion in 2003. In Asia, the total area under organic management is rapidly raising. It rose from 0.33% in 2001 to 4% in 2004, a ten-fold increase in a period of three years (Hsieh-SungChing, 2005). The ability of blue green algae (Dolly, 2007) and *Sesbania* green manuring in rice (Sharma *et al.,* 1995, Sharma and Prasad, 1999), *Azotobacter* (Garcia-Gonzalez, 2005) and *Leucaena* green leaf manuring (Tomar *et al.,* 1992) in wheat coupled with FYM (Gurpreet, 2007) in meeting the nutrient requirements of RWCS is well established. Hence, the present study was made to compare different options of organic nutrition with inorganic nutrition on basmati rice-wheat cropping system.

Materials and Methods

Characteristics of Experimental Field

The experimental soil was conducted on a sandy clay loam (Ustochrept) using lowland rice (*Oryza sativa* L.) cultivar 'Pusa Basmati 1' and wheat (*Triticum aestivum* L.) cultivar 'PBW 343'

Farmyard manure (FYM) used was well decomposed. It was applied at three rates (20, 40 and 80 kg N ha^{-1} to both rice and wheat. Nutrient composition and nutrient added through FYM are given in Table 2 and 3, respectively.

In rice blue green algae (BGA) containing four micro-organisms *Aulosira fertilissima, Nostoc muscorum, Tolypothrix tenuis* and *Anabaena variabilies* was inoculated twice, first at 20 days after transplanting (DAT) and second at 30 DAT @ 4 kg ha^{-1}. The field was kept flooded for a month after each inoculation. Inoculation of *Azotobacter* was done by dipping the wheat seeds in culture slurry. The seeds were then dried in shade for 12 hours and sown.

Experimental Design and Treatment Details

The experiment was conducted at a fixed location for three years in randomized block design with four replicationsand five treatments. Three organic nutrition practices were i) *Sesbania* green manure (SGM) + 20 kg N ha^{-1} as FYM + BGA for rice and *Leucaena* green leaf manuring (LGLM) + 20 kg N ha^{-1} as FYM + *Azotobacter* (AB) for wheat, ii) SGM + 40 kg N ha^{-1} as FYM + BGA for rice and LGLM + 40 kg N ha^{-1} as FYM + AB for wheat, iii) SGM + 80 kg N ha^{-1} as FYM + BGA for rice and LGLM + 80 kg N ha^{-1} as FYM + AB for wheat. In inorganic nutrition treatment 120 kg N ha^{-1} as urea + 26 kg P ha^{-1} as single super phosphate + 30 kg K ha^{-1} as muriate of potash was applied to rice as well as to wheat. In absolute control no organic or inorganic source of nutrient was applied in the system.

Treatment Application and Field Technique

The field was divided in to 20 plots of 15 m x 7 m. The organic nutrition plots were seeded with *Sesbania aculeata* at a uniform row spacing of 30 cm in last week of May in first year and last week of April in the last two years. The crop was irrigated twice at 20 days interval starting from 15 days after sowing. The crop was grown for 55-60 days and incorporated 5-6 days before rice transplanting.

In organic nutrition plots FYM was applied at variable rate as per treatment at final pudding. Similarly, in inorganic nutrition treatment, half dose of N (60 kg ha^{-1}) as urea, full dose of P (26 kg ha^{-1}) as single super phosphate and K (33 kg ha^{-1}) as muriate potash was applied at final puddling Two- three seedlings $hill^{-1}$ of 20-25 days age were transplanted at 20 cm x 10 cm spacing during second week of August in first year and first week of July in the last two years. In organic nutrition plots blue green algae @ 4 kg ha^{-1} was inoculated twice, first at 20 DAT and second at 30 DAT. In inorganic nutrition plots remaining 60 kg N ha^{-1} as urea was applied at 40 DAT. The crop was kept intermittent flooded in all the plots. Rice was harvested in last week of November in first year and second week of November in the last two years.

In organic nutrition plots green *Leucaena* loppings @ 5 Mg ha^{-1} (dry weight basis) and FYM at variable rate as per treatment were incorporated during final discing. In inorganic nutrition treatment half dose of N (60 kg ha^{-1}) through urea and full dose of P (26 kg ha^{-1}) as single super phosphate and K (33 kg ha^{-1}) as muriate of potash was applied before sowing and remaining 60 kg N ha^{-1} as urea was applied 35 days after sowing (DAS) and remaining 60 kg N ha^{-1} as urea was applied at 30 DAS. Wheat (PBW 343) was sown at 23 cm row spacing using a seed rate of 100 kg ha^{-1}. Wheat crop received six irrigations at critical growth stages and was harvested in mid April.

Analysis of Plant and Soil Samples

Before start of experiment a composite soil sample was drawn from 0-30 cm soil depth and analyzed for physical and chemical properties. The data are presented in Table 1. The soil samples were also collected from 0-30 cm soil depth after completion of each cropping cycle and analysed for organic C, Kjeldahl N, 0.5 M $NaHCO_3$ extractable P and 1 N NH_4OAC extractable K as procedures described by Prasad *et al.,* (2006).

Table 1. Mechanical and chemical characteristics of soil of experimental field.

Soil parameter	*Value*
Mechanical compositionSand (%)Silt (%) Clay (%)Texture class	52.821.525.7Sandy clay loam
Organic C (mg kg^{-1} soil)	2577
Kjeldahl N (mg kg^{-1} soil)	325
0.5 M $NaHCO_3$ extractable P (mg kg^{-1} soil)	10.1
1N NH_4OAC extractable K (mg kg^{-1} soil)	88
Electrical conductivity (ds m^{-1} 25^0 C)	0.82
Cation exchange capacity (C mol kg^{-1} soil)	14.6
pH (1:2.5 soil : water ratio)	8.1

Before incorporation, the samples of *Sesbania* green manure*, Leucaena* green leaves and FYM were analyzed for C, N, P and K content and the values are presented in Table 2. The nutrients added through these organic materials in different treatments are given in Table 3.

Table 2. Mean C, N, Pand K content (g kg^{-1}) in organic manures applied in the experiment

Organic manure	*C*	*N*	*C:N ratio*	*P*	*K*
Sesbania aculeata (SGM)	495	27	18.3	3.9	22
Leucaenaleucocephala (LGLM)	482	26	18.5	2.6	14
Farmyard manure (FYM)	151	5	30.2	2.2	5

Table 3. Total nutrient addition to rice and wheat under different treatments (Mean over 3 years)

Treatment	*C (t ha^{-1})*		*N (kg ha^{-1})*		*P (kg ha^{-1})*		*K (kg ha^{-1})*		*Fe (g ha^{-1})*		*Zn (g ha^{-1})*		*Cu (g ha^{-1})*	
	R	*W*	*R*	*W*	*R*	*W*	*R*	*W*	*R*	*W*	*R*	*W*	*R*	*W*
Control	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GM[1] + 20 kg N as FYM[2] + Biofertilizers[3]	5.9	5.9	128	124	28.3	21.8	108	76	857	657	285	310	955	670
GM[1] + 40 kg N as FYM[2] + Biofertilizers[3]	9.3	9.3	148	144	37.1	30.6	128	96	1029	829	485	510	1135	850
GM[1] + 80 kg N as FYM[2] + Biofertilizers[3]	16.2	16.2	188	184	54.7	48.2	168	136	1201	1001	885	910	1315	1110
120 kg N + 26 kg P + 33 kg K ha^{-1}	-		120	120	26	26	33	33	-		-		-	

OC addition by GM + FYM (total) to rice- GLM + FYM (Total) to wheat
[a]2.43 + 3.44 (5.87) - 2.47 + 3.44 (5.91); [b]2.43 + 6.88 (9.31) -2.47 + 6.88 (9.35); [c]2.43 + 13.76 (16.19) - 2.47 + 13.76 (16.23)
** S addition through MOP is (18%) and SSP (12%S) and Fe & Al (<3.5%) from SSP

Statistical Analysis of Data

Data of each character were subjected to analysis of variance using F-test. Mean separation was done by least significant difference (LSD) at 5% error probability (Gomez and Gomez, 1984).

Results and Discussion

Productivity

The grain yields of rice, wheat and system were significantly influenced by organic and inorganic nutrition of rice and wheat crops in all the three years of study (Table 4). During the first year, the grain yield of rice and total productivity of the system increased significantly with increasing the rate of FYM in organic nutrition practices. Inorganic nutrition of the crops gave the grain yield of rice and total productivity of the system similar to that was obtained with a organic nutrition combination of GM + 20 kg N ha^{-1}as FYM and biofertilizers. However, lower yield of rice with inorganic nutrition as compared to higher rates of organic nutrition practice was due to fact that rice was transplanted very late on August 12 and there was poor grain filling with inorganic nutrition and resulted in poor yield as compared to higher rate of organic nutrition practice. One month delay in rice transplanting than optimum time (first week of July) normally results in about 50% reduction in productivity (~5 t ha^{-1}) with inorganic nutrition. In wheat, the combinations of GM + 20 kg N ha^{-1} as FYM + biofertilizers and GM + 40 kg N ha^{-1} as FYM + biofertilizers failed to increase the grain yield over no nutrition control, whereas the combination of GM + 80 kg N ha^{-1} as urea + biofertilizers significantly increased grain yield of wheat over no nutrition control. However, highest grain yield of wheat was obtained with inorganic nutrition which was significantly higher than that was obtained with highest rate of organic nutrition practice. During the last two years, grain yields of rice and wheat as well as total productivity of the system increased significantly with increasing rate of organic nutrition, however the differences between GM + 20 kg N ha + biofertizers and GM + 40 kg N ha + biofertizers and between GM + 40 kg N ha + biofertizers and GM + 80 kg N ha + biofertizers were not significant in case of grain yield of wheat in the second year of study. Inorganic nutrition produced significantly higher grain yield of both rice and wheat as well as total productivity of the system than all the organic nutrition practices.

Table 4. Effect of organic and inorganic nutrition practices on productivity (t ha^{-1}) of rice-wheat cropping system

Treatments	*2003-04*			*2004-05*			*2005-06*		
	Rice	*Wheat*	*Total*	*Rice*	*Wheat*	*Total*	*Rice*	*Wheat*	*Total*
Control	1.6	2.6	4.2	3.1	2.4	5.5	2.3	2.0	4.3
GM[1] + 20 kg N as FYM[2] + Biofertilizers[3]	2.5	3.0	5.5	4.0	2.9	6.9	2.8	2.9	5.7
GM[1] + 40 kg N as FYM[2] + Biofertilizers[3]	2.8	3.1	5.9	4.5	3.3	7.8	3.1	3.5	6.6
GM[1] + 80 kg N as FYM[2] + Biofertilizers[3]	3.6	3.2	6.8	5.4	3.5	8.9	3.6	4.4	8.0
120 kg N + 26 kg P + 33 kg K ha^{-1}	2.3	4.0	6.3	6.8	5.7	12.5	4.8	5.2	10.0
LSD (P=0.05)	0.2	0.5	0.8	0.5	0.5	0.9	0.3	0.6	0.7

[1]GM: *Sesbania* green manuring in rice and *Leucaena* green leaf manuring in wheat;
[2]FYM applied to both rice and wheat; [3]Biofertilizers: BGA in rice and *Azotobacter* in wheat

A perusal of mean data over three years (Fig. 1) indicates that extent of yield loss under the no nutrition and organic nutrition practices as compared to inorganic nutrition was higher in wheat than in rice. The yield loss in no nutrition control as compared to inorganic nutrition ranges between 30 and 54% in rice and 35 and 61% in wheat. The above values of yield loss were reduced to 41-42% in rice and 25-49% in wheat with the application of GM + 20 kg N ha^{-1} as FYM + biofertilizers. The loss was further reduced to 34-35% in rice and 22-42% in wheat with the application of GM + 40 kg N ha^{-1} as FYM + biofertilizers. Application of GM + 80 kg N ha^{-1} as FYM + biofertilizers minimized the yield loss to 21-25% in rice and 20-38% in wheat.

Organic C

Organic C content in soil decreased from the initial level (2577 mg kg^{-1} soil) in no nutrition control and increased with all the organic and inorganic nutrition practices of the crops (Table 5). The crops receiving no nutrition drew the nutrients from organic pool and thus resulted in the reduced organic C content in soil. A reduction in soil organic C content in unfertilized plots of rice-wheat cropping system was also reported by Yadav *et* al. (1998). The increase in organic carbon content of soil over initial level after three cycles of rice-wheat cropping system was least (223 mg kg^{-1} soil) with inorganic nutrition and highest (1853 mg kg^{-1}soil) with an organic combination of GM + 80 kg N ha^{-1} as FYM + biofertilizers. The organic combination of GM + 40 kg N ha^{-1} as FYM + biofertilizers increased organic C level over initial level by 673 and 973 mg kg^{-1} soil, respectively. Regarding the effect of different combinations of organic and inorganic nutrition in different years the inorganic combination of 120 kg N + 26 kg P +33 kg K ha^{-1} and organic combination of GM + 20 kg N ha + biofetilizers had no significant effect on organic C content in soil after first year, whereas after the second year both the combinations were at par and significantly increased organic C content in soil over no nutrition control. After the third year organic combination of GM + 20 kg N ha^{-1} + combinations of higher rates of organic nutrition were significantly superior to inorganic nutrition after all the three years. The organic C content in soil increased in proportion with the amount organic C added through organic manures and was highest with

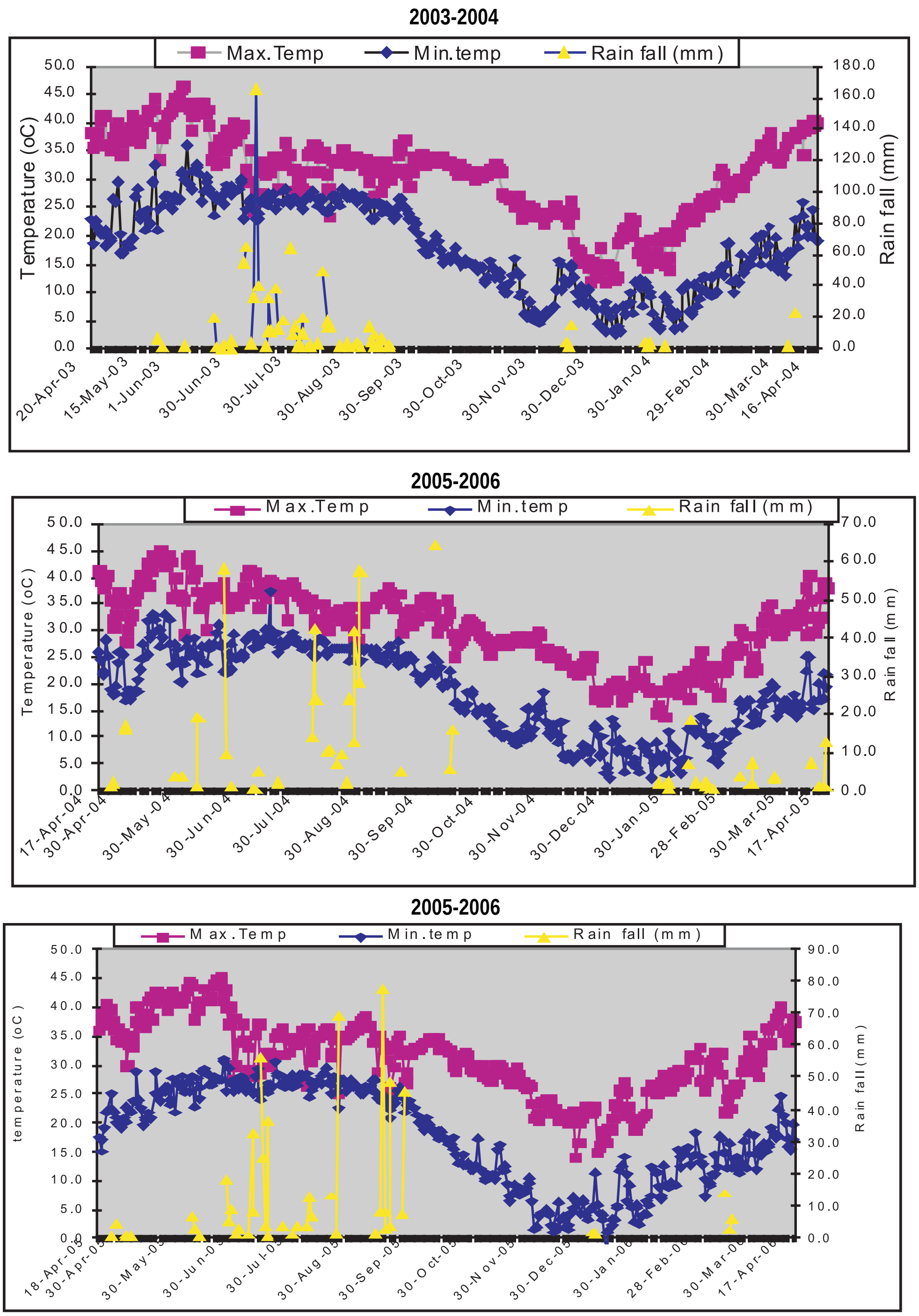

Fig.1. Weather data of experimental location

an organic combination of GM + 80 kg N ha + biofertilizers adding about 16t organic C ha^{-1} $year^{-1}$. The organic C content in soil proportionately increased with increasing rate of organic manures. This was ascribed to the addition of organic matter at rates higher than their decomposition.

Table 5. Effect of organic and inorganic nutrition practices on organic C content (mg kg^{-1} soil) of soil after completion of each cycle of rice-wheat cropping system

Treatments	*2003-04*	*2004-05*	*2005-06*
Control	2520	2430	2330
GM[1] + 20 kg N as FYM[2] + Biofertilizers[3]	2800	2910	3250
GM[1] + 40 kg N as FYM[2] + Biofertilizers[3]	2970	3200	3550
GM[1] + 80 kg N as FYM[2] + Biofertilizers[3]	3300	3900	4430
120 kg N + 26 kg P + 33 kg K ha^{-1}	2650	2725	2800
LSD (P=0.05)	430	220	600

Initial value**:** 2577 mg kg^{-1} soil

Kjeldahl N

The total Kjeldahl N content in soil increased significantly with the application of all the organic and inorganic combinations over no nutrition control after completion of all the cycles of rice-wheat cropping system (Table 6). There was no significant difference between different organic combinations in all the years. The inorganic combination was at par with lowest rate of organic combination after the first two years but significantly inferior to this combination after the third year. Urea N applied in inorganic nutrition might have lost through leaching and Denitrification as reported by Prasad and Power (1995), whereas mineralization of organic nitrogen takes place slowly and thus organic N can be retained in soil for longer period. The increase in total kjeldahl N content in soil after three cycles of rice-wheat cropping system over initial level was least (15 mg kg^{-1} soil) with inorganic nutrition and highest (45 mg kg^{-1} soil) with an organic combination of GM + 80 kg N ha^{-1} as FYM + biofertilizers. The total Kjeldahl N content in soil decreased over its initial level by 50 mg kg^{-1} soil in no nutrition control plots. Yadav *et* al. (1998) also reported a reduction in Kjeldahl content in soil in unfertilized plots of rice-wheat cropping system.

Table 6. Effect of organic and inorganic nutrition practices on total kjeldahl N (mg kg^{-1} soil) content in soil after completion of each cycle of rice-wheat cropping system

Treatments	*2003-04*	*2004-05*	*2005-06*
Control	300	290	275
GM[1] + 20 kg N as FYM[2] + Biofertilizers[3]	340	353	360
GM[1] + 40 kg N as FYM[2] + Biofertilizers[3]	345	359	364
GM[1] + 80 kg N as FYM[2] + Biofertilizers[3]	354	366	370
120 kg N + 26 kg P + 33 kg K ha^{-1}	330	336	340
LSD (P=0.05)	18	22	30

Initial value: 325 mg kg^{-1} soil

Available P

Application of GM + 20 kg N ha^{-1} as FYM + biofertilizers had no significant effect on 0.5 M

$NaHCO_3$ extractable P content in soil and registered a decline in available P over initial value (Table 7). The 0.5 M $NaHCO_3$ extractable P content in soil also registered a decline in no nutrition control plots over initial value. Similar results were also reported by Yadav *et* al (1998). The organic combination of GM + 80 kg N ha^{-1} as FYM + biofertilizers and inorganic nutrition were at par and significantly increased 0.5 M $NaHCO_3$ extractable P content in soil over no nutrition and organic nutrition of GM + 20 kg N ha^{-1} as FYM + biofertilizers after completion of all the cycles of rice-wheat cropping system The increase in 0.5 M $NaHCO_3$ extractable P in inorganic nutrition treatment was ascribed to the application of 52 kg P ha^{-1} $year^{-1}$ that was probably higher than its removal by the crops. Saleque *et al* (2006), experimenting with rice-wheat cropping system in Bangladesh, have also reported a soil P build up with soil test based NPK fertilization. The highest increase in 0.5 M $NaHCO_3$ extractable P content in soil over no nutrition control was due to the fact that P addition through manures was organic in nature that becomes slowly available and do not get fixed in unavailable form. Also organic acids produced during decomposition of organic manures might have solubilizes fixed form of P of the soil. An increase in available soil P with Application of GM + 40 kg N ha^{-1} as FYM + biofertilizers maintained 0.5 M $NaHCO_3$ extractable P content in soil at initial level but registered an increase in 0.5 M $NaHCO_3$ extractable P content in soil over no nutrition control after completion of last two cycles of rice-wheat cropping system.

Table 7. Effect of organic and inorganic nutrition practices on 0.5 M $NaHCO_3$ extractable P (mg kg^{-1} soil) content in soil after completion of each cycle of rice-wheat cropping system

Treatments	*2003-04*	*2004-05*	*2005-06*
Control	10.0	9.5	9.1
GM[1] + 20 kg N as FYM[2] + Biofertilizers[3]	10.2	10.0	9.6
GM[1] + 40 kg N as FYM[2] + Biofertilizers[3]	10.3	10.3	10.4
GM[1] + 80 kg N as FYM[2] + Biofertilizers[3]	10.5	10.7	11.1
120 kg N + 26 kg P + 33 kg K ha^{-1}	10.5	10.9	11.1
LSD (P=0.05)	0.46	0.77	0.77

Initial value: 10.1 mg kg^{-1} soil

Available K

The 1 N NH_4OAC extractable K content in soil was significantly affected by both inorganic and organic nutrition after completion of all the three cycles of rice-wheat cropping system (Table 8). After completion of first cycle of rice-wheat cropping system the organic combinations of GM + 20 kg N ha^{-1} as FYM + biofertilizers and GM + 40 kg N ha^{-1} as FYM + biofertilizers did not increase the 1 N NH_4OAC extractable K content in soil, whereas after completion of the second and third cycles both the combinations increased 1 N NH_4OAC extractable K content in soil over no nutrition control significantly. Other combination of organic nutrition (GM + 80 kg N ha^{-1} as FYM + biofertilizers) was at par with inorganic nutrition and significantly increased 1 N NH_4OAC extractable K content in soil over no nutrition control after completion of all the three cycles of rice-wheat cropping system. Though the addition of K to soil was more (184-304 kg K ha^{-1} $year^{-1}$) with organic nutrition practices than with inorganic nutrition practice (66 kg K ha^{-1} $year^{-1}$) the 0.5 M NH_4OAC extractable K content in soil was higher in inorganic nutrition treatment than organic nutrition practices.

Probably higher root biomass production with inorganic nutrition might have contributed towards higher content of 0.5 M NH_4OAC extractable K in soil with inorganic nutrition.

Table 8. Effect of organic and inorganic nutrition practices on 1 N NH_4OAC extractable K (mg kg^{-1} soil) content in soil after completion of each cycle of rice-wheat cropping system

Treatments	*2003-04*	*2004-05*	*2005-06*
Control	86.1	84.7	83.9
GM[1] + 20 kg N as FYM[2] + Biofertilizers[3]	87.8	88.7	90.1
GM[1] + 40 kg N as FYM[2] + Biofertilizers[3]	88.2	89.1	90.7
GM[1] + 80 kg N as FYM[2] + Biofertilizers[3]	90.9	91.6	92.5
120 kg N + 26 kg P + 33 kg K ha^{-1}	94.2	95.1	96.0
LSD (P=0.05)	3.38	3.93	3.90

Initial value: 88 mg kg^{-1} soil

Conclusion

Though organic farming of rice-wheat cropping system resulted in 20-30% less productivity, the net profit of organic farming was about 30% higher as compared to inorganic farming besides a significant increase in soil fertility parameters. The organic farming of rice-wheat cropping system thus holds a promise for the farmers.

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