Direct, residual and cumulative effects of organic manures and biofertilizers on yields, NPK uptake, grain quality and economics of wheat (*Triticum aestivum* L.) under organic farming of rice-wheat cropping system

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Abstract

Field experiments were conducted at the research farm of the Indian Agricultural Research Institute, New Delhi during rabi (winter) season of 2007-2008 and 2008-2009 on a sandy clay loam soil (typical Ustochrept, 51.46% sand, 23.02% silt and 25.52% clay) of low in organic C (0.57%), medium in available phosphorus (19.87 kg/ha), high in available potassium (247.12 kg/ha) and low in available nitrogen (163.2 kg/ha) and of pH 8. Results revealed that the cumulative effects of farmyard manure (FYM) and green manure (GM) were more effective than their direct and residual effects and GM was significantly superior to FYM for increasing the productivity, nutrient uptake, grain quality and gross and net income of wheat in the rice-wheat cropping system. Further, inoculation of biofertilizers (B) with GM was better than GM alone in its cumulative effect. The combination of GM + FYM was still better than GM or FYM alone in its direct and cumulative effects for increasing productivity and gross return, but net return was significantly reduced due to the higher cost of GM + FYM compared to FYM or GM alone. However, the residual effect of GM + FYM was similar to the cumulative effects of GM or FYM alone. The highest increase in productivity, grain quality and nutrient uptake was recorded with the application of GM + FYM + B. However, net return was significantly reduced due to the higher cost incurred in the combination of GM + FYM + B. It was concluded that the cumulative effect of GM + FYM + B for higher productivity and the cumulative effect of GM + B for higher net return were suitable for wheat in organic farming of the rice-wheat cropping system.

Keywords: Wheat, yields, NPK, grain quality, organic farming, gross and net return.

Introduction

Wheat (*Triticum aestivum*) is the second most important food crop in India (after rice) and occupies about 26.7 million hectares of area and contributes about 33.9% of the total food grain production in India. The rice-wheat cropping system covers 10 million ha representing 75% of the total rice area and 63% of the total wheat area in India (Mishra 2009). This signifies the important contribution of wheat in meeting the food requirements

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of the country. The production of rice and wheat in a rotation is, however, facing a sustainability problem due to some practices of the modern production system with its indiscriminate use of chemical fertilizers and pesticides (Nambiar 1994, Duxbury et al. 2000, Ladha et al. 2000, Yadav et al. 2000, Prasad 2005).

The adverse effects of agro-chemicals are clearly visible on soil structure, microflora, quality of water, food and fodder. The quality of the produce is deteriorated due to the entry of chemical residues in the plant body and then to the food chain. The concerns such as declining factor productivity (Biswas & Sharma 2008; Patil 2008; Yadav 1998; Yadav 2008), depletion of soil organic carbon and mineral nutrients (Prakash et al. 2008), waterlogging and salinization, increasing nitrate concentration in well water (Singh et al. 1995), are the consequents of the modern rice-wheat production system with its unbalanced and injudicious use of chemical fertilizers and pesticides. The emerging scenario necessitates the need for the adoption of practices which maintain soil health, makes the production system more sustainable, and provides quality food for meeting the nutritional requirements.

Organic farming is one of the practices to make the production system more sustainable without adverse effects on the natural resources and the environment (Stockdale et al. 2001; Ram et al. 2011a) and over the past decade India has exhibited a rapid uptake of organic farming (second only to Uruguay) (Paull, 2011). The application of ample amounts of organic manure is the key for success of organic farming (Swift and Woomer 1993). The role of biofertilizers for enhancing the productivity of soil by fixing atmospheric nitrogen, or by solubilising soil phosphorus, or by stimulating plant growth through synthesis of growth promoting substances has special importance in organic farming. Previous studies by Davari et al (2012) and Ram et al (2011b) reported where a package of different organic nutrient sources (FYM, crop residue, biofertilizers and vermicompost) and its combinations were tested for fulfilling the need of nutrients for wheat via organic sources. The present paper implements different treatments and is aimed at comparing the direct, residual and cumulative effects of different combinations of organic manures (including green manure) and biofertilizers to find out the effect of different combinations of organic manures and biofertilizers on yields, NPK uptake, grain quality and gross and net returns of wheat under organic farming.

Materials and Methods

Site and soil

Field experiments were conducted at the Research Farm of the Indian Agricultural Research Institute, New Delhi (77°10'N latitude; 228.4 m above mean sea level) during the rabi seasons (December to April) of 2007-08 and 2008-09. The soil of the experimental field was sandy-clay loam, alkaline in reaction (pH 8.0), low in organic carbon (0.57 per cent; Walkley and Black method, Prasad et al. 2006), low in available nitrogen (163.2 kg ha^{-1}), medium in available phosphorus (19.87 kg P ha^{-1}) and high in available potassium (247.1 kg K ha^{-1}) in 0-15 cm soil depth at the start of the experiment.

Experimental design and treatments

The experiment was laid out in a randomized block design with three replications and sixteen treatments. Treatments consisted of three sets of five treatments (Farmyard manure (FYM); Green manure (GM); GM + Biofertilizers (B); GM + FYM; and GM + FYM

+ B) and a control. The experiment was carried out in a rice-wheat cropping system and the rice crop was taken before the wheat crop. Hence one set of the treatments was applied to rice which was regarded as direct effect to rice and residual effect to the succeeding wheat. The second set of the treatments was applied to wheat which was regarded as direct effect to wheat and a residual effect to the succeeding rice, and the third set of treatments was applied to both rice and wheat which was regarded as a cumulative effect to both rice and wheat. For green manures, *Sesbania aculeata* (SGM) was used for rice, and Leucaena green leaf manuring (LGLM) was used for wheat. For biofertilizers, blue green algae (BGA) was used in rice, and Azotobacter in wheat. The allocation of various treatments was done by randomization using Fisher and Yates random table (Fisher & Yates, 1963). In tables of results non-significant differences are symbolised as NS.

Farmyard manure was well decomposed and used at 10 t ha^{-1} on a dry weight basis. The nutrient content of organic manures is presented in Table 1.

Table 1. Chemical composition of organic manures.

Composition	FYM				Green manure			
	2007-08		2008-09		2007-08		2008-09	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Organic C (mg kg^{-1})	143000	138600	139800	140200	386000	460000	389000	481000
Total N (mg kg^{-1})	4800	5000	4900	4900	24000	32000	27000	31500
Total P (mg kg^{-1})	2300	2500	2500	2400	3700	3300	3900	3000
Total K (mg kg^{-1})	4900	5200	5100	5000	20800	23000	21900	22800
Fe (mg kg^{-1})	20.85	22.35	21.9	22	74.6	83.2	77.2	80.3
Zn (mg kg^{-1})	10.6	11.7	12.05	11.9	34.2	36.4	34.8	33.7
Mn (mg kg^{-1})	38.9	39.6	39.95	40.1	88.2	96.2	90.4	94.8
Cu (mg kg^{-1})	2.6	2.7	2.79	2.83	8.5	9.2	8.7	8.8
C:N ratio	29.8	27.7	28.5	28.6	16.1	14.4	14.4	15.3

Sesbania aculeata was grown in the field in plots having the SGM treatment and incorporated *in-situ* after about 60 days of sowing, but before transplanting of rice, with the help of a tractor drawn mould board plough followed by heavy disc. The green lopes of *Leucaena leucocephala* (Subabul) were manually collected by pruning of shrubs planted on the side of Nala (Trench), located near the experimental field and applied at 5 t ha^{-1} on an oven dry weight basis in the plots having the LGLM treatment. It was incorporated into soil with a tractor drawn heavy disc at 20 days before the sowing of wheat. Multani mitti (Fuller's earth) based BGA culture containing four micro-organisms *Aulosira fertilissima, Nostoc muscorum, Tolypothrix tenuis* and *Anabaena variabilies* was obtained from the National Centre for Conservation and Utilization of Blue Green Algae, IARI, New Delhi and broadcasted uniformly at 2.5 kg ha^{-1} in plots having the BGA treatment after 10 days of transplanting of rice. Strains of *Azotobacter chroococcum* specific to wheat was obtained from the Division of Microbiology, IARI, New Delhi, and

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used to inoculate the seeds as per the treatments. Sowing of wheat was done by the *pora* method (sowing with the simplest form of drill consisting of a pipe with a funnel and attached with the plough dropping seeds through (naali) funnels) with the help of a hand plough in the rows spaced at a spacing of 15 cm using a seed rate of 120 kg ha^{-1}. The *pora* method was used because some plots were sown with *Azotobacter* culture treated seed, whereas other plots were sown with untreated seed.

The cost of cultivation of wheat was calculated on the basis of the prevailing rates of inputs, and gross income was calculated on the basis of the price of wheat grain (organic) and the prevailing market price of wheat straw. The net income was obtained by subtracting cost of cultivation from the gross income, i.e.

Net income = gross income – cost of cultivation

The data were analyzed by applying the technique of Analysis of Variance for randomized block design as described by Cochran & Cox (1957). The 15 degrees of freedom for treatments were split into 5 degrees of freedom for 6 combinations of different organic manures and biofertilizers (including the control), 2 degrees of freedom for 3 sets of treatments (i.e. one set of treatments applied to rice, second to wheat, and third to both rice and wheat) and 8 degrees of freedom for the interaction between 5 combinations of the various organic manures and biofertilizers (excluding the control) and 3 sets of treatments.

Results and discussion

Grain and straw yield

The data on grain and straw yield of wheat as influenced by the different combinations of organic manures & biofertilizers and their modes of application are presented in Table 2.

The grain and straw yields were significantly higher with the application of FYM than the control in both the years of study. GM was significantly superior to FYM in increasing grain and straw yields in both the years of study. Both Thakur & Patel (1998) and Singh & Agarwal (2004) have previously reported a beneficial effect of FYM on wheat. The addition of nutrients through GM resulted in significantly higher growth and yield attributes and consequently the straw and grain yield was further more with the application of GM over FYM. Saha et al. (2000) reported a significant increase in growth and yield attributes and yields of wheat due to the application of GM. Inoculation of GM with B resulted in a significantly higher grain and straw yield than GM alone. The application of B in wheat resulted in the addition of 17-20 kg N/ha and some amounts of N can be expected from the residual effect of B applied to the preceding rice crop. Thus the cumulative effect of GM + B proved more effective than GM alone. The application of B significantly increased all the growth and yield attributes and consequently yields were also increased. Apte and Shende (1981), Rabie et al. (1995), Khalid et al. (1997), Khosravi et al. (1998) and Kaushik et al. (2001) have previously reported a significant improvement in growth and yield attributes and yields of wheat by Azotobacter inoculation. Rathore et al. (1995) have reported a residual effect of BGA inoculated in rice on yields of the succeeding wheat. The combination of GM + FYM was significantly better than GM and FYM alone in increasing grain yield and straw yield in both the years of study. The combination of GM + FYM generated significantly higher amounts of nutrients than GM and FYM alone and resulted in significantly higher yields than GM and FYM alone.

Table 2. The effect of organic manures & biofertilizer combinations and modes of application on grain and straw yields of wheat.

Treatment	Grain (t ha^{-1})		Straw (t ha^{-1})	
	2007-08	2008-09	2007-08	2008-09
Organic manures & biofertilizers combination (N)				
Control	2.4	2.4	4.8	4.9
Farmyard manure (FYM)	3.3	3.4	5.6	5.7
Green manure (GM)	3.5	3.8	5.8	6.0
GM + biofertilizers (B)	3.8	4.1	6.1	6.3
GM + FYM	4.3	4.4	6.4	6.5
GM + FYM + B	4.5	4.6	6.5	6.6
Control vs others				
SEd±	0.16	0.19	0.20	0.17
CD (P=0.05)	0.32	0.39	0.41	0.34
Between others				
SEm±	0.08	0.09	0.10	0.08
CD (P=0.05)	0.23	0.27	0.29	0.24
Mode of application (M)				
Direct effect	3.9	4.1	6.2	6.3
Residual effect	3.2	3.3	5.7	5.9
Cumulative effect	4.5	4.7	6.3	6.5
SEm±	0.06	0.07	0.08	0.07
CD (P=0.05)	0.18	0.21	0.23	0.19
N x M				
SEm±	0.14	0.16	0.17	0.15
CD (P=0.05)	0.39	0.47	NS	NS

Across the modes of application, the cumulative effect of nutrient combinations recorded significantly higher yields than direct effect. The direct effect was significantly more than the residual effect of nutrient combinations in both the years of study. The nutrient combinations applied to wheat, as well as to the preceding rice, resulted in improved soil fertility status than nutrient combinations applied to only wheat (direct) or to only preceding rice (residual). Previously Sharma et al. (1995) and Dwivedi & Thakur (2000) also reported that cumulative effects of organic manures were higher as compared to their direct effects.

Interactions between nutrient combinations and their modes of application were not significant in respect to straw yield in either year. Interactions in respect to grain yield (Fig.1) revealed that the effects of FYM and GM were similar in their direct and residual effects, but the cumulative effect of GM was significantly better than FYM in both the years. Inoculation of GM with B resulted in significantly more grain yield than GM (alone) in its direct and cumulative effect but the residual effect was not significant over GM (alone). The combination of GM + FYM was better than the application of either GM or FYM alone. Inoculation of GM + FYM with B did not result in higher grain yield than GM + FYM in its all the modes of applications.

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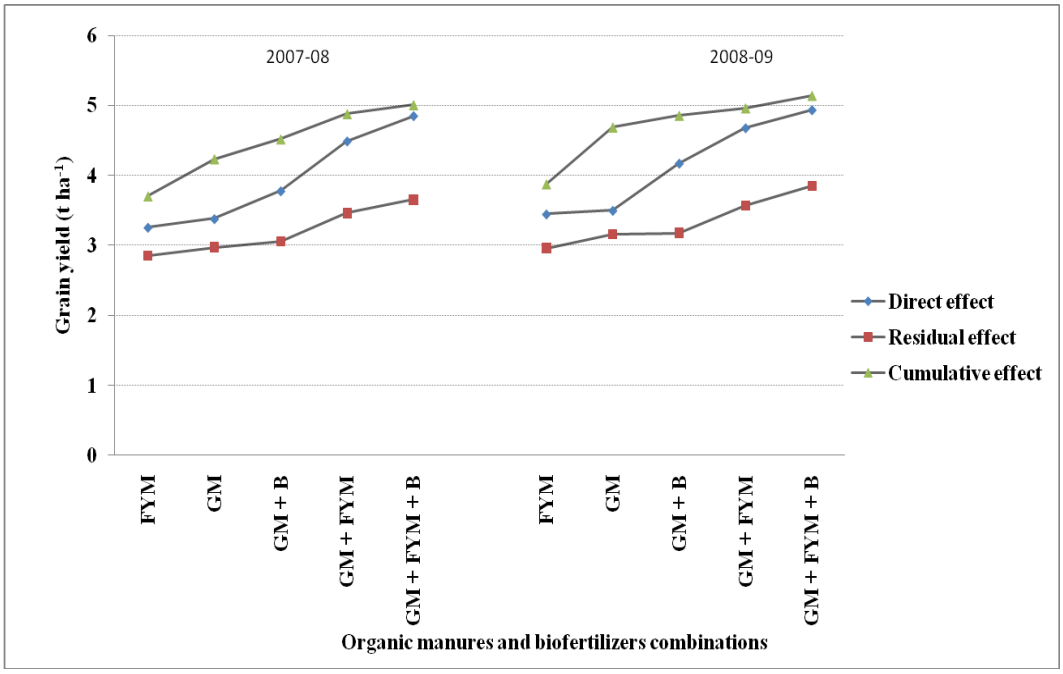

Fig. 1. The interaction effects of organic manures and biofertilizer combinations and modes of application on grain yield (t ha^{-1}) of wheat.

N, P and K uptake

The data on N, P and K uptake by wheat as influenced by the different combinations of nutrients and their modes of application are presented in Table 3. The effects of FYM and GM were similar and significantly higher than the control in respect to the N and P uptake by wheat in the first year of study, whereas in the second year GM resulted in significantly higher N and P uptake than FYM. This may be due to the higher cumulative effect of GM in the second year. In respect to the K uptake, the effects of FYM and GM were similar in both the years of study. Previously Bhardwaj & Tyagi (1994), Ghosh & Shah (1997) and Singh & Agarwal (2004) have reported increased NPK uptake by wheat with FYM application. Inoculation of GM with B showed significantly higher N uptake than GM alone. The P and K uptake was not significantly increased with the application of B with GM in either year of study. The combination of GM + FYM supplied significantly more nutrients and improved soil fertility. Consequently growth and yield were increased significantly and resulted in significantly higher N, P and K uptake than GM or FYM alone.

N, P and K uptake were significantly influenced by the mode of application. The cumulative effect of nutrient combinations resulted in significantly higher N, P and K uptake than the direct effect which in turn was significantly superior over residual effects of the nutrient combinations. These results are explained as due to the higher fertility status of plots receiving nutrient combinations in both the crops (cumulative effect) than those receiving either in wheat (direct effect) or in rice (residual effect).

Table 3. The effect of organic manures & biofertilizer combinations and modes of application on N, P and K uptake by wheat.

Treatment	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Organic manures & biofertilizers combination (N)						
Control	43.3	42.6	7.7	7.5	75.6	75.7
Farmyard manure (FYM)	67.3	72.9	12.4	14.9	93.9	98.8
Green manure (GM)	73.2	79.8	13.4	16.4	97.7	103.5
GM + biofertilizers (B)	80.0	86.5	15.0	18.3	102.7	109.6
GM + FYM	91.5	97.0	17.6	20.3	112.2	117.2
GM + FYM + B	97.3	102.7	18.7	22.1	118.5	122.9
Control vs others						
SEd±	4.32	4.25	0.87	0.99	6.4	9.0
CD (P=0.05)	8.81	8.67	1.78	2.03	13.0	18.4
Between others						
SEm±	2.16	2.12	0.44	0.50	3.2	4.5
CD (P=0.05)	6.23	6.13	1.26	1.43	9.2	13.0
Mode of application (M)						
Direct effect	83.6	89.7	15.7	18.6	106.9	110.0
Residual effect	64.9	69.8	11.8	14.4	89.9	94.9
Cumulative effect	97.0	103.8	18.7	22.3	118.2	126.3
SEm±	1.67	1.64	0.34	0.38	2.5	3.5
CD (P=0.05)	4.83	4.75	0.97	1.11	7.1	10.1
N x M						
SEm±	3.7	3.7	0.75	0.86	5.5	7.8
CD (P=0.05)	NS	NS	NS	NS	NS	NS

The interactions between nutrient combinations and their modes of application were not significant in either year of study; this may be due to the relatively short period (2 years) of experimentation.

Grain quality

Nutrient content

The data on N, P and K and micronutrient (Fe, Mn, Zn, Cu) concentrations in wheat grain as influenced by different combinations of nutrients and their modes of application are presented in Table 4. Nutrient content in wheat grain was significantly higher with the application of different nutrient combinations compared to the control. The effect of FYM and GM were similar in respect to nutrient concentration in wheat grain in both the years of study. The inoculation of either GM or GM + FYM with B did not result in a significantly higher concentration of nutrients over GM alone or GM + FYM. The combination of GM + FYM led to significantly higher concentrations of nutrient in wheat grain than GM or FYM alone in both the years of study.

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Across the modes of application, the cumulative effects were not significantly different to the direct effects but resulted in significantly higher concentration of nutrients than the residual effects. There was no significant difference between direct and residual in respect to Mn concentration (in either year) and K concentration (in second year of study). In respect to the P concentration in wheat grain, the cumulative effect was also significantly superior to the direct effect of nutrient combinations. The interactions between nutrient combinations and their modes of application were not significant in either year of study.

Table 4. Effect of nutrient combinations and modes of application on nutrient concentrations in wheat grain

	N, P and K concentration (%)						**Micronutrients concentration (ppm)**							
	N		**P**		K		**Fe**		**Mn**		**Zn**		**Cu**	
Treatment	**2007-08**	**2008-09**	**2007-08**	**2008-09**	**2007-08**	**2008-09**	**2007-08**	**2008-09**	**2007-08**	**2008-09**	**2007-08**	**2008-09**	**2007-08**	**2008-09**
Organic manures & biofertilizers combination (N)														
Control	1.23	1.22	0.254	0.248	0.352	0.351	28.0	27.8	35.2	35.0	33.3	33.1	7.0	6.9
Farmyard manure (FYM)	1.42	1.47	0.304	0.356	0.386	0.400	30.6	30.8	37.8	38.3	37.4	38.0	7.4	7.9
Green manure (GM)	1.46	1.50	0.307	0.360	0.389	0.402	31.9	32.2	37.9	38.7	38.9	39.3	7.5	7.9
GM + biofertilizers (B)	1.48	1.52	0.321	0.374	0.403	0.420	33.4	33.5	38.7	38.8	41.9	42.0	7.6	8.0
GM + FYM	1.55	1.59	0.338	0.387	0.417	0.431	37.1	37.4	39.1	39.4	45.8	46.0	7.6	8.1
GM + FYM + B	1.57	1.61	0.343	0.401	0.425	0.439	37.6	37.9	39.5	39.7	47.5	47.7	7.6	8.1
Control vs others														
SEd±	0.08	0.07	0.018	0.014	0.018	0.021	1.25	1.43	0.91	0.73	2.00	1.88	0.08	0.14
CD (P=0.05)	0.17	0.15	0.037	0.029	0.037	0.042	2.55	2.92	1.85	1.50	4.09	3.85	0.16	0.29
Between others														
SEm±	0.04	0.04	0.009	0.007	0.009	0.010	0.62	0.72	0.45	0.37	1.00	0.94	0.04	0.07
CD (P=0.05)	0.12	0.11	0.026	0.020	0.026	0.030	1.80	2.07	1.31	1.06	2.89	2.72	0.11	0.21
Mode of application (M)														
Direct effect	1.51	1.55	0.324	0.375	0.405	0.419	34.5	34.6	38.6	39.0	43.2	43.3	7.5	8.0
Residual effect	1.41	1.46	0.299	0.355	0.380	0.398	32.4	32.9	37.7	38.3	39.2	39.8	7.4	7.8
Cumulative effect	1.57	1.61	0.346	0.397	0.427	0.438	35.5	35.6	39.5	39.7	44.5	44.6	7.6	8.1
SEm±	0.032	0.028	0.007	0.005	0.007	0.008	0.48	0.55	0.35	0.28	0.78	0.73	0.03	0.06
CD (P=0.05)	0.092	0.082	0.020	0.016	0.020	0.023	1.39	1.60	1.01	0.82	2.24	2.11	0.09	0.16
N x M														
SEm±	0.07	0.06	0.016	0.012	0.016	0.018	1.08	1.24	0.78	0.63	1.74	1.63	0.07	0.12
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Protein content and physical quality parameters

The data on protein content and physical parameters of wheat grain as influenced by the different combinations of nutrients and their modes of application are presented in Table 5. The effects of FYM, GM, and GM + B were statistically similar and significantly higher than the control on protein content of wheat grain in both the years of study. The highest protein content was recorded by GM + FYM + B, however, there was no significant difference between GM + FYM in either year of study. Previously, Kharub (2008) reported that protein content in wheat increased with increase in the dose of FYM, but the highest protein content (11-24%) was recorded under inorganic fertilizer. Hardness and sedimentation value of wheat grain were not significantly affected by FYM application in either year of study, whereas GM significantly increased the hardness in wheat grain over the control in both the years, and sedimentation value only in the second year of the study. The highest increase in hardness and sedimentation values were recorded with the combination of GM + FYM + B followed by GM + FYM. Inoculation of GM or GM + FYM with B did not show any significant advantage over GM alone or GM + FYM in either year of study.

Table 5. The effect of organic manures & biofertilizer combinations and modes of application on protein content and physical quality parameters of wheat grain.

Treatment	Protein content (%)		Hardness (HL)		Sedimentation value (ml)	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Organic manures & biofertilizers combination (N)						
Control	7.08	6.99	79.67	79.81	38.20	38.00
Farmyard manure (FYM)	8.17	8.47	82.77	83.10	41.01	41.39
Green manure (GM)	8.40	8.65	84.94	85.40	41.22	41.58
GM + biofertilizer	8.48	8.74	85.44	85.76	41.39	41.81
GM + FYM	8.93	9.15	88.95	89.24	43.33	43.92
GM + FYM + biofertilizer	9.01	9.26	89.68	90.30	43.36	43.92
Control vs others						
SEd±	0.47	0.42	1.96	1.77	1.63	1.75
CD (P=0.05)	0.96	0.86	4.00	3.62	3.33	3.57
Between others						
SEm±	0.24	0.21	0.98	0.89	0.82	0.87
CD (P=0.05)	0.68	0.61	2.83	2.56	2.36	2.52
Mode of application (M)						
Direct effect	8.67	8.90	86.93	87.32	42.32	42.53
Residual effect	8.10	8.39	82.78	83.18	40.71	41.03
Cumulative effect	9.02	9.26	89.36	89.78	43.15	44.01
SEm±	0.18	0.16	0.76	0.69	0.63	0.68
CD (P=0.05)	0.53	0.47	2.19	1.98	1.82	1.95
N x M						
SEm±	0.41	0.36	1.70	1.53	1.41	1.51
CD (P=0.05)	NS	NS	NS	NS	NS	NS

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Across the modes of application, the cumulative effect was significantly superior only over the residual effect in respect to protein content and sedimentation values, whereas there was a significant difference between the direct and cumulative effects in respect to the hardness value of wheat grain in both the years of study.

The interactions between nutrient combinations and their modes of application were not significant in either year of study.

Economics of wheat cultivation

The data on gross return, cost of cultivation, net return and the benefit-cost (B:C) ratio of wheat cultivation as influenced by the different combinations of nutrients and their modes of application are presented in Table 6.

Table 6. The effect of nutrient combinations and modes of application on the economics of the cultivation of wheat.

Treatment	Gross return ($x10^3$ Rs. ha^{-1})		Cost of cultivation ($x10^3$ Rs. ha^{-1})		Net return ($x10^3$ Rs. ha^{-1})		B:C ratio	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Organic manures & biofertilizers combination (N)								
Control	48.49	48.53	11.08	11.42	37.41	37.10	3.4	3.2
Farmyard manure (FYM)	65.15	68.08	16.76	17.44	48.39	50.63	2.9	2.9
Green manure (GM)	69.59	74.07	12.05	12.38	57.54	61.69	4.8	5.0
GM + biofertilizers (B)	74.13	79.11	12.16	12.49	61.96	66.62	5.1	5.3
GM + FYM	82.65	84.91	25.12	26.01	57.53	58.90	2.3	2.3
GM + FYM + B	86.90	89.20	25.23	26.12	61.67	63.08	2.4	2.4
Control vs others								
SEd±	2.68	3.08			2.68	3.08	0.31	0.25
CD (P=0.05)	5.48	6.29			5.48	6.29	0.63	0.52
Between others								
SEm±	1.34	1.54			1.34	1.54	0.15	0.13
CD (P=0.05)	3.87	4.45			3.87	4.45	0.44	0.37
Mode of application (M)								
Direct effect	77.16	80.33	21.86	22.62	55.30	57.7	2.5	2.6
Residual effect	63.90	66.44	11.08	11.42	52.82	55.0	4.8	4.8
Cumulative effect	85.99	90.45	21.86	22.62	64.13	67.8	2.9	3.0
SEm±	1.04	1.19			1.04	1.19	0.12	0.10
CD (P=0.05)	3.00	3.45			3.00	3.45	0.34	0.28
N x M								
SEm±	2.32	2.67			2.32	2.67	0.27	0.22
CD (P=0.05)	6.71	7.70			6.71	7.70	0.77	0.63

Note: Price of wheat grain (organic) was taken as Rs. 1650 q^{-1} and the price of wheat straw as Rs. 200 q^{-1} in both the years of study

There were significant effects: FYM over control; GM over FYM; GM + B over GM; GM + FYM over GM + B; and GM + FYM + B over GM + FYM; recorded in respect to the increase in gross return of wheat in both the years. However, the difference between GM + FYM and GM + FYM + B was not significant in the second year of the study. The cost of cultivation of a particular treatment did not vary in the three replications. The cost of rice cultivation varied from Rs 11080.5 ha^{-1} for control plots to Rs 25023.2 ha^{-1} for GM + FYM + B in first year, and from Rs 11424.4 ha^{-1} for control plots to Rs 26122.3 ha^{-1} for GM + FYM + B in the second year of study. The addition of FYM, GM, GM + B, GM + FYM and GM + FYM + B increased the cost of cultivation over the control by 51.3%, 8.8%, 9.8%, 126.7% and 127.7% respectively, in the first year and 52.7%, 8.3%, 9.3%, 127.7% and 128.7% respectively, in the second year of the study. The net return was significantly increased with the application of FYM over the control, GM over FYM, and GM + B over GM. The combination of GM + FYM was significantly superior to FYM, but not against GM alone. The highest net return was recorded with GM + B due to its low cost and comparable higher yields. The B:C ratio was decreased due to the application of FYM over the control whereas GM significantly increased the B:C ratio over the control and FYM in both the years of study. The highest B:C ratio was obtained with the application of GM + B as well as GM alone. Combinations of GM + FYM and GM + FYM + B significantly deceased the B:C ratio of wheat cultivation over all the rest of the nutrient combinations due to highest cost of cultivation incurred in these combinations.

Across the modes of application, the cumulative effect resulted in significantly higher gross and net return followed by direct and residual effects. However, there was no significant difference between direct and residual effects in respect to the net return in the second year of study. The B:C ratio was significantly higher in the residual effect compared to the cumulative and direct effects of nutrient combinations in both the years of the study.

Interactions between nutrient combinations and modes of application in respect to gross return (Fig. 2) showed that FYM and GM were similar in their direct and residual effects, but the cumulative effect of GM was significantly higher than the cumulative effect of FYM in both the years of study. The combination of GM + B was significantly superior over both FYM and GM in direct effect but no different in the residual and cumulative effects of nutrient combinations. Combinations of GM + FYM and GM + FYM + B were significantly superior to GM and FYM in all of the effects. Interactions in respect to the net return (Fig. 3) revealed that the net return was significantly higher with GM than FYM, and GM + B was superior over GM alone, in the direct and cumulative effects in both the years. However, in the second year of study GM + B was not different to GM alone. The combination of GM + FYM and GM + FYM + B were not significantly different to GM and FYM alone in their direct and cumulative effects, but the residual effects of these combinations were significantly superior over GM alone and FYM alone in both the years of the study. Interactions in respect to B:C ratio (Fig. 4) indicated that GM resulted in significantly higher B:C ratio than FYM in its cumulative and direct effects. There was no significant advantage of GM + B recorded over GM alone in respect to the B:C ratio. Combinations of GM + FYM and GM + FYM + B were not different to each other, and were both significantly superior over GM and FYM only in their residual effects.

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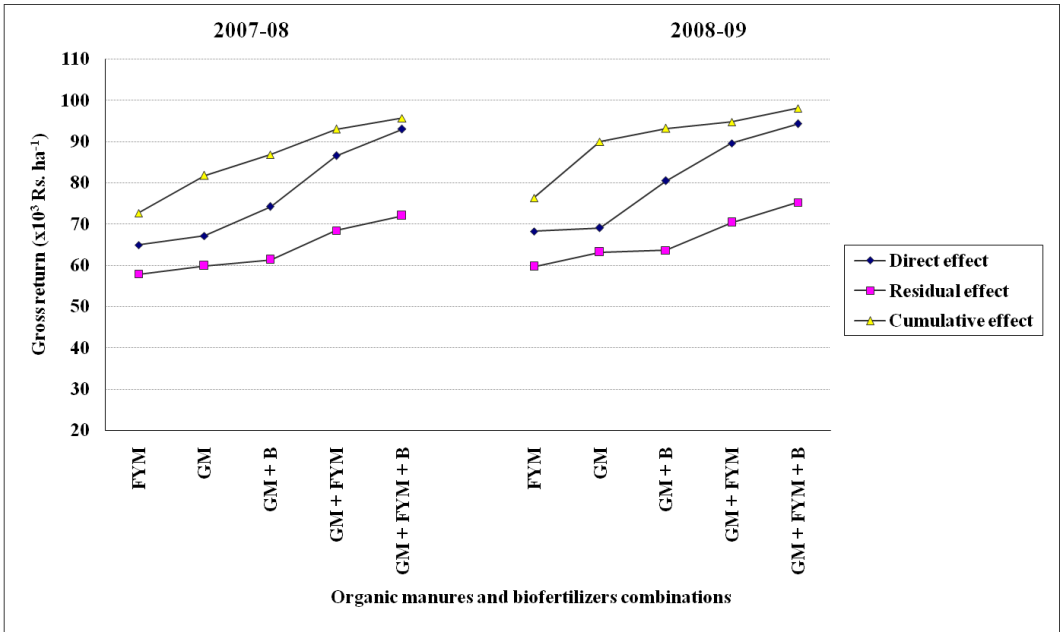

Fig. 2. The interaction effects of organic manures and biofertilizer combinations and modes of application on gross return (x103 Rs. ha^{-1}) of wheat.

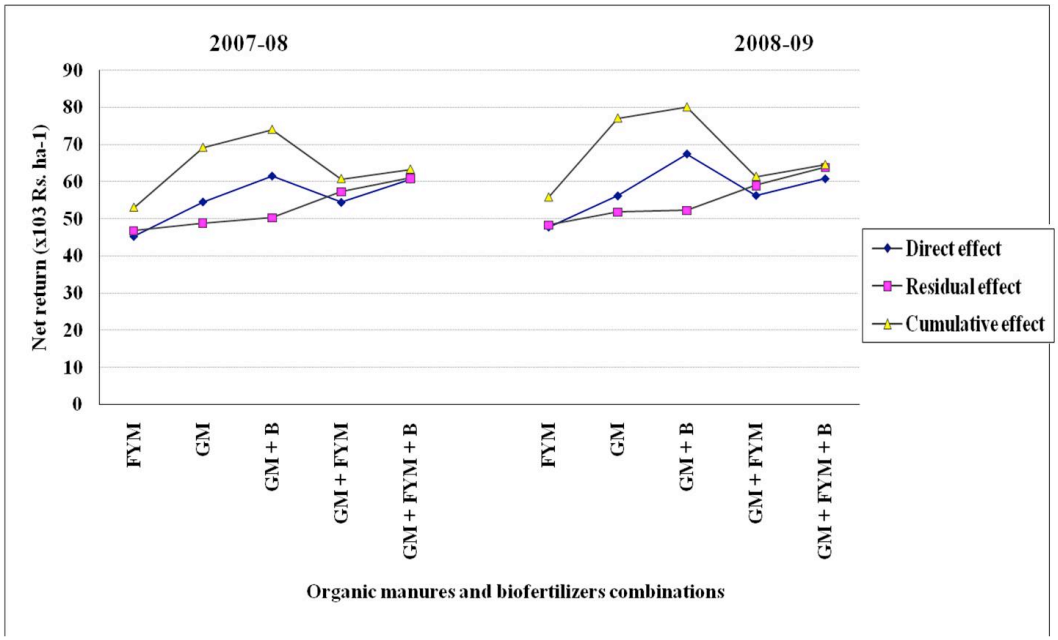

Fig. 3. The interaction effects of organic manures and biofertilizer combinations and modes of application on net return (x103 Rs. ha^{-1}) of wheat.

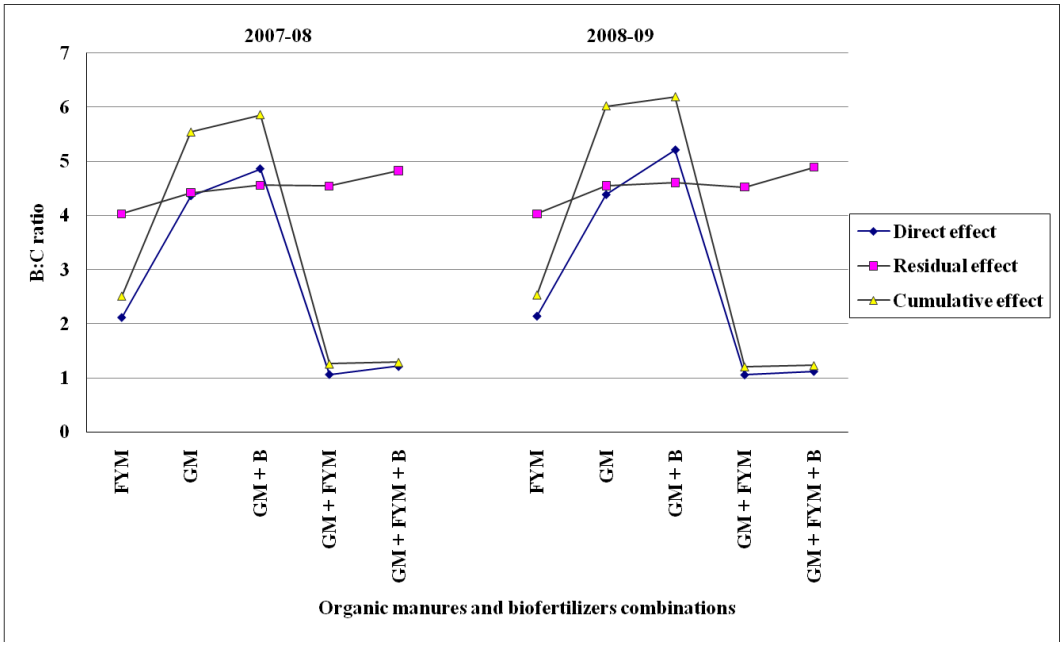

Fig. 4. The interaction effects of organic manures and biofertilizer combinations and modes of application on B:C ratio of wheat

Conclusion

The application of a combination of green manuring + farm yard manure + biofertilizers in a cumulative manner was found to achieve the highest yields of wheat. However, with lower input costs, an appreciable yield of wheat with enhanced net returns can be obtained by the application of green manuring and biofertilizers in a cumulative manner in organic farming of rice-wheat cropping system. This latter result applies under the costs established for the present study and assumes a buy-in by the farm of the inputs. However, where a farm is self producing of farm yard manure, or the costs of farm yard manure are lower than reported in this study, then in that case the application of farm yard manure can be expected to both enhance grain yields and net returns. Higher organic nutrient inputs result in higher yields. The challenge for the farmer is always to make the trade-off between the changing cost of inputs versus the changing market price for the produce and the changing premium for organic produce.

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