Int.J.Curr.Microbiol.App.Sci (2017) *6*(4): 920-928

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 4 (2017) pp. 920-928**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.604.116

Conjoint Application of Organic and Inorganic Sources of Nutrients in Relation to System Productivity, Profitability, Soil Fertility and Economics of Rice (*Oryza sativa*)-Wheat (*Triticum aestivum*) Cropping System

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Keywords

System productivity, System profitability, Rice equivalent yield, Rice-wheat system and Economics.

Article Info

Accepted:
06 March 2017
Available Online:
10 April 2017

A B S T R A C T

A field experiment was conducted to study the direct effect of organic manures (sewage sludge, vermicompost and sesbania) and chemical fertilizers on rice and their residual effect on wheat grown in sequence during 2013-14 at Agriculture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Among the nutrient sources, highest grain yield of rice (4.22 t ha^{-1}) and wheat (3.55 t ha^{-1}), system productivity (25.02 $kg^{-1}day^{-1}$), system profitability (251.91 $Rs^{-1}day^{-1}$), rice equivalent yield (80.62 q ha^{-1}) and economics were recorded with 100% recommended dose of fertilizer (RDF) along with S_{40} kg, Zn_5 kg and $B_{1.5}$ kg ha^{-1} (T_3) followed by customized fertilizer (T_4). Lower yield and economics was recorded in control (T_1). The use of organics amendment such as sewage sludge, vermicompost and sesbania along with chemical fertilizer were found to supplement 25% RDF along with significant increase of P in post harvest soil of rice and N and P in post harvest of wheat.

Introduction

Due to different agro-climatic conditions in the India, a large number of crops are grown. Rice (*Oryza sativa*) stands first among all food grain crops of the world and is staple food for more than half of world's population. It contributes around 40% of the total food grain production in India.

Presently, about 10.5 million hectares land is covered by rice – wheat crop which constitute a major area covered in the Indo-Gangetic plain region (Prasad, 2005). Out of total fertilizer used in India, 65% used in rice and wheat crop alone (Yadav and Kumar, 2009). Such use of unbalanced fertilizer not only aggravates the deficiency of phosphorus (P), potassium (K), sulphur (S) and a number of micro-nutrients, but also proves uneconomical (Sharma *et al.,* 2003).

A significant increase in productivity of this system has been achieved during Green Revolution due to introduction of high yielding and disease resistant crop varieties, increased use of inorganic fertilizers, better irrigation facilities, better farm machineries and implements, etc. Recent evidences from long-term experiments, however, showed that increase in yield is slowing down and sometimes even declining (Ladha *et al.*, 2003). Thus, there is serious concern related to the production and productivity of both rice and wheat for fulfilling our future demands. Use of organic manures in present agriculture is increasing day by day, because of its utility not only for improving the physical, chemical and biological properties of soil but also maintaining the good soil health. So, it is time to adopt measures to ensure sustainability in production of rice on long- term basis. Organic manures like FYM, poultry manure, vermicompost and sesbania should be applied to sustain production of rice wheat system. Application of organic manures, improves the availability of macronutrients Dahiphale *et al.,* 2003.

A continuous rice-wheat cropping system has some negative impacts on the soil properties because of the specific type of the agricultural practices followed therein. These practices have a very crucial role in altering the soil properties like bulk density, water infiltration and formation of hard pan in sub soil, decreasing microbial diversity and deficiency of some specific plant nutrients due to continuous mining up to a definite depth. The inputs given by the farmers to the soil are limited while they use high yielding varieties for obtaining higher yields. In this way the fertility status of soil is declining continuously.

The productivity of rice- wheat system is much less compared to the developed countries. The nutrient management practices based on soil test basis and use of organic manure to minimize the use of chemical fertilizers would be most effective in improving crop productivity and maintaining soil health. Therefore, the presently experiment was under taken to study the effect of organic sources as sewage sludge, vermicopost and sesbania in combination with chemical fertilizers on growth, yield and economics of rice- wheat sequence grown in eastern Uttar Pradesh.

Materials and Methods

A field experiment was conducted during 2013- 2014 at Agricultural Research farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, to study the response of organic sources and along with chemical fertilizers on productivity of rice–wheat cropping system. The farm lies in the Northern Gangetic Alluvial plain (25°18' N, 83°03' E) at 129 m above the mean sea-level. The soil was sandy loam having pH (8.18), electrical conductivity (0.18 dS/m), organic carbon (0.47%), available N (138.5 kg/ha), P (23.5 kg/ha), K (139.1 kg/ha). The N, P, K, S, Zn, and B were applied through urea, diammonium phosphate (DAP), muriate of potash (MOP), gypsum, zinc sulphate and borax, respectively. Half dose of N and full dose of P_2O_5, K_2O, S, Zn and B were applied as basal. Remaining N was applied in 2 equal splits at 30 and 60 days after transplanting (DAT) both rice and wheat. The soil samples were analysed for pH (Spark, 1996) and EC as per method of Chopra and Kanwar (1982). For analysis of organic carbon, Wet digestion method of Walkley and Black (1934), available N was estimated by Alkaline $KMnO_4$ method (Subbiah and Asija 1956), P by Olsen’s method (Olsen *et al.*, 1954) and K by Flame Photometer method (Hanway and Heidal, 1952). The experiment was conducted in randomized block design having 7 treatments and three replications. The treatment details are given in table 1. One treatment of customized fertilizers formulated for rice and wheat separately was also included in the experiment. Organic sources of nutrients were analyzed for its N content and their amount were calculated on the basis 25% of recommended dose of nitrogen. The customized fertilizer was applied @ 312.5 kg ha^{-1} in rice and @ 375.0 kg ha^{-1} in wheat and split application of urea was done to provide the remaining dose of recommended dose of nitrogen.

The harvest index, rice equivalent yield, system profitability and system productivity was calculated using following formula.

$$\text{Harvest Index} = \frac{\text{Economic Yield}}{\text{Biological Yield}} \times 100$$

$$\text{Rice equivalent yield q ha}^{-1} = \frac{\text{Wheat yield (q ha}^{-1}\text{) x market price wheat}}{\text{Market price of rice (Rs.)}} + \text{Rice grain yield (q ha}^{-1}\text{)}$$

$$\text{System Profitability (Rs./ha/day)} = \frac{\text{Net return}}{365}$$

$$\text{System Productivity kg/ha/day} = \frac{\text{REY}}{365}$$

Results and Discussion

Grain and Straw yield of rice and wheat

Grain yield of rice increased significantly (Table 2), the maximum was in 100% RDF + S_{40} + Zn_5 + $B_{1.5}$ (T_3) followed by customized fertilizer (T_4) and then 75% RDF + 25% N through vermicompost (T_6) which was 93.7, 93 and 92.6% higher, over control (T_1), respectively. Rice grain yield recorded under treatment customized fertilizer (T_4), 100% RDF + S_{40} + Zn_5 + $B_{1.5}$ (T_3) and 75% RDF + 25% N through vermicompost (T_6) were statistically at par with each other. Kumar (2014) and Samant and Patra (2016) reported that maximum grain yield in rice and straw yield in greengram, whereas 75% RDF + 5 t/ha FYM to *kharif* rice followed by 3 t ha^{-1} FYM to *rabi* greengram gave the maximum grain yield in greengram and straw yield in rice, which was about 128% higher than that in the control. The treatment customized fertilizer and 100% RDF increased the straw yield by 125 and 116%, respectively, over control. Rice straw yields recorded under treatments 75% RDF + 25% N through vermicompost (T_6) and75% RDF + 25% N through Sesbania (T_7) were statistically similar. Grain yield of wheat varied from 0.89 to 3.55 t ha^{-1}. The highest yield was recorded in treatment 100% RDF + S_{40} + Zn_5 + $B_{1.5}$ (T_3) which was 2.3% higher over 100% RDF (T_2) and 299% higher over control (T_1).Treatment T_5 and T_7 were statistically at par. The straw yield of wheat was highest under treatment T_3 and T_6 which were statistically similar. The findings are in close conformity with those of Jamwal (2005) and Singh *et al.*, (2014).

System Profitability

Data presented in table 2 showed that application of 100% RDF + S_{40} + Zn_5 + $B_{1.5}$ ha^{-1} to rice followed by 100% RDF to wheat (T_3) though remained at par with T_2 (100% RDF to both rice and wheat) recorded significantly higher system profitability than other treatments. The T_5 being comparable to

T_4 and T_7 proved distinctly superior to T_6 and T_1. Similar results have been reported by Singh *et al.,* (1997), Parihar *et al.,* (1999). However, the lower system profitability was observed in control (T_1). Based on rice- wheat cropping system, combined application of 100% recommended dose fertilizer with S, Zn and B was more profitable (251.91 Rs./ha/day) than application of recommended dose fertilizer (243.11 Rs./ha/day) which was 5.6 and 5.4 times more profitable over control (37.60 Rs./ha/day), respectively. Dubey *et al.,* (2014) also reported similar result from their studies.

Rice Equivalent Yield and System Productivity

Application of 100% RDF + S_{40} + Zn_5 + $B_{1.5}$ ha^{-1} to rice followed by 100% RDF to wheat (T_3) produced the highest rice equivalent yield (REY) of 91.33 q ha^{-1} being comparable to customized fertilizer + urea application in both the seasons, (Table 2). The T_3 also gave maximum system productivity and system profitability; though it remained at par with T_4 for system productivity and T_2 for system profitability, although significantly superior to other treatments. The control (T_1) recorded the lowest REY. Choudhary *et al.,* (2001) also reported greater productivity by replacing a part of inorganic sources of nutrients with organic sources in rice-wheat system. System productivity followed the similar trend as that of REY (Maurya *et al.,* 2013). The chemical fertilizer sustained the yield through increased nutrients availability and enhancing nutrient use efficiency in rice-wheat system if applied in balanced form (Yadav and Kumar, 2009). Among different management practices, higher productivity of rice-wheat cropping system up to (25.02 kg/ha/day) was recorded in the treatment where 100% RDF + S, Zn and B was applied followed by customized fertilizer (23.95 kg/ha/day) and recommended dose of fertilizer (23.43 kg/ha/day) which was 113, 104 and 100% higher, over control, respectively. Treatment T_2, T_3 and T_4 were statistically at par with each other and minimum system productivity was recorded in control (17.72 kg/ha/day). Ray *et al.,* (2009) and Samui *et al.,* (2004) and Ray *et al.,* (2016) also observed similar trend in their studies of rice based cropping system.

Gross return, cost of cultivation, net return and B: C ratio of rice- wheat cropping system

Owing to highest cost of customized fertilizer, maximum cost of cultivation of rice wheat system was noticed in T_4 (customized fertilizer + urea) in both seasons (Table 2). This was closely followed by T_6 and the lowest in control (T_1). The highest system gross return, net return and benefit: cost ratio were recorded with application of 100% RDF + S_{40} + Zn_5 +B $_{1.5}$ ha^{-1} to rice followed by 100% RDF to wheat (T_3) which was comparable to T_2 and T_4 and significantly higher than other treatments. Similarly, T_3 through remained at par with T_2 and T_5 proved significantly superior to other treatments with respect to net return and B: C ratio. Yadav and Kumar (2009) and Maurya *et al.,* (2013) also reported similar results from rice–wheat system using organic amendments and chemical fertilizers. However, the control (T_1) recorded the lowest value of gross return, net return and B: C ratio. The results obtained are in close conformity with the findings of Ghosh *et al.,* (2003) and Kumar and Singh (2006).

Soil fertility

Application of organic and inorganic sources of nutrients did not significantly affect soil pH (Table 3).The pH of post harvest soil varied from 7.71 to 7.89. The highest was recorded in 100% RDF + S_{40} + Zn_5 +B $_{1.5}$ ha^{-1} (T_3). The electrical conductivity was maximum in the treatment where customized fertilizer was used (T_4) and minimum was in control (T_1) this might be due to the release of salts which increased EC of soil. Post harvest rice soils showed buildup of organic carbon in 75% RDF + 25% N through vermicompost followed by 75% RDF + 25% N through sewage sludge and 75% RDF + 25% N through sesbania compared to control. The available N content of soil was the highest with application of 100% RDF. The increase in N content with 100% RDF (T_2), 100% RDF + S_{40} + Zn_5 +$B_{1.5}$ ha^{-1} (T_3) and 75% RDF + 25% N through sewage sludge (T_5) was 13, 8 and 6%, respectively, over customized fertilizer (T_4). Treatment control (T_1) and 100% RDF + S_{40} + Zn_5 +$B_{1.5}$ ha^{-1} (T_3) were statistically similar and the minimum was recorded in customized fertilizer (T_4). The soil available P increased by 61, 48 and 14% for 75% RDF + 25% N through vermicompost, 75% RDF + 25% N through sewage sludge and customized fertilizer, respectively over the control (T_1). The minimum available P was recorded in 100% RDF.

Soil analyzed after the harvest of wheat crop did not affect soil pH significantly (Table 3). However, non significant increase in electrical conductivity over control was observed with application of 100% RDF. A significant increase in organic carbon content with the application of 100% RDF, 75% RDF + 25% N through vermicompost (0.54%) and 75% RDF + 25% N through sewage sludge (0.50%) as compared to control was recorded. The highest organic carbon content was in treatment T_6. The available N content of soil was the highest in treatment where customized fertilizer was applied (T_4) followed by T_6 and T_7 and the lowest was in control (T_1).

The treatment T_2 and T_3 was statistically similar. The soil available P increased by 62, 45 and 36% for treatments T_4, T_5 and T_6, respectively over the control (T_1), it was reported that organic manuring as sludge, vermicompost and sesbania played a beneficial role in retaining a major portion of the added P in plant available form by suppressing P sorption (Iyamuremye and Dick 1996) and improving soil P fertility status (Reddy *et al.*, 1999 and Behera *et al.*, 2007). Significantly higher concentration of available P in customized fertilizer might be attributed to its higher rate of addition. The lowest K content was recorded in treatment T_2 (100% RDF) which was 1.7% lower the control (T_1). The highest K content was recorded with application of customized fertilizer (T_4) followed by T_5 and the lowest was in control (T_1). Subba Rao *et al.*, 1998 and Behera *et al.*, 2007 reported similar result.

Table.1 Treatments details

Treatment	Rice (Variety: HUR 105)	Wheat (Variety Malviya- 234)
T_1	Control-NPK(00-00-00)	Control-NPK(00-00-00)
T_2	RDF - NPK (120-60-60) ha^{-1}	RDF - NPK (120-60-60) ha^{-1}
T_3	RDF + S, Zn, B (40-05-1.5) ha^{-1}	RDF - NPK (120-60-60) ha^{-1}
T_4	Customized Fertilizer* [11: 32: 13: 0.9: 0.24 (N: P_2O_5: K_2O: Zn: B)]	Customized Fertilizer [10: 18: 25: 3.0: 0.5 (N: P_2O_5: K_2O: S:Zn)]
T_5	75% RDF + 25% N through sewage sludge ha^{-1}	RDF - NPK (120-60-60) ha^{-1}
T_6	75% RDF + 25% N through Vermicompost ha^{-1}	RDF - NPK (120-60-60) ha^{-1}
T_7	75% RDF + 25% N through *Sesbania* (GM) ha^{-1}	RDF - NPK (120-60-60) ha^{-1}

Table.2 Effect of organic and inorganic source of plant nutrients application on Yield, REY, system productivity, profitability and economics of rice – wheat cropping system

Treatment*	Rice yield (t ha^{-1})		Wheat yield (t ha^{-1})		REY (q ha^{-1})	System productivity kg/ha/day	System Profitability (Rs./ha/day)	Gross return (Rs.) ha^{-1}	Cost of cultivation (Rs.) ha^{-1}	Net return (Rs.) ha^{-1}	B:C ratio
	Grain	Straw	Grain	Straw							
T_1	2.18	2.71	0.89	1.55	32.20	11.72	37.60	56121	42398	13723	1.32
T_2	4.08	5.86	3.47	5.57	78.37	23.43	243.11	142480	53744	88736	2.65
T_3	4.22	6.17	3.55	5.93	80.62	25.02	251.91	148114	56169	91945	2.64
T_4	4.21	6.09	3.07	5.46	75.88	23.95	198.08	138126	65825	72301	2.10
T_5	3.95	5.73	3.29	5.70	75.27	22.32	234.48	139321	53735	85586	2.59
T_6	4.20	5.47	3.49	5.93	79.98	22.83	225.85	145661	63225	82436	2.30
T_7	4.10	5.47	3.47	5.70	78.55	22.53	228.85	142859	59330	83529	2.41
SEm±	0.10	0.10	0.10	0.08	1.09	0.51	5.22				
CD (P=0.05)	0.31	0.31	0.32	0.26	3.36	1.57	16.09				

Table.3 Effect of organic and inorganic sources of plant nutrients on pH, electrical conductivity (EC), organic carbon (OC) and nutrients content in post harvest soil

	Rice post harvest soil						Wheat post harvest soil					
Treatment*	pH	EC (dSm^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	pH	EC (dSm^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1	7.83	0.155	0.27	233.1	35.19	166.5	8.08	0.018	0.26	105.4	47.14	151.6
T_2	7.85	0.614	0.29	244.3	35.17	180.7	8.20	0.021	0.32	110.8	60.45	149.0
T_3	7.89	0.589	0.29	233.1	35.30	204.6	8.07	0.023	0.32	111.9	56.51	146.3
T_4	7.78	0.639	0.25	215.9	40.23	196.0	8.21	0.021	0.46	127.5	76.39	160.2
T_5	7.78	0.512	0.36	228.9	52.06	177.7	8.26	0.022	0.50	107.3	68.44	157.9
T_6	7.82	0.198	0.37	222.7	56.54	179.2	8.20	0.020	0.54	122.3	64.29	154.9
T_7	7.71	0.497	0.36	218.5	38.87	178.5	8.31	0.020	0.44	122.3	60.50	152.7
SE m±	0.05	0.048	0.04	13.28	3.73	10.65	0.06	0.002	0.04	4.59	3.96	3.28
CD (P=0.05)	NS	0.147	NS	NS	11.49	NS	NS	NS	0.12	14.14	12.22	NS

This was evidently due to addition of organic matter containing major and micronutrients, as well as their solubilizing effect on native nutrients (Manna *et al.,* 2003 and Behera *et al.,* 2007). Thus, it may be concluded that conjoint application of organic and inorganic sources of nutrients enhanced yield and improved soil fertility. The highest rice grain yield was recorded with application of 100% RDF + S_{40}, Zn_5 and $B_{1.5}$ and statistically similar yield was found with customized fertilizer. The maximum REY, system productivity and profitability and economics was also found with 100% RDF + S_{40}, Zn_5 and $B_{1.5.}$ This indicates the necessity for balanced use of nutrients (macro and micro) for enhancing systems rice equivalent yield, productivity and profitability without depleting soil fertility.

Acknowledgements

The authors are grateful to M/S Sathguru Management Consultant, Hyderabad for providing financial assistance under USAID-AIP programme during the course of investigation.

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How to cite this article:

Singh, S.K., Maneesh Kumar, R.P. Singh, J.S. Bohra, J.P. Srivastava, S.P. Singh and Singh, Y.V. 2017. Conjoint Application of Organic and Inorganic Sources of Nutrients In Relation to System Productivity, Profitability, Soil Fertility and Economics of Rice (*Oryza Sativa*)-Wheat (*Triticum Aestivum*) Cropping System. *Int.J.Curr.Microbiol.App.Sci.* 6(4): 920-928.
doi: https://doi.org/10.20546/ijcmas.2017.604.116