Response of integrated nutrient management on crop productivity and soil fertility under rice (*Oryza sativa*)–wheat (*Triticum aestivum* L.) cropping system in Chhattisgarh plain agro-climatic zone

ABSTRACT

The study was conducted during 2016–2017 to and 2018–2019 at farmer's field under Farmer FIRST Project (FFP), JNKVV – College of Agriculture, Balaghat, Madhya Pradesh, to assess the impact of integrated nutrient management on crop productivity, soil nutrient balance and economics of rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L.) cropping system. Application of 75% NPK + 2.5 t vermicompost/ha + biofertilizers (BGA & PSB) produced significantly higher grain yield of rice and wheat (4495 kg/ha and 3455 kg/ha, respectively) over the Farmer Practice (3855 kg/ha and 2655 kg/ha, respectively). Maximum nutrients uptake (N, P & K) by rice and wheat crops were recorded in the treatment receiving 75% NPK + 5t/ha vermicompost/ha + biofertilizers. The conjunctive use of inorganic fertilizers along with organic manure and biofertilizers gave highest availability of soil N, P, K and Zn at post-harvest of wheat crop as compared to other treatment combinations. Further, results showed that the highest cost of cultivation (₹ 72400/ha) and net returns (₹ 84380/ha) were obtained in 75% NPK + 2.5 t/ha vermicompost/ha + biofertilizers treatments. The benefit cost ratio computed for rice – wheat cropping system suggested that the higher B:C ratio is associated with higher production and better quality of the produce.

Key words: FFP, INM, Nutrient availability, Production Efficiency, Net Return, Vertisol

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Introduction

Rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L.) is the prevalent cropping system in Chhattisgarh plain agro-climatic zone of Balaghat district. Wheat is most important cereal crop after paddy in India and both the crops are major staple foods, contributing a key portion of digestible energy and protein in human intake and occupying a premium position among all food communities [1, 2]. The rice–wheat cropping system is one of the most prominent cropping systems prevailing on the Indian subcontinent and is considered to be of utmost importance for food security and livelihood [3]. Thus, rice – wheat cropping system emerged as an efficient cropping system of Madhya Pradesh and India.

The availability of nutrients in the soil for plant utilization is affected not only by the inherent soil characteristics but also by the fertilizer use and practices followed in a cropping system. It has been observed that a major part of the applied nutrient gets fixed and only a small part of it becomes available to the crop plants at farmer's field [4, 5]. The organic matter like vermicompost being the storehouse of nutrients, combined application of organic and inorganic fertilizers can increase the yield, improve the fertility status of soil, improve the input-use efficiency by the crop and can certainly cut down the expenditure on costly fertilizers [6]. However, the microbial inoculants (biofertilizers) are required to promote adequate supply of nutrients to the host plants to ensure their proper growth and development, by regulating various physiological processes. Among the biofertilizers N_2 fixing biofertilizers *i.e.* BGA (*Cyanobacteria*), *Azotobactor* and Phosphate Solubilizing Bacteria (PSB) offer great promise to the crops enabling the inoculated plants for more uptake of nutrients particularly nitrogen and phosphorus from the soil.. Further, the integration of inorganic fertilizers, organic manures and biofertilizers will not only sustain the crop production but also is effective in improving soil health and enhancing the nutrient use efficiency [7]. Thus, the balance dose of inorganic fertilizers along with organic manure and biofertilizers offers a great scope for increasing productivity of different cropping systems and for sustaining soil health.

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Integrated nutrient management (INM) or integrated nutrient supply (INS) help to achieve efficient use of synthetic fertilizers integrated with organic sources of nutrients. INM is developed with an understanding of the interactions among crops, soils, and climate, which advocates the integration of inorganic and organic sources of nutrients. This approach is based on the maintenance of plant nutrition supply to attain a certain level of crop production by enhancing the benefits from all potential sources of plant nutrition in a cohesive manner, applicable to each cropping pattern and farming scenario. The inclusion of organic manures regulates the uptake of nutrients, positively affecting production, improving soil quality (physical, chemical, and biological), and producing a synergistic effect on crops. INM integrates traditional and recent practices of nutrient management into an environmentally sound and cost-effective ideal farming system that uses remunerations from all probable sources of nutrition (organic, inorganic, and biological) in a careful, effective, and combined way. It optimizes the balance between input sources and outputs with the goal of coordinating the nutritional demand of the crop and its discharge in its surroundings [8]. Therefore, different field demonstrations were undertaken to assess the impact of integrated nutrient management on crop productivity, profitability of rice – wheat cropping system and sustainable soil health.

MATERIALS AND METHODS

The present study was conducted under the ongoing ICAR funded project on Farmer FIRST at JNKVV – College of Agriculture, Balaghat, Madhya Pradesh, India. Balaghat is one of the tribal district of Madhya Pradesh (21º34'56" N latitude and 79º47'31" E longitude) and uniquely situated in Chhattisgarh plain agro climatic zone. The study area possesses a semi-arid and sub-tropical climate with a characteristic feature of dry summer and cold winter. The total annual rainfall varies from 1400 to1500 mm with the mean value of around 1400 mm.

The field demonstrations were conducted during *kharif* and *rabi* season of 2016–2017, 2017–2018 and 2018–2019 in the adopted villages i.e. Lendejhari, Chillod and Koppe under Farmer FIRST project running through College of Agriculture, Balaghat, Madhya Pradesh. At the beginning of the experiment, soil samples were collected before treatments application and analyzed for basic soil properties (Table 1).

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The experiment was laid out in a randomized block design with five treatments comprising of different combinations of inorganic fertilizers, organic manures and biofertilizers replicated four times. The details of the treatments were T_1 = Farmer Practice (as Control), T_2 = 100% NPK, T_3 = 100% NPK + Zn, T_4 = 75% NPK+ 2.5t/ha Vermicompost ha and T_5 = 75% NPK + 2.5t/ha Vermicompost + Biofertilizers (BGA/*Azotobacter* & PSB). The demonstrations were conducted at college field and in adopted villages (Lendejhari, Chillod and Koppe) under FFP which were treated as replication for the present investigation.

The 100% optimal NPK doses based on soil test values were 120:60:40 (N: P_2O_5: K_2O) kg/ha for rice and wheat, respectively. The sources used for N, P and K supply were urea, single super phosphate and muriate of potash, respectively. In both rice and wheat crops 50% N, 100% P and 100% K were applied as basal before last harrowing and rest 50% N was applied in two equal splits first half at 21–25 days and rest at 51-55 days after transplanting or sowing. In addition to these applications, $ZnSO_4$ was applied @ 25 kg/ha only in rice crop to the treatment with Zn. The vermicompost was applied @ 2.5 t/ha/year to rice crop only before 10 – 15 days before transplanting. The different biofertilizers used in different crops *i.e.* BGA in rice, *Azotobacter* in wheat and PSB was applied @ 3–5 kg/ha in both the crops. In Farmer Practice treatments, application of only Di-ammonium Phosphate (DAP) fertilizer was done @ 125 kg/ha in both the crops just before transplanting and/or sowing. While, urea was applied @ 250 kg/ha in two equal split doses i.e. first at 21–25 days and at 51-55 days after transplanting or sowing of both the crops.

Rice variety JR-206 was grown as rainfed in the first/second week of July during *Kharif* and harvested in 115 - 120 days which was followed by wheat variety JW3388 was sown in the second week of November as also rain fed situation during *rabi* and harvested in115– 120 days. Chemical herbicides i.e. Bispyribac sodium @ 250 ml/ha for rice and Clodinofop and meta sulfosulfuron methyle @ 25 gm/ha for wheat were used for weed control. Insects and diseases were kept under control by following suitable control measures. Rice and wheat crops were harvested at maturity and yield data were recorded after threshing.

The grain and straw of rice and wheat were taken to determine nutritional (NPK) content. On the basis of nutrient content, the nutrient uptake was calculated in kg/ha in relation to dry matter production (yield kg/ha). To assess the resource-use efficiency of the system in terms of production efficiency (%) was calculated by dividing standard output (yield) by your actual output, and expressed in percentage form. The economics was calculated on the basis of prevailing market prices of different inputs and outputs. However, soil samples (0 –15 cm depth) were collected after harvesting of wheat crop during 2018-19. The soil samples were analyzed through standard laboratory procedures for different soil properties viz. soil pH, organic carbon, available N, P and K. Further, the data generated on soil analysis, yields and nutrient uptake were statistically analyzed to draw inferences [9].

RESULTS AND DISCUSSION

Crop Productivity: The data pertaining to the mean grain yields of rice and wheat have been presented in (Table 1) The data indicated that highest pooled average grain yield of rice (4495 kg/ha) and wheat (3455 kg/ha) were obtained in treatment 75% NPK with organic manure and biofertilizers (75% NPK + Vermicompost + BF) and the lowest yield of rice (3855 kg/ha) and wheat (2655 kg/ha) were recorded in control plot (Farmers Practice). The results of three cycles of experiment indicated that the imbalance dose of nutrients (N & P only) had reduced the yield by 16.6 % and 30.1% for rice and wheat, respectively from 100% NPK. Continuous application of N and P only exhibited declining trend with time due to imbalance use of nutrients [10]. These findings clearly indicated that the highest crop response in terms of yield was found with balance fertilization. Hence balance fertilization is the key to efficient fertilizer utilization for sustaining high yields. These findings indicated that integrated use of inorganic fertilizer, organic manure and biofertilizers treatment was superior over optimal application of fertilizers (100% NPK). Thus, the balance use of

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fertilizer either alone or in combination with organic manure is necessary for sustaining soil fertility and productivity of crops [11].

Nutrients (NPK) uptake by rice – wheat cropping system: The highest nutrients (NPK) uptake by rice and wheat were observed in 75% NPK + Vermicompost + Biofertilizers treatments while, the lowest uptake was found in Farmer Practice (Table 1). The pooled data of three years revealed that the integrated nutrient management (INM) treatments increased nutrients uptake by rice and wheat. The higher nutrient uptake with organic manure and biofertilizers treatment might be attributed due to solubilization of native nutrients, chelation of complex intermediate organic molecules produced during decomposition of added organic manures, their mobilization and accumulation of different nutrients in different plant parts [12, 13].

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Basic soil properties: There were no significant a difference in soil reaction (pH) was noticed due to different treatments of fertilizers and manure (Table 2). The soil organic carbon content had increased significantly from its initial value of 6.2 g/kg to attain a maximum value of 7.3 g/kg in the treatment comprised of 75% NPK along with vermicompost and Biofertilizers. This could be ascribed due to the addition of organic material by annual use of 2.5 t/ha vermicompost during the period of experimentation. Further, increasing levels of fertilizer application helped in increasing the soil organic carbon content due to increased contribution from the biomass, as it was also observed that with increasing levels of fertilizer application, the crop yields was increased. The contribution from root stubble could also be expected to follow the same trend [14, 15, 16]

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The perusal of data indicated that the available nitrogen content ranged from 264.0 to 314.3 kg/ha (Table 2) and the highest value was noted with treatments where integration of inorganic fertilizer with organic manure and biofertilizers was done. Such increase in available N might be due to the mineralization of FYM and atmospheric nitrogen fixation by BGA and *Azotobacter* biofertilizers [17, 18, 19]. The soil available P (Table 2) was either maintained or significantly improved due to addition of different organic manure and PSB with inorganic fertilizers over the Farmer Practice (17.8 kg/ha). Organic manures, on decomposition, solubilize insoluble organic P fractions through release of various organic acids, thus resulting into a significant improvement in available P status of the soil [20, 21]. Similarly, the highest value of available K was recorded (278.0 kg/ha) under conjoint use of inorganic fertilizers with organic manure and biofertilizers treatment and the lowest in Farmer Practice (244.6 kg/ha). Further, the available K content was depleted in Farmer Practice plot over its initial value (248.6 kg/ha). This may be due to continuous application of imbalance nutrition (N or NP alone) in soil. Continuous omission of K in crop nutrition caused mining of its native pools that caused reduction in the crop yields [22, 23]. The findings further revealed that addition of zinc along with 100% NPK significantly raised the level of available Zn content (0.62 mg/kg) in the soil (Table 2). A significant buildup of available Zn due to application of zinc sulphate has been reported by Sawarkar *et al.*,[24]. Further, the inclusion of vermicompost also contributed significantly to the buildup of Zn content (0.60 mg/kg) in soil over the initial value (0.54 mg/kg). This could be attributed due to the direct contribution of vermicompost to nutrient pool or its beneficial effects either through complexation or mobilization of native Zn [25].

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Nutrient balance in rice – wheat cropping system: It is essential to calculate the apparent nutrient balance to attain the desired level of production without depleting the native reserves and ensuring the maintenance and improvement in soil fertility. The maximum available nitrogen status was observed in 100% NPK + Vermicompost treatment (15.6 kg/ha/yr) from its initial values (Table 3). In case of phosphorus balance, P was relatively immobile in soil as compared to N and K especially in Vertisol and it was confined only to upper layer of profile. Appreciable increase in available P status in soil was recorded in all the treatments except Farmer Practice. The maximum negative balance of K in soil was recorded in Farmer Practice [26].

Production Efficiency (PE)**:** Production efficiency of the rice - wheat cropping system was calculated and found the highest production efficiency of rice – wheat cropping system under the integrated nutrient management practice of 75% NPK + Vermicompost + Biofertilizers (99.8% and 76.7%) and the lowest in Farmer Practice [21, 26].

Economics of rice – wheat cropping system**:** The results revealed that the higher cost of cultivation of rice – wheat cropping system under integrated nutrient management practices (Table 4) was observed in 75% NPK + Vermicompost + Biofertilizers (₹ 72400/ha). While, lower cost of cultivation was noted in Farmer Practice (₹ 62000/ha). The net returns were also found the highest under the nutrient management of 75% NPK + Vermicompost + Biofertilizers treatments (₹ 84380/ha) and the least in Farmer Practice (₹ 69706/ha). The benefit-cost ratio was calculated significantly higher under the integrated nutrient management treatments i.e. 2.23 in 75% NPK + Vermicompost + Biofertilizers over Farmer Practice (2.12). Thus, it is suggested that the rice – wheat cropping system cultivation grown with integrated application of inorganic fertilizers with organic manure and biofertilizers was found to be productive and profitable [27, 28].

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Thus, it is concluded that the conjoint use of organic manure and biofertilizer along with 75% NPK not only sustains the higher yield of rice–wheat cropping system, but also improves the soil health/fertility.

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Table 1. Response of different nutrients on yields and nutrient (NPK) uptake by rice – wheat cropping system (pooled mean of three year)

Treatment	Pooled grain yield and nutrient (NPK) uptake by rice (kg/ha)	Pooled grain yield and nutrient (NPK) uptake by wheat (kg/ha)

	Yield	N	P	K	Yield	N	P	K
Farmer Practice	3855	57.7	14.5	89.2	2655	131.2	24.1	141.5
100% NPK	4235	65.3	16.9	95.8	2840	147.5	29.2	158.6
100%NPK+Zn	4311	67.9	17.3	96.1	2950	140.2	26.7	150.4
75%NPK+ Vermicompost	4386	58.6	14.9	93.2	3230	143.7	27.8	154.4
75%NPK+ Vermicompost +BF	4495	61.8	15.6	95.1	3455	146.4	28.5	155.6
CD *(P=0.05)*	218.0	3.52	2.01	4.63	186.0	5.87	2.58	4.78

Table 2. Effect of continuous cropping and fertilizer use on nutrient status of soil after harvest of wheat (2018–19)

Treatment	Soil pH	OC (g/kg)	Available Nutrients (kg/ha)			Av. Zn (mg/kg)
			N	P	K	
Farmer Practice	7.3	6.1	264.0	17.8	244.6	0.50
100% NPK	7.2	6.4	301.3	20.0	270.2	0.53
100%NPK+Zn	7.2	6.7	306.2	20.4	271.8	0.62
75%NPK+Vermicompost	7.3	6.9	310.7	21.2	277.3	0.60
75%NPK+ Vermicompost +BF	7.1	7.3	314.3	22.1	278.0	0.61
CD *(P=0.05)*	NS	0.11	25.2	2.69	16.2	0.13
Initial value (2016–17)	7.2	6.2	267.4	18.3	248.6	0.54

Table 3. Nutrient balance under rice–wheat cropping system after harvest of wheat (2018–19)

Treatment	Available nutrient contents after harvest of Wheat (kg/ha)			Apparent nutrient changes as compared to their initial values (kg/ha)			Increase/decrease in nutrient content of soil per year (kg/ha/yr)		
	N	P	K	N	P	K	N	P	K
Farmer Practice	264	17.8	244.6	-3.4	-0.5	-4.0	-1.1	-0.2	-1.3
100% NPK	301.3	20.0	270.2	33.9	1.7	21.6	11.3	0.6	7.2
100%NPK+Zn	306.2	20.4	271.8	38.8	2.1	23.2	12.9	0.7	7.7
75%NPK+ Vermicompost	310.7	21.2	277.3	43.3	2.9	28.7	14.4	1.0	9.6
75%NPK+ Vermicompost +BF	314.3	22.1	278.0	46.9	3.8	29.4	15.6	1.3	9.8
Initial value (2016-17)	267.4	18.3	248.6	–	–	–	–	–	–

Table 4. Effect of different treatments on production efficiency (PE) and economics of rice – wheat cropping system (pooled mean of 3 year)

Treatment	PE (%)		Cost of cultivation (₹ /ha)			Gross Returns (₹ /ha)			Net returns (₹ /ha)			B:C ratio
	Rice	Wheat	Rice	Wheat	Total	Rice	Wheat	Total	Rice	Wheat	Total	
Farmer Practice	85.6	59.0	34500	27,500	62000	75558	56418	131706	41,058	28648	69706	2.12
100% NPK	94.1	63.1	36150	29,400	65550	83006	60350	143356	43856	30950	74806	2.18
100%NPK+Zn	95.8	65.5	37100	30100	67200	84495	62687	147182	43995	32287	76282	2.19
75%NPK+ Vermicompost	97.4	71.7	38900	31100	70000	85965	68637	154602	44065	37037	81102	2.20
75%NPK+ Vermicompost +BF	99.8	76.7	40100	32300	72400	88,102	73418	161520	44432	39948	84380	2.23