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Research Paper

Productivity and profitability of wheat (*Triticum aestivum*)-based cropping systems under different nutrient-management practices

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ABSTRACT

A field experiment was conducted during the winter (*rabi*), summer and rainy (*kharif*) seasons of 2011–12 and 2012–13 at New Delhi, to evaluate the productivity, profitability and land-use efficiency of 4 wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.]-based cropping systems involving wheat, vegetable cowpea [*Vigna sinensis* (L.) Walp.], mungbean [*Vigna radiata* (L.) Wilczek], maize (*Zea mays* L.) and potato (*Solanum tuberosum* L.), and under 4 nutrients-management practices. System productivity of wheat-based cropping system in terms of wheat-equivalent yield (WEY) was significantly the highest under wheat–fallow–maize–potato (14.12 t/ha and 15.02 t/ha), followed by wheat–vegetable cowpea–maize (11.54 t/ha and 12.78 t/ha) during both the years. The land-use efficiency was comparatively higher in wheat–vegetable cowpea–maize and wheat–mungbean–maize systems than to wheat–fallow–maize–potato and wheat–fallow–maize systems during both the years. Wheat–fallow–maize–potato system recorded the highest system production efficiency (37.86 and 41.16 kg WEY/ha/day), whereas wheat–vegetable cowpea–maize recorded highest system economic efficiency (₹339 and ₹416/ha/day). Wheat–vegetable cowpea–maize recorded maximum net returns (₹123.7 × 10^3/ha and ₹151.7 × 10^3/ha) during both the years. Application of 100% recommended dose of fertilizer (RDF) in wheat, vegetable cowpea, mungbean, maize and potato gave significantly highest yield, followed by 50% RDF + 50% RDN through FYM and 50% RDF + 25% RDN through FYM + biofertilizers during the first years. However, all these 3 treatments did not differ significantly during the second year. Highest wheat equivalent yield (WEY) was achieved with the application of 100% RDF followed by 50% RDF + 50% RDN through FYM and 50% RDF + 25% RDN through FYM + biofertilizers during the first years. However, all these three treatments did not differ significantly during the second year. Substitution of either 50% or 25% RDN through FYM and biofertilizers significantly increased the available nitrogen, phosphorus and potassium content at the harvest of different crops over control as well as 100% RDF alone.

***Key words* :** Cropping systems, Land-use efficiency, Net returns, Nutrient management, Productivity, Profitability, Wheat

In India, wheat is the second most important cereal crop after rice grown under sub-tropical environment during November to April, covering an area of 30.21 million ha. Total annual production of wheat in India is 94.88 million tonnes, with the productivity of 3.14 tonnes/ha (DES, 2013). India is the second largest producer of wheat with approximately 12% world's wheat production and it is also the second largest consumer of wheat after China, and has a huge and growing demand. Of late, agricultural production systems in India are struggling for sustained growth to achieve food and nutritional security. Since there is very little scope for horizontal growth, only alternative left is vertical growth through increased intensity and productivity of the crops. Besides adoption of proper input-management technologies, diversification or intensification through crops of diverse nature may be a good proposition to break the monotony of the system (Tripathi and Singh, 2008).

Imbalanced use of fertilizers is an important issue in an Indian agriculture. Latest nutrient-management strategies target to deliver soluble inorganic nutrients directly to crops and have uncoupled carbon, nitrogen and phosphorus cycles spatially and temporally. The existing system of fertilizer application is based on the nutrient demand of individual crop ignoring the carry-over effect of fertilizer or organic manure applied to the succeeding crop to a

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great extent. Further, sustainable system productivitis achieved through integrated use of organic and inorganic sources of nutrients (Singh *et al*., 2008). Integration of inorganic fertilizers with organic manures and biofertilizers will not only help sustain the crop productivity but also will be effective in improving soil health and hastening the nutrient-use efficiency (Verma *et al*., 2005). Therefore, an attempt was made to diversify wheat–maize cropping system under different sources of nutrient to find out the most economical and sustainable system.

MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*), summer and rainy (*kharif*) seasons of 2011–12 and 2012–13 at the research farm of the Indian Agricultural Research Institute, New Delhi. The soil of the experimental site was sandy clay loam (sand 62.3 %, silt 12.1 % and clay 25.8 %) with pH 8.0 and electrical condcutivity (EC) 0.36 dS/m in the top 15 cm of soil. The soil was low in available nitrogen (166 kg/ha) and organic carbon (0.39%) and medium in phosphorus (15.8 kg/ha) and potassium (272 kg/ha). The treatments comprised 4 cropping systems, viz. wheat–fallow–maize (CS_1), wheat–vegetable cowpea–maize (CS_2), wheat–mungbean–maize (CS_3) and wheat–fallow–maize–potato (CS_4), and 4 nutrient-management practices, viz. control (NS_0), 100% RDF (NS_1), 50% RDF + 50% RDN through FYM (NS_2) and 50% RDF + 25% RDN through FYM + biofertilizers (NS_3). The experiment was laid out in strip-plot design and replicated thrice. Wheat 'HD 2967', vegetable cowpea 'Pusa Sukomal', mungbean 'Pusa 0672', maize 'PEHM 5' and potato 'Kufri Surya' were taken for experiment. The recommended dose of fertilizers (RDF) for different crops were decided based on soil-test-crop research (STCR) approach as per initial soil-test values of available N, P and K at the beginning of experiment and targeted yield of crops as 5.0, 1.0 and 5.0 t/ha for wheat, mungbean and maize respectively. The recommended dose of fertilizer (RDF) for vegetable cowpea and potato were decided based on prevailing recommended rates as STCR equations were not available. The RDF of wheat, vegetable cowpea, mungbean, maize and potato were 177:55:30, 71:62:0, 71:62:0, 210:120:67 and 150:60:80 kg $N:P_2O_5:K_2O$/ha respectively. Farmyard manure (FYM) was applied before sowing/planting of crops based on the nitrogen-equivalent basis and nutrient requirement of each crop in respective treatment. The FYM consisted 0.63, 0.25 and 0.56% of N, P and K respectively. The fertilizers and FYM were applied as per recommended methods and time of application for each crop. Seeds/tubers of crops were treated with *Rhizobium*/*Azotobactor* and phosphate-soubilizing bacteria PSB according to treatments. Higher and relatively well-distributed rainfall was received during 2012–13 as compared to 2011–12. The total rainfall received during 2011–12 and 2012–13 was 545 and 1,533 mm respectively. The average monthly air temperature, relative humidity and sunshine hours were almost similar during both the years. However, during 2012–13 the minimum temperature decreased up to freezing point in the last week of December.

Wheat was sown in the fourth week of November and harvested in the third week of April. The summer crops (vegetable cowpea and mungbean) were sown in the fourth week of April and harvested in the second week of July. Maize was planted in the third week of July and harvested in the second week of October. Potato was planted immediately after maize harvest in the third week of October and digging was done in the third week of December. Economic yields of the component crops were converted to wheat-equivalent yield (WEY), taking into account the prevailing minimum support price (MSP)/market prices of the crops. System productivity was calculated by adding the WEY of the component crops. Total field duration of a cropping system expressed in percentage of 365 days was taken as the land-use efficiency (LUE) of the system (Tomar and Tiwari, 1990). System productivity and system profitability values in terms of kg/ha/day and ₹/ha/day were calculated by WEY and net returns of the system divided by 365 days respectively (Sharma *et al.*, 2014).

RESULTS AND DISCUSSION

Productivity of winter crops

Differences in wheat grain yield due to different wheat-based cropping systems were not significant in both the years (Table 1). Differences in wheat grain yield and potato tuber yield were significant owing to different nutrient sources in both the years (Table 1). In the first year, wheat grain yield and potato tuber yield was significantly highest under the treatment which received 100% recommended dose of fertilizer (RDF). However, differences in wheat grain yield and potato tuber yield were not significant under the treatments, i.e. 50% RDF + 50% RDN through FYM and 50% RDF + 25% RDN through FYM + biofertilizers. But in second year, differences in wheat grain yield and potato tuber yield among treatments, i.e. 100% RDF, 50% RDF + 50% recommended dose of nitrogen (RDN) through FYM and 50% RDF + 25% RDN through FYM + biofertilizers were not statistically significant. It may be due to organic source, i.e. FYM which act as a substrate for microorganisms and use of biofertilizers improves soil conditions favourable for availability of nutrients to the crops (Sharma *et al.,* 2008).

Productivity of summer crops

Differences in vegetable cowpea pod yield and mungbean grain yield due to nutrient-management practices was significant in both the years (Table 1). In first year, 100% RDF recorded significantly highest vegetable cowpea pod yield and mungbean grain yield over 50% RDF + 50 RDN through FYM, 50% RDF + 25% RDN through FYM + biofertilizers and the control. However, differences between treatments, i.e. 50% RDF + 50 RDN through FYM and 50% RDF + 25% RDN through FYM + biofertilizers were not significant. The variations in vegetable cowpea pod yield and mungbean grain yield due to treatments, i.e. 100 % RDF, 50% RDF + 50% RDN through FYM and 50% RDF + 25% RDN through FYM + biofertilizers, were not significant in the second year; however, they resulted in significantly highest yield of both the crops over the control. Use of FYM and biofertilizers resulted in increased availability of nutrients along with retention of higher moisture in soil profile and moderation of soil temperature during summer which favoured better growth and yield of vegetable cowpea and mungbean.

Productivity of rainy-season crop

Maize grain yield indicated that grain yield differed significantly due to various wheat based cropping systems in both the years (Table 1). Significantly highest maize grain yield was recorded under wheat–vegetable cowpea–maize and wheat–mungbean–maize cropping systems over wheat–fallow–maize and wheat–fallow–maize–potato cropping systems. It might be owing to legume effect because vegetable cowpea and mungbean grown as preceding crops. Improvement in performance of cereals following legumes occurs to the tune of 0.5 to 3 t/ha which amounts to around 30 to 35% yield increase in comparison to cereal-cereal cropping sequence (Peoples and Craswell, 1992). Kolar and Gill (1994) also observed that inclusion of leguminous crops after wheat proved beneficial to succeeding maize crop than keeping the land fallow.

The differences in maize grain yield due to different nutrient sources were significant in both the years (Table 1). In first year, 100% RDF resulted in significantly highest maize grain yield over 50% RDF + 50% RDN through FYM, 50% RDF + 25% RDN through FYM + biofertilizers and control. However, treatments, i.e. 50% RDF + 50% RDN through FYM and 50% RDF + 25% RDN through FYM + biofertilizers, were statistically equal. In the second year, differences in maize grain yield was not significant due to different nutrient sources, i.e. 100% RDF, 50% RDF + 50 RDN through FYM and 50% RDF + 25% RDN through FYM + biofertilizers; however, they all showed significantly higher maize grain yield over

Table 1. Effect of cropping systems and nutrient-management practices on yields of crops and system productivity (t/ha)

Treatment	Yield of crops											
	Wheat grain		Vegetable cowpea green pod		Mungbean grain		Maize grain		Potato tuber		System productivity	
	2011–12	2012–13	2011–12	2012–13	2011–12	2012–13	2011–12	2012–13	2011–12	2012–13	2011–12	2012–13
Cropping systems												
Wheat–fallow–maize	4.68	5.26	-	-	-	-	5.31	5.51	-	-	8.77	9.98
Wheat–vegetable cowpea–maize	4.67	5.26	3.04	3.41	-	-	5.89	5.92	-	-	11.54	12.78
Wheat–mungbean–maize	4.68	5.28	-	-	0.51	0.56	5.85	5.90	-	-	10.57	12.10
Wheat–fallow–maize–potato	4.11	4.57	-	-	-	-	5.41	5.53	12.67	13.32	14.12	15.02
SEm±	0.04	0.06					0.04	0.02			0.05	0.09
CD (P=0.05)	NS	NS					0.13	0.06			0.19	0.31
Nutrient management												
Control	4.02	4.48	2.20	2.63	0.48	0.48	5.06	5.13	8.36	8.58	9.63	10.65
100% RDF	4.88	5.36	3.52	3.84	0.56	0.61	5.90	5.99	14.84	15.54	12.18	13.32
50% RDF + 50% RDN through FYM	4.64	5.27	3.30	3.67	0.51	0.58	5.78	5.90	13.87	14.80	11.67	13.01
50% RDF + 25% RDN through FYM + biofertilizers	4.60	5.27	3.14	3.53	0.51	0.57	5.72	5.86	13.61	14.37	11.52	12.91
SEm±	0.05	0.05	0.06	0.09	0.004	0.01	0.03	0.05	0.17	0.38	0.05	0.13
CD (P=0.05)	0.16	0.17	0.25	0.42	0.02	0.07	0.10	0.17	0.78	1.71	0.18	0.43

the control.

System productivity

System productivity in terms of wheat-equivalent yield (WEY) indicated that WEY differed significantly due to different wheat-based cropping systems in both the years. Significantly highest WEY was recorded under wheat–fallow–maize–potato followed by wheat–vegetable cowpea–maize, wheat–mungbean–maize and lowest in wheat–fallow–maize. Similar trend was observed in both the years. Significantly maximum WEY was achieved under wheat–fallow–maize–potato cropping systems was owing to higher potato yield potential.

The wheat equivalent yields (WEY) were differed significantly due to various nutrient sources in both the years (Table 1). In the first year, significantly highest WEY was recorded under 100% RDF however, difference between 50% RDF + 50% RDN through FYM and 50% RDF + 25% RDN through FYM + biofertilizers (11.52 t/ha) was similar statistically. In the second year, system productivity did not differ significantly due to different nutrient sources, i.e. 100% RDF, 50% RDF + 50% RDN substituted through FYM and 50% RDF + 25% RDN substituted through FYM + biofertilizers; however, they all recorded significantly higher WEY over control.

System economics

Significantly highest net returns were obtained under wheat–vegetable cowpea–maize followed by wheat–fallow–maize–potato and wheat–mungbean–maize and lowest in wheat–fallow–maize in both the years (Table 2). Significantly highest net returns were obtained with 100% RDF followed by 50% RDF + 25% RDN substituted through FYM + biofertilizers in both the years (Table 2). Integration of FYM had increased the cost of treatment, therefore, reduced the system net returns as compared to RDF.

Land-use efficiency and system productivity

Wheat–vegetable cowpea–maize and wheat–mungbean–maize systems expressed the maximum land-use efficiency (LUE) during both the years (Table 2). These 2 systems occupied land for almost similar duration, thereby achieved similar LUE. Wheat–fallow–maize recorded lowest LUE, as no summer crops was grown in this system. The LUE did not differ significantly among different nutrient sources during both the years. Wheat–fallow–maize–potato system recorded the highest system production efficiency during both the years (Table 2). However, wheat–vegetable cowpea–maize system recorded the highest system economic efficiency during both the years. Further, application of 100% RDF through fertilizers recorded the highest system production economic efficiency and economic efficiency during both the years.

Soil-fertility status

The available nitrogen, phosphorus and potassium content of soil was not affected significantly by different crop-

Table 2. Economics and land-use efficiencies of wheat-based cropping systems and nutrient-management practices

Treatment	Total cost (×10^3 ₹/ha)		Net returns (×10^3 ₹/ha)		LUE (%)		Production efficiency (kg WEY/ha/day)		Economic efficiency (₹/ha/day)	
	2011–12	2012–13	2011–12	2012–13	2011–12	2012–13	2011–12	2012–13	2011–12	2012–13
Cropping systems										
Wheat–fallow–maize	49.5	53.1	91.8	116.1	62.1	61.6	23.2	27.3	252	318
Wheat–vegetable cowpea–maize	70.3	75.7	123.7	151.7	83.8	82.4	30.7	35.0	339	416
Wheat–mungbean–maize	64.0	69.4	101.8	130.9	83.8	82.4	28.0	33.1	279	359
Wheat–fallow–maize–potato	101.7	107.8	108.2	131.2	75.8	72.6	37.8	41.1	297	360
SEm±			0.7	1.1						
CD (P=0.05)			2.6	4.1						
Nutrient management										
Control	57.2	62.4	97.4	118.5	76.4	74.7	25.6	29.1	267	325
100% RDF	69.9	75.0	121.6	147.0	76.4	74.7	32.4	36.4	333	403
50% RDF + 50% RDN through FYM	83.8	88.9	99.8	128.4	76.4	74.7	31.0	35.6	274	352
50% RDF + 25% RDN through FYM + biofertilizers	74.6	79.7	106.8	136.0	76.4	74.7	30.7	35.3	293	373
SEm±			0.7	1.2						
CD (P=0.05)			2.7	4.3						

The Minimum Support Price (MSP)/market prices of wheat, vegetable cowpea, mungbean, maize and potato during 2011–12 and 2012–13 were 12.9, 10, 35, 10, 6 and 13.5, 10, 44, 12, 6 ₹/kg respectively; LUE, Land-use efficiency

Table 3. Effect of wheat-based cropping systems and nutrient-management practices on available N, P and K status (kg/ha) of soil at the end of cropping cycle

Treatment	Nitrogen	Phosphorous	Potassium
Cropping system			
Wheat–fallow–maize	168.9	15.8	273.3
Wheat–vegetable cowpea–maize	171.2	16.1	277.1
Wheat–mungbean–maize	170.3	16.0	276.2
Wheat–fallow–maize–potato	169.9	15.8	275.0
SEm±	0.95	0.03	0.57
CD (P=0.05)	NS	NS	NS
Nutrient management			
Control	146.3	12.8	258.3
100% RDF	165.4	15.4	271.1
50% RDF + 50% RDN through FYM	185.3	17.9	287.5
50% RDF + 25% RDN through FYM + biofertilizers	183.2	17.6	284.7
SEm±	0.63	0.09	0.81
CD (P=0.05)	2.14	0.31	2.81
Initial value	166.8	15.8	272.3

ping systems at the end of cropping cycle, as the treatment applied to different cropping systems were similar during both the years (Table 3). With regard to the effect of nutrient sources on soil-available nitrogen, phosphorus and potassium content, application of 100% RDF had no significant effect at the end of study. However, substitution of either 50% or 25% RDN through FYM and biofertilizers significantly increased the available nitrogen, phosphorus and potassium content at the harvest of different crops over the control as well as 100% RDF alone and the highest value was observed with the application of 50% RDF + 50% RDN through FYM followed by 50% RDF + 25% RDN through FYM + biofertilizers. The enhanced available nutrients content of soil might also be owing to favourable soil conditions under organic manure (FYM) which might have helped in the mineralization of nutrients leading to higher built up of available nutrients.

Wheat–fallow–maize–potato was found to be most productive. As responses of system productivity (WEY) varied with nutrient sources among cropping systems, this shows scope of optimization of nutrient sources according to needs of crops in particular system. In terms of monetary returns wheat–vegetable cowpea–maize was found to be most remunerative. To get optimum yields and improved soil health the part of RDF can be substituted with organic manure and biofertilizers almost equivalent to 100% RDF.

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