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Research Paper

Influence of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) system diversification on productivity and profitability under Garhwal Himalayan region

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ABSTRACT

The experiment was conducted at 12 farmers' fields during 2009–10 and 2010–11 to find out the alternate efficient cropping systems in rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) cropping system in Garhwal Himalayas. Five cropping systems including the existing rice–wheat–fallow cropping system were tested at 12 farmers' fields as researcher designed farmer managed trials. Highest rice-equivalent yield (26.45 t/ha) was recorded with the rice–vegetable pea (*Pisum sativum* L.)–vegetable Frenchbean (*Phaseolus vulgaris* L.) cropping system and it was followed by rice–Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson]–blackgram [*Vigna mungo* (L.) Hepper] (16.0 t/ha), rice–mustard–greengram [*Vigna radiata* (L.) Wilczek] (14.97 t/ha) and rice–wheat + Indian mustard–fallow (10.43 t/ha) cropping systems. Highest net returns (₹236.7 thousand/ha) was also recorded under rice–vegetable pea–vegetable Frenchbean system and it was followed by rice–Indian mustard–blackgram (₹115.5 thousand/ha), rice–Indian mustard–greengram (₹109.5 thousand/ha). The highest benefit: cost ratio (2.74) was recorded with rice–vegetable pea–vegetable Frenchbean cropping system. The highest increase in net profit over the traditional rice–wheat cropping system (₹150.8 thousand/ha) was recorded under the rice–vegetable pea–vegetable Frenchbean cropping system

***Key words**:* Diversification, Economics, Productivity, Rice–wheat cropping system

In northern India, the rice–wheat cropping system (RWCS) is the predominant cropping system. This system covers about 10.5 million ha area and contributes about 38% to the national food basket, and is considered as the backbone of food security. In future too, rice–wheat system is likely to play important role in sustaining the foodgrain self-sufficiency. The system productivity of traditional RWCS can be increased up to the level of 9.1 to 21.5 t/ha/year, depending on the choice of high-value crops involved in diversification of rice–wheat system (Gangwar, 2009).

Continuous cultivation of RWCS during the last 3 decades has resulted in many second- generation problems like decline in watertable, emergence of multi-nutrient deficiencies, formation of hard pan and build up of several weeds; besides that, the stagnation in system productivity and profitability is being experienced in recent years. The RWCS is the predominant cropping system in Uttarakhand state too; here rice and wheat crops are being grown on 295,000 and 398,000 respectively. The average productivity of rice and wheat in Uttarakhand was 2.08 and 2.15 t/ha, respectively during 2009–10 (Government of Uttarakhand, 2011). Due to multifold problems and stagnation in productivity of rice–wheat system a need is being felt to diversify and intensify the existing RWCS with remunerative and efficient crops like pulses, oilseeds and vegetables. Therefore present study was undertaken to find out the productivity and economics of various possible cropping systems by incorporating pulses and vegetable crops that can replace traditional RWCS.

MATERIALS AND METHODS

The experiment was conducted at 12 farmers' fields during 2009–10 and 2010–11, to study the influence of RWCS diversification on productivity and profitability. For this study, 12 farmers were selected from 3 different blocks of district Pauri, namely Dugadda, Pauri and Khirsu. The soil in general was sandy loam, with available nitrogen, phosphorus and potassium varied from 175 to 210 kg/ha (low), from 12.5 to 19.0 kg/ha (medium), from

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150 to 204 (medium) respectively. The organic carbon was 0.68–0.82% (medium to high), *p*H 6.1–7.4 (neutral) and electrical conductivity 0.50–1.00 dS/m.

Five cropping systems, viz. rice–wheat–fallow, rice–wheat + Indian mustard–fallow, rice–Indian mustard–blackgram, rice–Indian mustard–greengram and rice–vegetable pea–vegetable Frenchbean were evaluated for productivity and economics. During the second year of experimentation (2010–11), the blackgram crop was replaced by the cowpea crop, as blackgram suffered due to early rains. All the crops under different cropping systems were sown and harvested as per their sequence. Fertilizers, irrigation and plant-protection measures as per recommended package of practices were followed for all the crops under different cropping systems.

The details of agricultural operations for different crops in different cropping sequences have been summarized in Table 1.

The experiment was laid out in randomized block design, taking every farmer as a replication. For comparison between different cropping systems, the yield of all the crops in the sequences were converted into rice-equivalent yield. Productivity values in terms of kg/ha/day was calculated by dividing the production of the sequence by 365 days and profitability in terms of ₹/ha/day was obtained by dividing net returns of the sequence by total duration of the sequence (Rautaray, 2005). The economics and the rice-equivalent yield were computed as per market prices during crop season.

Fertilizer doses for every crop were as follows: rice 100 (150 for hybrid rice), 60 and 40, wheat 150, 60 and 40, Indian mustard 100, 60 and 40, blackgram 15, 45 and 0, cowpea 15, 45 and 0, greengram 15, 45 and 0, pea 30, 70 and 50, Frenchbean, 90, 70 and 50 kg/ha of N, P_2O_5 and K_2O, respectively, as per recommended dose. The data were analysed statistically as per the procedure given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Productivity

Pooled analysis of 2 years data for different crops in different cropping systems on crop grain/pod yield, straw yield, rice-equivalent yield, duration of cropping system, productivity efficiency and relative production efficiency of different cropping systems are depicted in Table 2. Rice-grain yield in different cropping systems varied from 5.75 to 5.85 t/ha. The grain yield of wheat was 4.35 t/ha when it was grown as pure crop and reduced to 4.0 t/ha

Table 1. Details of variety and agricultural operation for different crops in different cropping systems

Crop	Variety	Sowing time	Harvesting time	Weed-control measures	Number of irrigations	N : P : K applied (kg/ha)
Rice	‘Pant Sankar Dhan 3’, ‘Pusa 1401' (2010–11)	1–15 July*	15–30 October	Butachlor 50 EC @ 1.5 kg a.i./ha	4–5	150 : 60 : 40 (PSD 3), 100 : 60 : 40 (Pusa 1401)
Wheat	‘PBW 550’	15–30 November	1–15 April	Sulfosulfuron 75 WG @ 25 g a.i./ha	3–4	150 : 60 : 40
Indian Mustard	‘Kanti, ‘PYS 1’ (2010–11)	15–30 November	March	Pendimethalin 30 EC @ 1 kg a.i./ha	3–4	100 : 60 : 40
Blackgram	‘Pant Urd 31’	15 March–5 April	15–30 June	Pendimethalin 30 EC @ 1 kg a.i./ha	5–6	15 : 45 : 0
Cowpea	‘Pant Lobia 1’	15 March–5 April	10–30 June	Pendimethalin 30 EC @ 1 kg a.i./ha	5–6	15 : 45 : 0
Greengram	‘Pant Mung 5’	15 March–5 April	10–30 June	Pendimethalin 30 EC @ 1 kg a.i./ha	5–6	15 : 45 : 0
Pea	‘Arkel’	20 October–15 November	March	Pendimethalin 30 EC @ 1 kg a.i./ha	2–3	30 : 70 : 50
Frenchbean	‘Anupama, Contender’	March	15–30 June	Pendimethalin 30 EC @ 1 kg a.i./ha	4–7	90 : 70 : 50

*Transplanting in main field (sowing in nursery was done between 1 and 10 June) when intercropped with Indian mustard; however, Indian mustard crop provided additional yield of 0.27 t/ha. Pure crop of Indian mustard gave yield 1.37–1.38 t/ha under different cropping systems. Vegetable pea crop provided pod yield of 7.39 t/ha, while it was 3.95 t/ha for the Frenchbean crop. The blackgram and green gram crops gave grain yield of 1.73 and 1.13 t/ha respectively.

The highest rice-equivalent yield was recorded with the rice–vegetable pea–vegetable Frenchbean cropping system and it was significantly higher than the rest of the treatments. It was followed by rice–Indian mustard–blackgram, rice–mustard–green gram and rice–wheat + Indian mustard–fallow cropping systems. All the diversified cropping systems except the rice–wheat + Indian mustard–fallow revealed higher rice-equivalent yield than the traditional rice–wheat cropping system. Higher rice-equivalent yield under the diversified cropping systems may be owing to better prices of vegetables, pulses and oilseeds. Kumar *et al.* (2012), Singh and Kumar (2012) and Singh *et al.* 2012 and Singh and Kumar (2014) also reported suitability of vegetable crops for diversification of rice–wheat system

Crop duration

Traditional rice–wheat–fallow cropping system and rice–wheat + Indian mustard–fallow took minimum time from sowing to harvesting of all the crops in sequence and these were followed by rice–vegetable pea–vegetable Frenchbean. Rice– Indian mustard–blackgram system required the highest time period (356 days) to complete and it was closely followed by rice–Indian mustard–greengram system.

Productivity efficiency

Trend for productivity efficiency was the same as of rice-equivalent yield it was the highest (72.5 kg/ha/day) with rice–vegetable pea–vegetable Frenchbean system, being significantly higher than the rest of the treatments (Table 2). It was followed by rice–Indian mustard–blackgram and rice–Indian mustard–greengram. Traditional rice–wheat system showed the lowest system productivity and it was at par with the rice–wheat + Indian mustard–fallow cropping system. Higher productivity efficiency under the diversified cropping system with vegetables, pulses and oilseed may be owing to higher rice equivalent yield under these cropping systems.

Relative production efficiency

Highest relative production efficiency of 160% was recorded with the rice–vegetable pea–vegetable Frenchbean cropping system, and it was followed by rice–Indian mustard–blackgram and rice–Indian mustard–greengram cropping systems. The rice–wheat + Indian mustard–fallow system had only 2% relative production efficiency over the traditional rice–wheat–fallow cropping system. This trend for relative production efficiency is obvious, as it is in accordance with the rice-equivalent yield of the system.

Economics

Economics of different cropping systems is shown in Table 3. Traditional rice–wheat system recorded the lowest cost of cultivation (₹57.6 thousand/ha) and net returns (₹85.8 thousand/ha). Cost of cultivation and net returns increased with the diversification of this system. The highest cost of cultivation was recorded with the rice–vegetable pea–vegetable Frenchbean cropping system (₹86.3 thousand/ha) and it was followed by rice–Indian mustard–blackgram and rice–Indian mustard–greengram cropping systems having cost of cultivation of ₹74.3 and ₹71.5 thousand/ha respectively. Rice–wheat + Indian mustard–fallow system incurred ₹57.8 thousand/ha as cost of cultivation and it was very near to traditional rice–wheat system (₹57.6 thousand/ha). The highest net returns (₹236.7

Table 2. Mean crop grain and straw yield, rice-equivalent yield and other parameters under different cropping systems (pooled data of 2 years)

Cropping system	Mean crop grain yield (t/ha)			Mean crop straw yield (t/ha)			Rice-equivalent yield (t/ha)	Duration (days)	Productivity efficiency (kg/ha/day)	Relative production efficiency (%)
	Kharif	*Rabi*	Summer	*Kharif*	*Rabi*	Summer				
Rice–wheat–fallow	5.81	4.35	-	7.31	6.11	-	10.18	277	27.9	-
Rice–wheat + Indian mustard–fallow	5.77	4.00+0.27#	–	7.27	5.67	–	10.43	277	28.6	2
Rice–mustard–blackgram	5.75	1.38	1.73	7.34	0.62	0.46	16.00	356	43.8	57
Rice–mustard–greengram	5.79	1.37	1.13	7.30	0.61	0.36	14.97	351	41.0	47
Rice–vegetable pea–vegetable Frenchbean	5.85	7.39	3.95	7.40	0.71	0.53	26.45	331	72.5	160
SEm±	-	-	-	-	-	-	0.59	-	0.92	-
CD (P=0.05)	-	-	-	-	-	-	1.70	-	2.62	-

#Indian mustard

Table 3. Economics of different cropping systems (pooled data of 2 years)

Cropping system	Cost of cultivation (₹000/ha)	Net returns (₹000/ha)	Benefit: cost ratio	Economic efficiency (₹/ha/day)	Net profitor loss over rice–wheat system (000/ha)	Relative economic efficiency (%)
Rice–wheat–fallow	57.6	85.9	1.49	310	-	-
Rice–wheat + Indian mustard–fallow	57.8	89.9	1.56	325	4.0	4.7
Rice–Indian mustard–blackgram	74.3	115.5	1.55	325	29.6	34.5
Rice–Indian mustard–greengram	71.5	109.5	1.53	312	23.6	27.4
Rice–vegetable pea–vegetable Frenchbean	86.3	236.7	2.74	715	150.8	175.5

thousand/ha) were produced by rice–vegetable pea–vegetable Frenchbean system and it was followed by rice–Indian mustard–blackgram (115.5 thousand/ha), rice–mustard–greengram (109.5 thousand/ha). Net returns from the rice–wheat + Indian mustard–fallow and rice–wheat–fallow cropping system were very close, i.e. 89.9 and 85.9 thousand/ha respectively. The highest net returns under the rice–vegetable pea–vegetable Frenchbean cropping system may be owing to better prices of vegetable crops included in this system. Singh and Kumar (2012), Singh *et. al.* (2012) and Singh and Kumar (2014) also reported increased productivity and profitability by inclusion of different vegetables in rice–wheat system.

The highest benefit: cost ratio (2.74) and highest system profitability (715/ha/day) were recorded under rice–vegetable pea–vegetable Frenchbean system. Profitability from traditional rice–wheat–fallow system was recorded lowest (310/ha/day).

The highest increase in net profit over the traditional rice–wheat cropping system (150.8 thousand/ha) was recorded under the rice–vegetable pea–vegetable Frenchbean cropping system and it was followed by rice–Indian mustard–blackgram (29.6 thousand/ha) and rice–Indian mustard–greengram. The lowest additional returns over traditional rice–wheat system thousand/ha) was obtained under rice–wheat + Indian mustard–fallow system. The highest relative economic efficiency (175.5%) was also recorded with rice–vegetable pea–vegetable Frenchbean system. Singh *et al.* (2008), Kumar *et al.* (2012) and Singh and Kumar (2014) also reported better economic parameters under the diversified rice–wheat systems by vegetables and pulses.

Thus, rice-equivalent yield, system productivity, relative production efficiency, net returns, benefit: cost ratio, system profitability and relative economic efficiency were higher under the diversified cropping systems over the traditional rice–wheat system. Out of these diversified cropping system, rice–vegetable pea–vegetable Frenchbean system was superior to the other systems for all economic parameters. Hence, it can be concluded that the rice–vegetable pea–vegetable Frenchbean cropping system may be recommended over the traditional existing rice–wheat system for irrigated situations of Garhwal Himalayas for better returns.

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