Indian Journal of Agronomy **59** (2): 200–203 (June 2014)

Research Paper

Influence of diversification of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) system on productivity, energetics and profitability under on-farm conditions

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Received : June 2013; Revised accepted : February 2014

ABSTRACT

A field experiment was conducted at farmers' fields in the district of Dehradun, Uttarakhand, during 2009–10 and 2010–11, to find out the alternate efficient cropping systems for rice (*Oryza sativa* L.)–wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] in western Himalayas. Five cropping systems including the existing rice–wheat system were tested at 12 farmers' fields as researcher designed farmer managed trials. The wheat equivalent yield under the rice–potato (*Solanum tuberosum* L.)–greengram [*Vigna radiata* (L.) Wilczek], rice–potato–vegetable cowpea [*Vigna unguiculata* (L.) Walp.] and rice–vegetable pea (*Pisum sativum* L.)–vegetable Frenchbean (*Phaseolus vulgaris* L.) was 135, 124 and 105% higher than the rice–wheat system. The rice–potato–greengram cropping system recorded highest net returns (₹1,61,928/ha), followed by rice–vegetable pea–vegetable Frenchbean (₹1,58,192/ha) and rice–potato–vegetable cowpea cropping systems (₹1,52,415/ha). The highest benefit: cost ratio (1.93) was recorded with the rice–vegetable pea–vegetable Frenchbean cropping system owing to its lower cost of cultivation and higher returns.

Key words : Crop production, Diversification of rice–wheat cropping systems, Energetics, Productivity

The rice–wheat is the predominant cropping system of Indo-Gangetic planes of India, covering about 10.5 million ha area and contributing about 38% to the national food basket (Gangwar, 2009) and is considered as the backbone of foodgrain security. This system is likely to play its important role in sustaining the foodgrains self-sufficiency in future too. The system production of existing rice–wheat system can be increased up to the level of 9.1 to 21.5 t/ha/year depending on the choice of high-value crops included in the diversification. Continuous cultivation of rice and wheat in a sequence during the last 3 decades has been causing many second-generation problems like decline in watertable, emergence of multi-nutrient deficiencies, formation of hard pan and build up of weeds like *Phalaris minor* in wheat. Moreover, the stagnation in system productivity and profitability is experienced in recent years.

In Uttarakhand, rice–wheat is the predominant cropping system of the Garhwal region and of the state as well. In the state, rice and wheat crops are being grown in 295 and 398 thousand hectares respectively. The average productivity of rice and wheat in the state was 2.08 and 2.15 kg/ha respectively, during 2009–10 (Government of Uttarakhand, 2011).

Need is being felt to diversify and intensify the existing rice–wheat system with remunerative and efficient crops like pulses, oilseeds and vegetables. Under Garhwal Himalayan conditions, viable alternative is the selection of suitable cropping systems that generate maximum net profit per unit investment per unit time to farmers. Therefore, present study was undertaken to find out the productivity and economics of various possible cropping systems by incorporating pulses, oilseed and vegetable crops that can replace rice–wheat system.

MATERIALS AND METHODS

The experiment was conducted to study the influence of diversification of rice–wheat system on productivity, energetics and profitability at farmers' fields during 2009–10 and 2010–11. For the study 12 farmers were selected from the 12 different villages, spread in 3 blocks of the district Dehradun namely, Kalsi, Vikasnagar and Doiwala. The soils varied from clay loam to sandy loam, available

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nitrogen, phosphorus and potassium ranged from 194 to 206 kg/ha (low), from14.8 to 15.9 kg/ha (medium), from 175 to 179 kg/ha (medium) respectively. The organic carbon, ranged from 0.74 to 0.82% (medium to high), pH ranged from 7.2 to 7.3 (neutral) and mean electrical conductivity ranged from 0.78 to 0.90 dS/m.

Five cropping systems, viz. rice–wheat, rice–wheat + Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson], rice–potato–vegetable cowpea, rice–potato–greengram and rice–vegetable pea–vegetable Frenchbean, cropping systems were evaluated for the productivity and economics. The urdbean [*Vigna mungo* (L.) Hepper], crop in the crop sequence rice–potato–urdbean was replaced by the vegetable cowpea during the second year of experimentation as the urdbean crop suffered due to early monsoon showers during 2009–10. The yield of urdbean crop was converted to vegetable cowpea-equivalent yield using the price of both the crops. 'Pusa 1121' and 'Pusa Sugandha 1401' varieties of rice, 'PBW 550' (during both the years) of wheat, 'Kanti' and 'Pusa Tarak' of Indian mustard, 'Kufri Badshah' and 'Kufri Pukhraj' of potato, 'PU 31' of urdbean 'Pant Lobia 1' of cowpea, 'PM 5' (during both the years) of greengram, 'Arkle' of pea, 'VL Bauni 1' and 'Anupama' of Frenchbean were used in experimentation in all farmers' fields.

Recommended package of practices were followed for all the crops in different cropping systems. The experiment was laid out in randomized block design with every farmer acting as a replication. For comparision between different cropping systems, the yields of all crops in the sequences were converted into wheat-equivalent yield using the standard procedure. 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 net returns of the sequence divided by the total duration of the sequence (Rautararay, 2005). The economics and wheat-equivalent yield were computed using the market rates of 2009–10 and 2010–11. The energy input for a particular cropping system was calculated as the summation of energy requirement for human, diesel, seed, herbicide, farmyard manure (FYM) and chemical fertilizers used in that system. The energy-use efficiency (EUE) and energy-output efficiency (EOE) were obtained by:

EUE = Energy output (MJ/ha)/ Energy input (MJ/ha)

EOE = Energy output (MJ/ha)/ Duration of the system (Day)

Fertilizer doses as per the recommended dose for every crop were (rice: 100, 60 and 40, wheat: 150, 60 and 40; blackgram, cowpea and greengram: 15, 45 and 0; pea: 30, 70 and 50, Frenchbean: 120, 70 and 50; potato: 160, 100 and 120 kg/ha of N, P_2O_5 and K_2O, respectively).

In case of wheat + Indian mustard, the fertilizer doses were applied as recommended for wheat crop only. Intercropping of wheat and Indian mustard was done as per the recommendation (9:1 ratio).

RESULTS AND DISCUSSION

Productivity

Pooled analysis of 2 years data indicated that the wheat-equivalent yield was recorded highest with rice–potato–greengram cropping system, being significantly higher than rest of the cropping systems (Table 1). This was followed by rice–potato–vegetable cowpea and the rice–vegetable pea–vegetable frenchbean. Existing predominant rice–wheat system had only 9.36 t/ha wheat-equivalent yield which was at par with the rice–wheat + Indian mustard cropping system (9.40 t/ha). The wheat-equivalent yield under the rice–potato–greengram, rice–potato–vegetable cowpea and rice–vegetable pea–vegetable Frenchbean was respectively 135, 124 and 105% higher than the existing rice–wheat system. Suitability of potato for diversifying rice–wheat system was also reported by Jaiswal *et al.*, (1994), Singh, (1997) and Singh *et al.*, (2005).

When Indian mustard was intercropped with wheat its grain yield decreased from 4.69 to 4.46 but Indian mustard crop provided additional grain yield of 0.13 t/ha to this system. However, intercropping of Indian mustard with wheat could not significantly increase the wheat equiva-

Table 1. Wheat-equivalent yield, mean crop yield and other parameters under different cropping systems (pooled data of 2 years)

Cropping system	Mean crop yield (t/ha)			Wheat-equivalent yield (t/ha)	Duration (days)	System productivity (kg/ha/day)	Relative production efficiency (%)
	Rainy season	Winter season	Summar				
Rice–wheat	4.11	4.69	-	9.36	286	25.6	-
Rice–wheat + Indian mustard	4.13	4.46+(0.13)	-	9.40	286	25.7	0.49
Rice–potato–cowpea	4.14	20.42	1.37	20.98	338	57.4	124
Rice–potato–greengram	4.15	20.72	1.22	22.02	339	60.3	135
Rice–vegetable pea–vegetable Frenchbean	4.18	5.63	3.81	19.23	333	47.1	105
SEm±				0.25			

lent yield of this system over the existing rice–wheat system.

Rice–wheat and rice–wheat + Indian mustard cropping system took 286 days period from sowing to harvesting of all the crops in sequence. Highest duration of 339 days was recorded with the rice–potato–greengram cropping system and it was followed by rice–potato–vegetable cowpea (338 days) and rice–vegetable pea–vegetable Frenchbean (333 days).

Highest system productivity was recorded under the rice–potato–greengram system and it was followed by rice–potato–vegetable cowpea, rice–vegetable pea–vegetable Frenchbean cropping systems. The lowest system productivity was recorded with traditional rice–wheat system, which was almost at par with rice–wheat + Indian mustard cropping system.

Economics

Economic analysis (Table 2) revealed that the rice–potato–greengram cropping system recorded the highest net returns followed by rice–vegetable pea–vegetable Frenchbean and rice–potato–vegetable cowpea system (Table 2). Rice–wheat and rice–wheat + Indian mustard cropping systems provided only ₹84,667 and ₹84,835/ha of net returns respectively. Sharma *et al.* (2007) also reported increased productivity and profitability by inclusion of different vegetables in rice–wheat system.

The cropping systems having the potato crop fetched the highest cost of cultivation (₹1,11,334/ha and ₹1,11,367/ha with rice–potato–vegetable cowpea and rice–potato–greengram cropping systems respectively). Cost of cultivation of rice–vegetable pea–vegetable Frenchbean (₹81,922/ha) was also higher than the traditional rice–wheat system (₹55,911/ha) and the rice–wheat + Indian mustard cropping system. In rice–wheat + Indian mustard system, every tenth row of wheat was replaced by the Indian mustard crop, so this system had almost similar cost of cultivation to that of rice–wheat system. The highest benefit: cost ratio was recorded with the rice–vegetable pea–vegetable Frenchbean cropping system owing to its lower cost of cultivation and higher returns. This system was followed by rice–wheat, rice–wheat + Indian mustard, rice–potato–greengram and rice–potato–cowpea (1.36). All cropping systems having the potato crop, despite recording the higher net returns, recorded lower benefit: cost ratio due to their higher cost of cultivation. Highest system profitability (₹/ha/day) was recorded under rice–potato–greengram cropping system, followed by rice–vegetable pea–vegetable Frenchbean and rice–potato–cowpea. The system profitability was very less under the traditional rice–wheat system (296) and rice–wheat + Indian mustard. The rice–potato–greengram system provided additional returns of ₹77,261/ha over the rice–wheat system. Almost similar additional returns were also recorded with the rice–vegetable pea–vegetable Frenchbean system (₹73,525/ha) and rice–potato–vegetable cowpea system (₹67,748/ha). Rice–wheat + Indian mustard provided only ₹168 additional returns.

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

Cropping system	Cost of cultivation ($\times10^3$/ha)	Net returns from system ($\times10^3$/ha)	Benefit: cost ratio	Profitability (₹/ha/day)	Net profit or loss over rice–wheat system(₹/ha)	REE (Relative economic efficiency) (%)
Rice–wheat	55.9	84.7	1.51	296	-	-
Rice–wheat + Indian mustard	55.9	84.8	1.51	297	168	0.19
Rice–potato–cowpea	111.3	152.4	1.36	451	67,748	80
Rice–potato–greengram	111.4	162.0	1.45	478	77,261	91
Rice–vegetable pea–vegetable Frenchbean	82.0	158.2	1.93	475	73,525	86

Table 3. Energy values in total inputs, total output, energy use efficiency and energy output efficiency (pooled data of 2 years)

Cropping system	Total inputs ($\times10^3$ MJ/ha)	Total output ($\times10^3$ MJ/ha)	Energy-use efficiency (ratio)	Energy-output efficiency (MJ/ha/day)
Rice–wheat	24.9	226.7	9.10	0.79
Rice–wheat + Indian mustard	24.8	226.4	9.12	0.79
Rice–potato–cowpea	64.5	185.0	2.86	0.54
Rice–potato–greengram	65.4	201.5	3.08	0.59
Rice–vegetable pea–vegetable Frenchbean	33.2	155.8	4.69	0.46

The highest relative economic efficiency was recorded with rice–potato–greengram cropping system and it was followed by the rice–vegetable pea–vegetable Frenchbean system (86%) and rice–potato–vegetable cowpea (80%). The rice–wheat + Indian mustard cropping system had recorded only 0.19% as relative economic efficiency.

The wheat–equivalent yield, system productivity, relative production efficiency, net returns, profitability and relative economic efficiency were higher under the rice–potato–greengram, rice–potato–vegetable cowpea and rice–vegetable pea–vegetable Frenchbean cropping systems over the traditional rice–wheat system. The rice–potato–greengram system was found to be superior to the rest of the cropping systems in all parameters except benefit: cost ratio, being highest in rice–vegetable pea–vegetable Frenchbean cropping system owing to its lower cost of cultivation.

Energetics

Total input energy requirement was lowest in traditional rice–wheat system and rice–wheat + Indian mustard system (Table 3). Cropping system having potato had higher total input energy requirement in rice–potato–cowpea and rice–potato–greengram. Higher total energy output was recorded with traditional rice–wheat system and rice–wheat + Indian mustard cropping system. Higher energy-use efficiency was also noted in rice–wheat and rice–wheat + Indian mustard cropping systems and same trend was also recorded for the energy-output efficiency.

Based on two years study, it is concluded that the rice–potato–greengram/vegetable cowpea and the rice–vegetable pea–vegetable Frenchbean cropping system can be recommended for the farmers in the irrigated situations of Garhwal Himalayas.

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