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Research Paper

Diversification of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) system and its influence on productivity, profitability and energetics under on-farm situation

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ABSTRACT

A field experiment was conducted at farmers' fields in the district Nainital, Uttarakhand, during 2011–12 and 2012–13, to find out the alternate efficient cropping systems for rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* (L.) emend. Fiori & Paol.) system in western Himalayas. Five cropping systems including the existing rice–wheat were tested at 24 farmers' fields as researcher designed farmer managed trials. The rice equivalent yield of rice–chickpea (*Cicer arietinum* L.)–vegetable cowpea (*Vigna unguiculata* (L.) Walp.) was the highest (23.7 t/ha), followed by rice–wheat–vegetable cowpea (19.3 t/ha), rice–vegetable pea (*Pisum spp.*)–maize for cob (*Zea mays* L.) (17.4 t/ha) and rice–lentil (*Lens esculenta* (L.) Moench)–maize (fodder) (16.2 t/ha) systems. Existing rice–wheat system recorded rice equivalent yield of 11.8 t/ha, which is 50% lesser than rice–chickpea–vegetable cowpea system. The rice–chickpea–vegetable pea cropping system also recorded the highest net returns (₹222.2×10^3/ha) followed by rice–wheat–vegetable cowpea (₹203.6×10^3/ha) and rice–vegetable pea–maize (cob) (₹194.1×10^3/ha) systems. The highest benefit: cost ratio (1.91) was recorded with the rice–chickpea–vegetable cowpea system owing to its lower cost of cultivation and higher returns. Highest energy-use efficiency ratio (5.25) was recorded with the rice–lentil–maize (fodder) system. This system also produced second highest energy input-output efficiency (0.62MJ/ha/day), which is very close to the highest energy input-output efficiency (0.63 MJ/ha/day) of traditional rice–wheat system.

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

The rice–wheat is the predominant cropping system of Indo-Gangetic plains of India, covering about 10.5 million ha area and contributing about 38% to the national food basket (Gangwar, 2009). The system is considered as the backbone for food grain security. The productivity of rice and wheat in the country was 2.20 t/ha (during 2011–12) and 2.93 t/ha (during 2010–11) respectively. In Uttarakhand state too, rice–wheat is the predominant cropping system, here rice and wheat crops are being grown on 252.8 and 347.8 thousand hectares, respectively. The average productivity of rice and wheat in Uttarakhand was 2.29 and 2.42 t/ha, respectively during 2013–14 (Government of Uttarakhand, 2014).

The system productivity of traditional rice–wheat cropping 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 involved in diversification of rice–wheat system. Continuous cultivation of rice–wheat cropping system during last three decades has resulted in many second-generation problems like decline in water table, emergence of multinutrient deficiencies, formation of hard pan and build up of several weeds in rice and wheat crops, besides that, the stagnation in system productivity and profitability is being experienced in recent years (Ladha *et al.* (2003) and Busari *et al.* (2015)

A need is being felt to diversify and intensify the existing rice–wheat system with remunerative and efficient crops like pulses, oilseeds and vegetables due to multifold problems and stagnation of rice–wheat system productivity. Therefore, present study was undertaken to find out the productivity and economics of various possible cropping

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systems by incorporating pulses and vegetable crops that can replace rice–wheat system.

MATERIALS AND METHODS

The experiment was conducted at farmers' fields to study the influence of diversification of rice–wheat system on productivity, profitability and energetics, during 2011–12 and 2012–13. Twenty four farmers were selected from 6 villages from 2 blocks-Bhimtal and Kotabagh of district Nainital, Uttarakhand. The soil of experiment sites in general was sandy loam. Available nitrogen, phosphorus and potassium varied from 281–345 kg/ha (medium), from 16–18.5 kg/ha (medium), from 196–260 kg/ha (medium), respectively. The organic carbon ranged from 0.76–0.95% (medium to high) with *p*H ranging from 6.6 to 7.6 (neutral) and mean electrical conductivity (EC) of 0.65 to 0.78 dS/m.

Five cropping systems, viz. rice–wheat (control), rice–wheat–vegetable cowpea, rice–chickpea–vegetable cowpea, rice–lentil–maize (fodder) and rice–vegetable pea–maize (cob) were evaluated for productivity, economics and energetics. Initially during the first year of experimentation (2011–12), tomato crop was taken in place of chickpea, but it suffered due to frost, so during the second year tomato crop was replaced by the chickpea crop. 'NPH 567' (hybrid) and 'PRH 10' varieties of rice, 'UP 2572' and 'DBW 17' varieties of wheat, 'Pant Lobia 1' and Pant Lobia 3' varieties of cowpea, 'Him Sona' variety of tomato, 'PG 114' variety of chickpea, 'PL 6' and 'PL 4' varieties of lentil, 'Vasu 555' and 'African Tall' varieties of maize (fodder), 'Arkle' variety of vegetable pea (during both the years) and 'Gaurav' and 'Naveen' varieties of maize (cob) were used in experimentation in all farmers' fields.

As a researcher designed farmer managed experiment, recommended package of practices were followed for all the crops in different cropping systems. The experiment was laid out in randomized block design taking every farmer as a replication. For comparison between different cropping systems, the yields 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 net returns of the sequence divided by total duration of the sequence (Rautararay, 2005). The economics and the rice-equivalent yield were computed using the farm gate prices of 2011–12 and 2012–13.

The energy-use efficiency (EUE), energy-output efficiency (EOE), specific energy, rotational intensity and land use efficiency were obtained by using the following formula:

EUE = Energy output (MJ/ha)/Energy input (MJ/ha);
EOE = Energy output (MJ/ha)/Duration of the system (days)

Specific energy=Energy input (MJ/ha)/rice grain equivalent yield (kg/ha)

Rotational intensity (%)=(number of crops grown in a rotation/duration of rotation in year) × 100

Land-use efficiency (%)=Total number of days field remained occupied under different crops in rotation/365) × 100

RESULTS AND DISCUSSION

Productivity

Diversified cropping systems had significantly higher rice equivalent yield than the rice–wheat system (Table 1 and 2). Highest rice equivalent yield (significantly higher than the rest of the systems) (23.7 t/ha) was recorded with rice–chickpea–vegetable cowpea system followed by rice–wheat–vegetable cowpea (19.3 t/ha), rice–vegetable pea–maize (cob) (17.4 t/ha) and rice–lentil–maize (fodder) (16.2 t/ha) systems. Existing pre-dominant rice–wheat system had only 11.8 t/ha as rice equivalent yield. The rice equivalent yield of rice–chickpea–vegetable cowpea, rice–wheat–vegetable cowpea, rice–vegetable pea–maize (cob) and rice–lentil–maize (fodder) cropping systems was higher by 99, 62, 46 and 37% respectively than the exist-

Table 1. Mean crop yields of different crops under different cropping systems

Cropping system	Mean crop yield (t/ha)					
	Rainy season (*kharif*)		Winter season (*rabi*)		Spring/summer (*zaid*)	
	2011–12	2012–13	2011–12	2012–13	2011–12	2012–13
Rice–wheat	8.09	5.65	5.05	5.08	0.00	0.00
Rice–wheat–vegetable cowpea	8.10	5.70	5.05	5.11	5.96	5.84
Rice–chickpea*–vegetable cowpea	8.07	5.70	13.75#	1.94	6.21	5.84
Rice–lentil–maize (fodder)	8.09	5.64	1.65	1.59	26.85	33.02
Rice–vegetable pea–maize (cob)	8.12	5.68	7.70	7.44	4.09	1.96

* during 2011–12 in place of chickpea tomato crop was taken # crop suffered up to some extent at some of the farmers' fields, average figure has been given

ing rice–wheat system. Suitability of vegetable and pulse crops for diversification of rice–wheat system was also reported by many workers (Singh *et al*., 2005; Singh *et al.,* 2008; Kumar *et al.,* 2012; Singh *et al.,* 2012 and Singh and Kumar, 2014)

Rice–wheat system took minimum time (277 days) from sowing to harvesting of all the crops in sequence and followed by rice–vegetable pea–maize (cob) (324 days) and rice–lentil–maize (fodder) (327 days). Rice–wheat–vegetable cowpea system required the highest time period (354 days) and it was closely followed by rice–chickpea–vegetable cowpea (339 days) system. All diversified cropping systems had cropping intensity of 300%, while it was 200% under the traditionl rice–wheat cropping system. Land-use efficiency was recorded the highest with rice–wheat–vegetable cowpea cropping system (96.9%), followed by rice–chickpea–vegetable cowpea (92.8%), which was significantly higher than the rice–lentil–maize for fodder (89.5%), rice–vegetable pea–maize for cob (87.7%) and traditional rice–wheat system (75.8%) (Table 2).

Highest and significantly higher over rest of the treatments system productivity was recorded with rice–chickpea–vegetable cowpea system (64.9 kg/ha/day), followed by rice–wheat–vegetable cowpea (52.9 kg/ha/day), which was significantly higher over rice–vegetable pea–maize (cob) (47.6 kg/ha/day), rice–lentil–maize (fodder) (44.6 kg/ha/day) and traditional rice–wheat system (32.5 kg/ha/day. Significantly higher over rest of the treatments and the highest relative production efficiency was recorded with rice–chickpea–vegetable cowpea system (99.6%), it was followed by rice–wheat–vegetable cowpea system (62.6%), which was superior to rice–vegetable pea–maize (cob) (46.4%) and rice–lentil–maize (fodder) system (37.0 %).

Economics

Rice–wheat system recorded lowest cost of cultivation (₹83.4×10^3/ha) and net returns (₹127.4 ×10^3/ha). Cost of cultivation and net returns increased with the diversification (Table 3). The highest cost of cultivation was recorded with the rice–chickpea–vegetable cowpea (₹116.0×10^3/ha) and it was closely followed by rice–wheat–vegetable cowpea and rice–vegetable pea–maize (cob) cropping systems having cost of cultivation of ₹111.9×10^3/ha. Rice–lentil–maize (fodder) system incurred ₹97.5×10^3/ha as cost of cultivation. Highest net returns (₹222.2×10^3/ha) were recorded in rice–chickpea–vegetable cowpea system and it was followed by rice–wheat–vegetable cowpea (₹203.7×10^3/ha), rice–vegetable pea–maize (cob) (₹194.1×10^3/ha) and rice–lentil–maize (fodder) (₹143.9×10^3/ha). Sharma *et al*. (2007), Singh *et al.* (2012)

Table 2. Rice-equivalent yield and other parameters under different cropping systems (pooled data of 2 years)

Cropping system	Rice equivalent yield (t/ha)	Duration (days)	Rotational intensity (%)	Land-use efficiency (%) (kg/ha/day)	System production efficiency	Relative production efficiency (%)
Rice–wheat	11.8	277	200	75.8	32.5	–
Rice–wheat–vegetable cowpea	19.3	354	300	96.9	52.9	62.6
Rice–chickpea–vegetable cowpea	23.7	339	300	92.8	64.9	99.6
Rice–lentil–maize (fodder)	16.2	327	300	89.5	44.6	37.0
Rice–vegetable pea–maize (cob)	17.4	324	300	88.7	47.6	46.4
SEm±	0.23	–	–	0.86	0.78	0.99
CD (P=0.05)	0.64	–	–	2.42	2.21	2.80

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

Cropping system	Cost of cultivation (×10^3₹/ha)	Net returns (×10^3₹/ha)	Benefit: cost ratio	Profitability (₹/ha/day)	Net profit or loss over rice–wheat system (×10^3₹/ha)	Relative economic efficiency (%)
Rice–wheat	83.4	127.4	1.53	460	–	–
Rice–wheat–vegetable cowpea	111.9	203.7	1.82	576	76.3	59
Rice–chickpea–vegetable cowpea	116.0*	222.2	1.91	657	94.9	76
Rice–lentil–maize (fodder)	97.5	143.9	1.48	441	16.5	13
Rice–vegetable pea–maize (cob)	111.9	194.1	1.75	600	66.8	53

*during 2011–12 in place of chickpea tomato crop was taken having high cost of cultivation 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 (1.91) was recorded with rice–chickpea–vegetable cowpea owing to its higher net returns and also system yield (Table 3). This system was followed by rice–wheat–vegetable cowpea (1.82), rice–vegetable pea–maize (cob) (1.75), rice–wheat (1.53) and rice–lentil–maize (fodder) (1.48). Highest system profitability (₹657/ha/day) was again recorded under rice–chickpea–vegetable cowpea, followed by rice–vegetable pea–maize (cob) (₹600/ha/day), rice–wheat–vegetable cowpea (₹576/ha/day) and rice–wheat system (₹460/ha/day). Rice–lentil–maize (fodder) system recorded the lowest system profitability (₹441/ha/day). Higher system profitability may be attributed to better price and lower duration of the crops in sequence. The highest increase in net profit over the traditional rice–wheat cropping system (₹94.9×10^3/ha) was recorded under the rice –chickpea–vegetable cowpea cropping system and it was closely followed by rice–wheat–vegetable cowpea (₹76.3×10^3/ha). The lowest additional returns over traditional rice–wheat system (₹16.5×10^3/ha) was obtained under rice–lentil–maize (fodder) system, while the rice–vegetable pea–maize (cob) system provided ₹66.8×10^3/ha additional returns over the traditional one. The highest relative economic efficiency (76%) was recorded with rice–chickpea–vegetable cowpea system and it was followed by rice–wheat–vegetable cowpea (59%), rice–vegetable pea–maize (cob) (53%) and rice–lentil–maize (fodder) (13%). Other workers have also reported higher economic returns under the diversified rice–wheat systems by vegetables and pulses due to better market price of vegetables and pulses and also due to higher rotational intensity (Singh *et al.,* 2008 and Kumar *et al.,* 2012).

Energetics

Total input energy requirement was lowest (35.0 MJ/ha) in rice–wheat system (Table 4) and it was closely followed by rice–lentil–maize (fodder) system (38.6 MJ/ha). Highest total input energy requirement was recorded with the rice–chickpea–vegetable cowpea (49.2 MJ/ha) followed by rice–vegetable pea–maize (cob) (47.2 MJ/ha) and rice–wheat–vegetable cowpea system (42.6 MJ/ha). Higher energy input requirement might be due to higher requirement of labour and inputs like seed, pesticide and irrigation. Highest total energy output (202.6 MJ/ha) was produced under the rice–lentil–maize (fodder) system and it was significantly higher over rest of the treatments, followed by rice–wheat–vegetable cowpea (187.3 MJ/ha) and rice–vegetable pea–maize (cob) (186.3 MJ/ha) cropping systems and these 2 cropping systems recorded significantly higher output energy over the rice–chickpea–vegetable cowpea (135.7 MJ/ha) and rice–wheat cropping system (175.4 MJ/ha). Highest-energy use efficiency (5.25) was recorded with rice–lentil–maize (fodder) cropping system followed by rice–wheat system (5.01). The energy output efficiency was recorded higher with rice–wheat system (0.63 MJ/ha/day) and it was closely followed by rice–lentil–maize (fodder) system (0.62 MJ/ha/day), which might be due to higher energy-output obtained in these cropping systems. Highest specific energy requirement was recorded with the rice–wheat system (2.97 MJ/kg), followed by rice–vegetable pea–maize for cob (2.71 MJ/kg), rice–lentil–maize for fodder (2.38 MJ/kg), rice–wheat–vegetable cowpea (2.20 MJ/kg) and rice–chickpea–vegetable cowpea (2.07 MJ/kg). Higher specific energy indicates these cropping systems require higher inputs to produce a unit of produce. Kachroo *et al.* (2012) also reported similar findings where inclusion of vegetables resulted in low input use/kg of produce.

Based on two years of experimentation, it can be concluded that the rice–chickpea–vegetable cowpea cropping system can be recommended for diversifying rice–wheat system to increase the productivity and profitability of farmers in the irrigated situations of Kumaon Himalayas. Under the input energy constraint situation, rice–lentil–maize (fodder) system can be recommended as alternate system.

Table 4. Energy values in total inputs, total output, energy-use efficiency and energy-output efficiency (pooled data of 2 years)

Cropping system	Input energy ($\times10^3$MJ/ha)	Output energy ($\times10^3$MJ/ha)	Energy-use efficiency (ratio)	Energy-output efficiency (MJ/ha/day)	Specific energy requirement (MJ/kg)
Rice–wheat	35.0	175.4	5.01	0.63	2.97
Rice–wheat–vegetable cowpea	42.6	187.3	4.40	0.53	2.20
Rice–chickpea–vegetable cowpea	49.2	135.7	2.77	0.40	2.07
Rice–lentil–maize (fodder)	38.6	202.6	5.25	0.62	2.38
Rice–vegetable pea–maize (cob)	47.2	186.3	3.95	0.57	2.71
SEm ±	–	2.70	–	–	–
CD (P=0.05)	–	7.60	–	–	–

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