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Economic evaluation of rice (*Oryza sativa*)-based cropping sequences in the foothills of Himalayas

V.K. SINGH[1] AND B.B. SHARMA

Department of Agronomy, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttaranchal 263 145

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ABSTRACT

A field experiment was conducted at Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, during 1996–97 and 1997–98, to identify the appropriate rice (*Oryza sativa* L.)-based cropping sequences for sustainable productivity and profitability under foothills of Himalayas. Rice as base crop was sequenced in 10 feasible crop sequences, viz. wheat (*Triticum aestivum* L. emend. Fiori & Paol.)–rice, chickpea (*Cicer arietinum* L.)–rice, lentil (*Lens culinaris* Medikus)–rice, field pea (*Pisum sativum* L.)–rice, wheat–mungbean (*Phaseolus radiatus* L.) green-manure–rice, wheat–sesbania (*Sesbania aculeata* Pers.) green-manure–rice, wheat–maize (*Zea mays* L.) + cowpea [*Vigna unguiculata* (L.) Walp.] fodder–rice (*Oryza sativa* L.), chickpea–maize + cowpea fodder–rice, lentil–maize + cowpea fodder–rice and field pea–maize + cowpea fodder–rice sequence. The green-manuring of sesbania and mungbean in rice–wheat system gave an additional rice-equivalent yield 1.11 and 0.9 tonnes/ha over wheat–rice, respectively, and showed maximum land-use efficiency (90.95%). Further chickpea–rice sequence (10.88 tonnes/ha) showed its superiority to all other sequences having 2 crops. Among 300% cropping intensity, sequence chickpea–maize + cowpea fodder–rice (13.90 tonnes/ha) proved most efficient in term of rice-equivalent yield, production efficiency (38.09 kg/ha) and mean economic returns (Rs 43,992/ha), while sequence wheat–maize + cowpea fodder–rice was highest carbohydrate (9.68 tonnes/ha) and chemical energy (50.51 K cal × 10^{-6}/ha) producer among all sequences.

Key words : Rice-based cropping sequences, Productivity and economics, Rice-equivalent yield, Energy production efficiency

The rice–wheat crop sequence in foothills of Himalayas (*tarai* region) played a significant role in crop production and improving the economics of farmer's. But from last few years the profitability and sustainability of this system is not encouraging, because of yield pleatuing and many other reasons. Therefore, along with improvement in

Present address : [1]Scientist, Project Directorate for Cropping Systems Research, Modipuram, Meerut, Uttar Pradesh 250 110

present level of rice–wheat system productivity, there is need to intensify the production system through the crop diversification, viz introduction of summer fodder and or green-manure crops in the present crop system, or replacement of wheat with short-duration legumes to achieve the target productivity level. Because of potential for compensation among component of the system such biological diversity can bring sustained yield level and economic stability. Hence, in search of an economically viable, technically feasible and production sustainable crop sequence for *tarai* region of Uttar Pradesh, the present investigation was planned and executed.

MATERIALS AND METHODS

A field experiment was conducted at Pantnagar during 1996–97 and 1997–98. The soil of experimental plot was clay loam having high organic carbon (0.89%), available P (27.3 kg/ha) and medium in K (184.6 kg/ha) content with neutral reaction (pH 7.4). The treatments consisting of 10 crop sequences, viz. wheat–rice, chickpea–rice, lentil–rice, field pea–rice, wheat–mungbean green-manure–rice, wheat–sesbania green-manure-rice, wheat–maize + cowpea fodder–rice, chickpea–maize + cowpea fodder–rice, lentil–maize + cowpea fodder–rice and field pea–maize + cowpea fodder–rice, were tested in randomized block design with 4 replications. Recommended package of practices were followed in all the crops included in different sequences (Table 1). The green biomass of maize + cowpea was harvested 45 days after sowing and used as fodder. Mungbean and sesbania were grown up to 60 days after sowing and the above-ground biomass was incorporated into the soil. During 1997–98, the crops were grown on undisturbed lay out, and similar cultural practices were followed. The experimental site was in humid sub-tropical climate with hot dry summer and cold winter had 1,247 and 1,723 mm annual rainfall during 1996–97 and 1997–98 respectively. The maximum portion of rainfall was received during rainy season (July to September) in both the years. Continuous rainfall from last week of November to mid-December (97.8 mm) during 1997–98 adversely affected all the growth and developmental processes of winter crop and resulted poor grain yield.

The cost of cultivation of individual crop and crop sequences was calculated as per standard rate of material exhausting in particular year. For comparison of different cropping systems, the yield of different crops was converted into rice-equivalent yield and gross returns in rupees based on government price for rice, wheat, and chickpea, and local market price for lentil, field pea and maize + cowpea fodder (Table 1). The intensification of time was measured by calculating land-use efficiency, taking total duration of crops in an individual crop sequence divided by 365 days. Production efficiency was calculated as rice-equivalent yield in a cropping sequence divided by 365 (Tomar and Tiwari, 1990). Energy value of economic produce and their carbohydrate equivalent obtained from different cropping sequences were computed as per calculation made by Aykroyed and Doughty (1973) for rice, wheat and lentil; Chatterjee and Bhattacharya (1986) for field pea and chickpea and Pachouri *et al.*

(1988) for maize + cowpea green fodder (Table 1).

RESULTS AND DISCUSSION

Crop productivity

The grain yield of rice showed a significant variation under different cropping sequences and the maximum grain yield (16.51 tonnes/ha) was found when sequenced in wheat–mungbean green-manure–rice. The rice yield was comparatively low in wheat–rice sequence. The nutrient exploitative behaviour of the both cereals included in the sequence may be the reason for the decrease in rice yields, whereas inclusion of legume or green-manure helped in maintaining soil nutrient status (Patil *et al.* 1995). Among different legume crops, included in various crop sequences, chickpea had the highest seed yield, followed by field pea and lentil. The green fodder production of maize + cowpea was spectacular when grown after chickpea (Table 2).

Rice-equivalent yield

In general, sequences having 300% cropping intensity produced significantly more rice equivalent than the rotations of 2 crops in a year and sequence chickpea–maize + cowpea fodder–rice gave 34.68% and 3.68% more rice-equivalent yield than wheat–rice and wheat–maize + cowpea fodder–rice respectively. Though the lentil and field pea being legume benefited their succeeding crop (fodder and rice), but due to their own very poor yield performance could not reach the level that of chickpea (Table 3). Green-manuring of mungbean and sesbania after wheat harvest benefited the rice crop and consequently resulted 10.72% and 8.74% higher rice-equivalent yield than wheat–rice respectively. Likewise, the work of Aktar *et al.* (1993) also established the importance of green-manuring under cropping sequences. Again it may be envisaged that, although the yield of chickpea was lower than wheat during experimentation but due to higher market price of chickpea (Rs 7.60 and 8.15/kg) more rice-equivalent yield was calculated in chickpea–rice sequence over wheat–rice.

Production efficiency

The crop production efficiency was maximum in chickpea–maize + cowpea fodder–rice sequence, followed by wheat–maize + cowpea fodder–rice sequence (Table 3). On the other hand, sequence field pea–rice had the lowest per day equivalent productivity among all sequences included in the experiment. In the light of facts, it may be visualized that the economic yield and its price are important factor for influencing the production efficiency of a particular system, and were the major reasons for higher production efficiency of chickpea–maize + cowpea fodder–rice system.

Land-use efficiency

The greater land-use efficiency was noted with sequences having 3 crops (Table 3). The highest land-use efficiency was recorded when green-manure crops, i.e. mungbean and sesbania, were grown between wheat and rice and it was 3.83% more than wheat –maize + cowpea fodder–rice sequence. The green-manure crop of sesbania and mungbean took a bit longer

Table 1. Details of package of practices, market price and unit values used for comparison of different crops in various cropping sequences

Crop in rotation	Variety	Seed rate (kg/ha)	Row-to-row spacing (cm)	Sowing date		Carbohydrate (%)	Energy (cal/ 100 g economic produce)	Market price (Rs/q economic produce)			
				1996–97	1997–98			1996–97		1997–98	
								Grain/ green fodder	Straw/ stover	Grain/ green fodder	Straw/ stover
Wheat	'WH 542'	120	20	26 Nov. 1996	29 Dec. 1997	75.5	370	475	40	510	40
Pea	'Rachna'	80	30	26 Nov. 1996	29 Dec. 1997	56.5	315	900	40	1,200	40
Lentil	'PL 4'	50	20	26 Nov. 1996	29 Dec. 1997	60.8	346	900	40	1,100	40
Chickpea	'Avrodhi'	80	30	26 Nov. 1996	29 Dec. 1997	60.9	360	760	40	815	40
Maize + cowpea (2:1)	'Naveen'+	35+20	30	12 Apr. 1997*	22 Apr. 1998*	46.9	343	40		40	
	'VL 30'			27 July 1997**	05 May 1998**						
Mungbean green-manure	'Pant M 2'	20	30	27 Apr. 1997	01 May 1998						
Sesbania green-manure	*S. aculeata*	40	20	27 May 1998	01 May 1998						
Rice	'PD 4'	40	20	12 July 1997	10 July 1997	78.9	360	415	30	440	30

*Fodder (maize + cowpea) was sown in lentil–maize+cowpea–rice and pea–maize+cowpea–rice sequence;
**fodder (maize+cowpea) was sown in wheat–maize+cowpea–rice and chickpea–maize+cowpea–rice sequence

Table 2. Economic yields of different crops in various cropping sequences (q/ha)

Sequence	Winter crops			Summer crops			Rainy-season crops		
	1996–97	1997–98	Mean	1996–97	1997–98	Mean	1996–97	1997–98	Mean
Wheat–rice	56.46	27.50	41.98				57.29	52.71	55.00
Chickpea–rice	33.33	18.54	25.94				65.21	56.88	61.05
Lentil–rice	29.58	8.04	18.81				58.96	50.42	54.96
Field pea–rice	18.23	5.31	11.77				57.08	55.00	56.04
Wheat–mungbean–rice	57.08	28.54	42.81	285.00**	254.16**	269.58	67.92	62.29	65.11
Wheat–sesbania–rice	56.35	30.21	43.28	280.00**	238.34**	259.17	65.83	59.16	62.50
Wheat–maize + cowpea–rice	55.71	28.83	42.27	343.75*	262.50*	303.13	60.62	53.54	57.08
Chiken–maize + cowpea–rice	33.17	21.04	27.11	383.33*	275.00*	329.17	62.08	55.21	58.65
Lentil–maize + cowpea–rice	29.38	8.67	19.03	293.75*	300.00*	296.88	58.54	50.63	54.59
Field pea–maize + cowpea–rice	18.02	4.17	11.10	345.83*	281.25*	313.54	63.54	55.83	59.69
CD (P = 0.05)							5.06	5.26	5.04

*Green manure biomass added to soil:
**fresh maize+cowpea fodder

Table 3. Equivalent yields, system efficiency and economics as affected by crop sequence treatment

Sequence	Rice-equivalent yield (q/ha)			System efficiency		Carbohydrate equivalent (kg/ha)			Chemical energy equivalent (k cal ×10^{-4}/ha)			Economics of crop sequences (Rs/ha)*		
	1996–97	1997–98	Mean	Production efficiency	Land-use efficiency	1996–97	1997–98	Mean	1996–97	1997–98	Mean	Gross returns	Total variable cost	Returns over variable cost
Wheat–rice	121.89	84.58	103.24	28.28	71.78	8,785	6,236	7,510.5	4,151	2,915	3,533.0	48,302	16,114	32,188
Chickpea–rice	126.25	91.25	108.75	29.79	71.73	71,780	5,617	6,397.5	3,548	2,715	3,131.5	49,203	13,736	35,467
Lentil–rice	123.58	70.52	97.05	26.59	68.49	6,335	4,464	5,399.5	2,146	2,093	2,119.0	44,460	13,082	31,378
Field pea–rice	97.17	70.27	83.72	22.94	68.49	53,360	4,637	4,936.5	3,629	2,147	2,388.0	39,929	13,257	26,672
Wheat–mung-bean–rice	133.25	95.37	114.31	31.32	90.95	9,669	7,068	8,368.5	45,56	3,298	3,927.0	53,587	17,858	35,729
Wheat–sesbania–rice	130.33	94.18	112.26	30.75	90.95	9,450	6,948	8,199.5	4,454	3,248	3,851.0	52,715	17,773	34,942
Wheat–maize + cowpea–rice	157.52	110.67	134.10	36.74	87.12	11,053	8,302	9,677.5	5,753	4,348	5,050.5	61,682	20,889	40,793
Chickpea–maize + cowpea–rice	159.77	118.31	139.05	38.09	83.84	9,795	7,612	8,703.5	5,533	4,197	4,865.0	62,503	18,511	43,992
Lentil–maize + cowpea–rice	150.58	97.50	124.04	33.98	82.47	8,624	6,669	7,646.6	4,693	3,693	4,193.0	56,408	17,855	38,553
Field pea–maize + cowpea–rice	135.56	92.77	114.16	31.28	82.47	8,666	6,645	7,655.5	4,319	3,605	3,962.0	52.,251	18,032	34,219
CD (P = 0.05)	7.00	6.48		6.64	8.31	573	477		321	333				2,955

*Based on means of yearly calculations of 1996–97 and 1997–98 at prevalent prices duration (60 days) than maize + cowpea fodder (45 days) and thereby increased the land-use efficiency. Further, chickpea–maize + cowpea fodder–rice showed its superiority to the remaining others sequences. Again between 2 crop sequences, wheat–rice was better in term of land-use efficiency, followed by chickpea–rice, whereas lentil–rice and field pea–rice sequences were poor. The smaller crop span of pulses (120 to 130 days) was the important factor in lowering down the land-use efficiency of legume component-based system.

Energy and carbohydrate equivalent

The wheat–maize + cowpea fodder–rice crop sequence was the highest energy producer, followed by chickpea–maize + cowpea fodder–rice (Table 3). The inclusion of third crop in system as fodder, proved beneficial in producing chemical energy by increasing overall production of the sequence. Further, higher per unit energy production ability of wheat crop included in sequence, i.e. 370 K cal/100 g produce had an additive effect on chemical energy production compared to pulses. Wheat–rice system with green-manuring produced comparatively more chemical energy equivalent than wheat–rice, owing to increase in yield of rice and wheat. The carbohydrate values of produce have linear relationship with energy-production efficiency, hence cereal-dominating sequences proved better in terms of chemical energy equivalents than the sequences involving legumes (Pillai *et al.* 1987).

Economics

The inclusion of third crop in summer season either as a fodder or green-manure markedly increased the cost of production (Table 3). Among these, wheat–maize + cowpea fodder–rice sequence had maximum cost of cultivation. Growing of pulses in place of wheat reduced the cost of production compared with that of wheat–rice sequence, in all sequences.

The sequence chickpea–maize + cowpea fodder–rice, followed by wheat–maize + cowpea fodder –rice gave significantly higher gross and net returns than all other sequences. The field pea–rice sequence gave lowest. Here the yield level of field pea was quite low, consequently gross returns and net profits were lower compared with other legumes. Chickpea–maize + cowpea fodder–rice, wheat–maize + cowpea fodder–rice, lentil–maize + cowpea fodder–rice, wheat–mungbean green-manure–rice, chickpea–rice, wheat–sesbania green-manure–rice and field pea–maize + cowpea fodder–rice gave an additional income of Rs 11,804; 8,605; 6,363; 3,540; 3,278; 2,787 and 2,331/ha, respectively, over wheat–rice sequence. The results clearly indicate superiority of inclusion of third crop in the sequence. The higher productivity of chickpea, its better sale price and congenial environment for succeeding crop growth had additional advantage to get more net profit over wheat in these systems. Singh *et al.* (1995) and Desh Pandey and Jadhav (1996) were also of the same opinion. Although the yield of rice was higher in green-manuring sequences, the additional cost of cultivation of green-manure crop in system lower down the net return compared the chickpea–rice. On the other hand, green-manured system registered its superiority to wheat–rice. Devi *et al.* (1997) was also of the similar views. Since chickpea–maize + cowpea fodder–rice had highest productivity and net profit, the same may be recommended for sustainable cultivation under *tarai* region and alternative to rice–wheat sequence.

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