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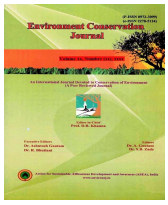

Performance of different rice-based cropping systems in the wet temperate zone of Himachal Pradesh

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ABSTRACT

A field experiment to diversify the rice–wheat system to increase employment and income was conducted during 2017-18 at the research farm of CSK Himachal Pradesh Krishi Vishwavidyalaya Palampur with eight cropping systems that were replicated four times. One-year results revealed that the highest rice grain yield (16477 kg/ha), net returns (₹ 219828/ha) and marginal returns (₹80946) were recorded from the rice – palak – cucumber sequence. Okra – radish – onion resulted in maximum food availability (55.16 kg/ha/day), whereas employment generation was maximum from rice – lettuce – potato + coriander (102.91%). In terms of carbohydrate yield (5146 kg/ha), protein yield (640.6 kg/ha) and energy equivalent (23919 MJ/ha), it was highest from the rice – wheat sequence; however, in the case of carbohydrate and energy equivalent, it was on par with rice – lettuce – potato + coriander.

Introduction

The Indian population is growing at a rate of 1.8% annually and is likely to surpass that of China within the next decade (Samir *et al.,* 2018). This is an inevitable concern that further raises other issues, such as food security, unemployment and poverty, in the country. Demand for food is increasing with population rise and is expected to increase by 75-100% globally by 2050 (Keating *et al.,* 2010; Tilman *et al.,* 2011), which will be even higher for India. Cereal-based mono- and double-cropping cannot meet the food and income demand of the rising population and thus requires land intensification with high-value crops. Crop diversification is a sustainable way to intensify land use, which not only increases income but also provides employment to youth and balanced food to farmers. System integration improves both food and nutritional security, enhances land and water productivity, and preserves ecosystems (Ayyappan *et al.,* 2009). Rice – wheat is a predominant cropping system in India, which covers approximately 10.5 Mha of the country (Sarkar, 2015). This system is highly exhaustive and unsustainable, causing resource depletion. India is a land with a diverse climate that is rainfall dominant and allows farmers to grow different crops. Growing short-duration vegetables after rice or replacing both cereal crops with vegetables has a positive effect on equivalent yield and employment. Diversification with high-value crops such as vegetables is also required to fulfill the motto of doubling farmers' income by encouraging the export of farm produce. Therefore, traditional rice–wheat cropping systems can be replaced by vegetable crops for more profitability and sustainability.

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Therefore, the present study was carried out to diversify the rice–wheat system to increase employment and income.

Material and Methods

Study area

A field experiment was conducted during 2017-18 under the All India Co-ordinated Research Project at the Bhadiarkhar research farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, which is situated at $32^0 6'$ N latitude and $76^0 3'$ E longitude and at an altitude of 1223.7 m above mean sea level. Farm soil was acidic in reaction with silty clay loam texture at the start of the experiment. The soil of the study area was medium in available nitrogen and potassium and high in available phosphorus. The research farm received 2851 mm of rainfall during the one-year crop cycle, the majority of which was received from June to September (Figure 1).

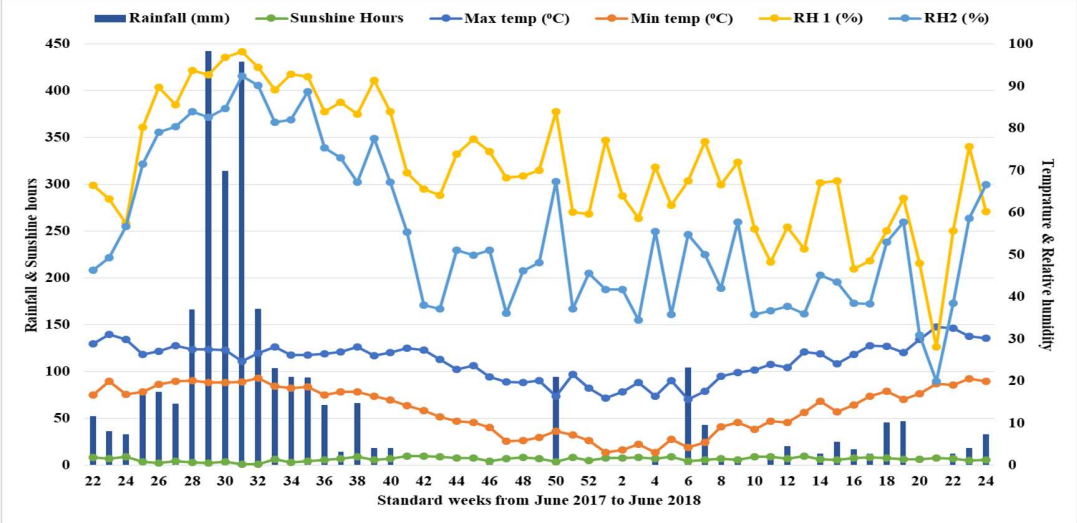

Figure 1: Mean weekly meteorological data from June 2017 to June 2018

Treatment details

Eight rice-based cropping systems, viz. T_1: Rice – Wheat, T_2: Rice – Pea – Summer squash, T_3: Okra – Radish – Onion, T_4: Turmeric – Pea – Summer squash, T_5: Rice – Lettuce – Potato + Coriander, T_6: Rice – Palak – Cucumber, T_7: Rice – Broccoli – Radish and T_8: Colocasia – Pea + Coriander were evaluated in a randomized block design with four replications.Economic yield obtained from different crop sequences has been expressed in terms of carbohydrate yield, protein yield and chemical energy to facilitate comparison among crop sequences based on their content in the economic part.

$$\text{Rice equivalent yield (kg/ha)} = \text{Economical yield of a crop (kg/ha)} \times \frac{\text{Price (₹/kg) of same crop}}{\text{Price (₹/kg) of rice}}$$

$$\text{Relative production efficiency (\%)} = \frac{\text{REYD} - \text{REYE}}{\text{REYD}} \times 100$$

where REYD is the rice equivalent yield under the diversified system and REYE is the rice equivalent yield of the existing system.

$$\text{Relative economic efficiency (\%)} = \frac{\text{NRD} - \text{NRE}}{\text{NRE}} \times 100$$

where NRD is the net returns obtained under a diversified system and NRE is the net returns of the existing system.

$$\text{Employment generation (\%)} = \frac{\text{MDD} - \text{MDE}}{\text{MDE}} \times 100$$

where MDD is the man-days required in the diversified system and MDE is the man-days required in the existing system.

The cost of cultivation of each crop was computed based on the prevailing market price of the inputs during the respective crop season.

Net returns were measured by deducting total returns from the cost of cultivation.

Results and Discussion

Economic yield and rice equivalent yield

The yields of most of the crops were reported to be lower than the reported yields in the region except for rice, wheat, onion and cucumber (Table 1) Yield of kharif crops viz. okra, turmeric and colocasia were very low because of adjacent flooded rice plots, which made conditions unfavorable for the growth of these crops. Rice yield was maximum for the rice – palak – cucumber 164.77 q/ha) sequence, followed by okra – radish – onion (140.25 q/ha). The lowest rice yield was recorded in the rice–wheat system. The equivalent yield of rice–wheat was reported to be 2.6–1.2 times less than that of other vegetable-intensive cropping systems because of the low cropping intensity and lower sale price of cereals in the market compared to other high-value crops, such as vegetables. Babu *et al.* (2016) and Choudhary *et al.* (2013) also reported higher yields in diversified systems than in existing traditional systems.

Table 1: Economic yield. Rice grain equivalent yield (RGEY), production efficiency and relative production efficiency of different cropping systems

Cropping sequence		Yield of crops (kg/ha)				RGEY (kg/ha)	Production efficiency	Relative production efficiency
		Kharif	Rabi	Summer	Intercrop			
T_1	Rice – Wheat	4072	2273	-	-	6259	21.44	
T_2	Rice – Pea – Summer squash	3598	2273	7292	-	13163	46.68	110.31
T_3	Okra – Radish – Onion	1098	5398	13636	-	14025	52.14	124.08
T_4	Turmeric – Pea – Summer squash	2794	1610	7008	-	13506	42.61	115.79
T_5	Rice – Lettuce – Potato + Coriander	3930	3409	8523	379	12547	45.96	100.46
T_6	Rice – Palak – Cucumber	3409	1420	11648	-	16477	63.62	163.25
T_7	Rice – Broccoli – Radish	2841	2367	3598	-	7599	29.46	21.41
T_8	Colocasia – Pea + Coriander	8144	1894		237	10630	40.26	69.84
	CD					1737	6.61	

Productivity and relative production efficiency

Productivity also followed a similar trend as rice grain equivalent yield. Significantly higher production efficiency was reported in the rice – palak – cucumber cropping system, whereas the rice – wheat cropping system recorded the lowest productivity. Production efficiency greatly depends upon the yield and market price of the crop (Dhiman, 2010). Similar results were also reported by Singh *et al.* (2007), where more productivity in diversified cropping systems was recorded. The relative production efficiency of rice – palak – cucumber was 163.25% higher than that of the existing rice – wheat system, which was followed by the okra – radish – onion sequence (124.08%). Overall, system productivity compared to the rice–wheat system varied from 163.25% to 21.41%.

Carbohydrate yield, protein yield and energy equivalent

Significantly higher carbohydrate yields (5146 kg/ha) and energy equivalents (23919 MJ/ha) were reported in the rice–wheat sequence (Table 2). This sequence was statistically at par with rice – lettuce – potato + coriander. The next highest carbohydrate yields were rice – pea – summer squash, rice – palak – cucumber, rice – broccoli – radish and turmeric – pea – summer squash. Significantly lower carbohydrate yield (1767 kg/ha) and energy equivalent (8120 MJ/ha) were reported in okra – radish – onion, which was on par with colocasia – pea+coriander (2034 kg/ha and 9765 MJ/ha, respectively). This was because of the higher carbohydrate content in rice, wheat and potato. Earlier similar results have been reported by Singh and Sharma (2002) in the case of carbohydrate yield in rice-based crop sequences. Sharma *et al.* (2008) reported similar results with higher energy equivalents of rice – wheat crop sequences than the rest of the rice-based sequences. The maximum protein yield (640.6 kg/ha) was recorded from the rice–wheat sequence. This sequence was followed by rice – lettuce – potato + coriander, rice – pea – summer squash, colocasia – pea + coriander, rice – palak – cucumber, turmeric – pea – summer squash and rice – broccoli – radish. A significantly lower protein yield (222.3 kg/ha). Sharma *et al.* (2008) reported similar results with higher energy equivalents of rice – wheat crop sequences than the rest of the rice-based sequences. The maximum protein yield (640.6 kg/ha) was recorded from the

rice–wheat sequence. This sequence was followed by rice – lettuce – potato + coriander, rice – pea – summer squash, colocasia – pea + coriander, rice – palak – cucumber, turmeric – pea – summer squash and rice – broccoli – radish. A significantly lower protein yield (222.3 kg/ha).

Table 2: Carbohydrates, protein yield, energy equivalent, man-days and employment generation in different cropping systems

Cropping sequence		Carbohydrate Yield (kg/ha)	Protein Yield (kg/ha)	Energy Equivalent (kg/ha)	Man-days per ha	Employment generation (%)
T_1	Rice – Wheat	5146	640.6	23919	172	
T_2	Rice – Pea – Summer squash	3369	470.0	15731	299	73.83721
T_3	Okra – Radish – Onion	1767	222.3	8120	322	87.2093
T_4	Turmeric – Pea – Summer squash	2433	326.9	12368	317	84.30233
T_5	Rice – Lettuce – Potato + Coriander	5049	515.2	22747	349	102.907
T_6	Rice – Palak – Cucumber	2947	330.7	13679	288	67.44186
T_7	Rice – Broccoli – Radish	2459	305.0	11246	281	63.37209
T_8	Colocasia – Pea + Coriander	2034	388.5	9765	257	49.4186
	SEm±	164	23.4	767		
	CD	481	68.9	2257		

was recorded in the okra – radish – onion crop sequence. Higher carbohydrate yield, protein yield and chemical energy equivalent in the rice – wheat sequence was because of more carbohydrates, protein and calories in cereals compared to vegetable crops.

Food availability and employment generation

Okra – radish – onion resulted in a significantly higher availability of food (55.16 kg/ha/day) throughout the year than the rest of the crop sequences (fig 2). This was due to the higher yield of onion. This sequence was followed by rice – palak – cucumber, rice – lettuce – potato + coriander and rice – pea - summer squash. The rice–wheat cropping sequence resulted in significantly lower food availability (18.94 kg/ha/day). All the systems generated more employment (table 2) compared to the rice – wheat system (172 man-days).

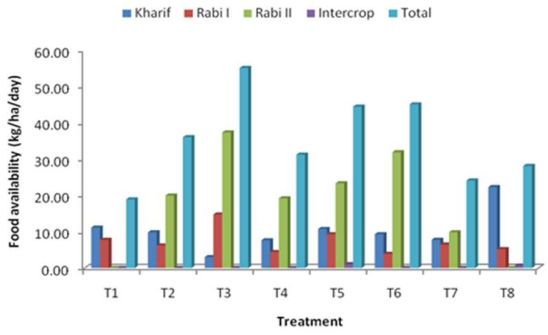

Figure 2: Effect of different treatments on food availability

The maximum employment generation was from rice – lettuce – potato + coriander, which generated 349 man-days. This was because of more intensification of land than other sequences. Similar observations were also recorded by *Chitale et al.* (2011) with diversified rice-based cropping systems. Relative employment generation shows that rice – lettuce – potato + coriander generated 102.91% more employment than the existing rice – wheat system.

Economic analysis

Table 3 and Figure 3 shows that the highest cost of cultivation was recorded in turmeric – pea – summer squash (₹ 168040/ha), followed by rice – lettuce – potato + coriander, okra – radish – onion and colocasia – pea + coriander sequences. This was due to the high seed rate of turmeric and potato as well as the labor-intensive nature of both crops. The rice–wheat sequence had the lowest cost of cultivation (Rs 82014/ha) among all the crop sequences. This was due to the less intensified system, which requires less labor for management. Significantly higher returns (gross and net returns) were observed from the rice – palak – cucumber crop sequence (₹ 344488/ha and ₹ 219828/ha, respectively), whereas the lowest returns were recorded from the rice – wheat and rice – broccoli – radish sequences. This may be attributed to the high yield and price of cucumber resulting in higher returns. Similar results were also reported by Prasad *et al.* (2013).

Table 3: Economic analysis of different cropping systems

Cropping sequence		Gross returns	Net returns	Relative economic efficiency (%)	Marginal Cost (MC)	Marginal Returns (MR)	MR:MC	Returns (₹/ha/day)
T_1	Rice – Wheat	163542	80163					274.53
T_2	Rice – Pea – Summer squash	285914	156903	95.73	45632	122372	2.68	556.39
T_3	Okra – Radish – Onion	282395	152392	90.10	46624	118853	2.55	566.51
T_4	Turmeric – Pea – Summer squash	275846	107806	34.48	84661	112304	1.33	340.08
T_5	Rice – Lettuce – Potato + Coriander	266004	84044	16.11	98581	102462	1.04	340.93
T_6	Rice – Palak – Cucumber	344488	219828	174.23	41281	180946	4.38	848.76
T_7	Rice – Broccoli – Radish	168196	45609	-43.10	39208	4654	0.12	176.78
T_8	Colocasia – Pea + Coriander	224091	94718	18.16	45994	60549	1.32	358.78
	SEm±	11999	11999					45.64
	CD	35295	35295					134.26

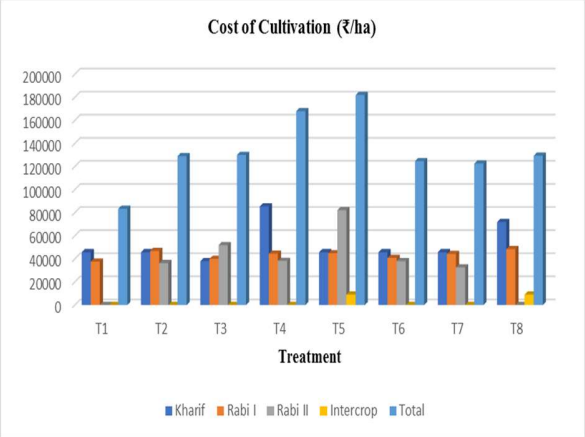

Figure 3: Cost of cultivation of different cropping systems

All cropping systems except rice – broccoli – radish were found to be advantageous over the rice – wheat system in terms of relative economic analysis. The highest economic efficiency was obtained in the rice – palak – cucumber sequence, which was 174.23% higher than that in the traditional rice – wheat system. This system was followed by the rice – pea – summer squash (95.73%) and okra – radish – onion sequences (90.10%). Similarly, marginal returns, MR:MC and returns (₹/ha/day) were also higher for the rice – palak – cucumber system (₹180946, 4.38 and 848.76 ₹/ha/day, respectively).

Conclusion

From the research, it can be concluded that in terms of rice grain equivalent yield, productivity, food availability, employment generation, profitability and returns, the diversified systems remained superior to the rice–wheat system. Therefore, farmers should opt for diversified cropping systems depending upon the available resources and market demand of crops.

Conflict of interest

The authors declare that they have no conflict of interest.

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