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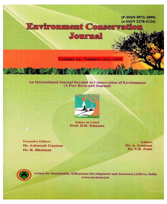

Diversification of traditional rice – wheat system with vegetables for sustainable productivity, profitability and energy efficiency

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ABSTRACT

Rice – wheat cropping system is backbone of agriculture and responsible for achieving food security in the country. However, because of threat to sustainability of this system there is urgent need of crop diversification. A field experiment to diversify the rice – wheat system in wet zone of Himachal Pradesh was carried out during the year 2017-18 at Bhadiarkhar research farm, Department of Agronomy, CSK HPKV, Palampur to evaluate productivity, profitability and energy pattern of eight different rice-based cropping systems. Results revealed that rice – palak – cucumber system resulted in significantly higher rice grain equivalent yield (16477 kg/ha), profitability (₹ 848.76/ha/day), productivity (63.62 kg/ha/day), net returns (₹ 219828/ha) and benefit cost ratio than other crop sequences whereas lowest rice grain equivalent yield (6259 kg/ha) and productivity (21.44 kg/ha/day) was recorded from traditional rice – wheat system. However, land utilization ratio and duration were found to be maximum from turmeric – pea – summer squash system (86.85) followed by rice – wheat. Energy utilization was noticed highest from rice – lettuce – potato + coriander system followed by turmeric – pea – summer squash. Maximum energy output (280.42×10³MJ/ha) and energy efficiency (10.58) were observed in rice – palak – cucumber system.

Introduction

Cereal-based cropping systems have significant role in attaining self-sufficiency in food-grain production in India. One of the most important cropping systems in country is rice – wheat system which is considered to be the major contributor to the national food basket. Maximum area of country is covered by this system (about 10.5 M ha area) (Sarkar, 2015). However, concern has been raised over the sustainability of this system due to natural resource degradation (declining soil fertility and lowering of groundwater tables), climate variability, reduction in profitability, and decelerating yield growth rates of both the crops (Lohan *et al.*, 2017; Jat *et al.*, 2021). As much of the food and economic security has been dependent on this cropping system, the low production level needs urgent attention. So, to maintain sustainability it is imperative to intensify and diversify rice – wheat system with other crops of high economic value. Crop diversification is a useful means to increase crop output, achieve stability and sustainability in production and stabilizing farm income. It is significant tool in minimizing the risk in farming (Hedge *et al.*, 2003). Diversified farms are resilient to shocks and stresses thus are economically and ecologically stable. Diversification is responsible for yield maximization owing to high cropping intensity. It

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provides large scale boost to Indian agricultural economy in terms of income, employment and nutritional improvement. Intensification in rice – wheat system can be achieved through either adding or replacing rice or wheat crop with some high value crops like vegetables which will not only increase production and profitability, but it also maintains sustainability to meet requirement of future generation (Samui *et al*., 2004). It also improves socio-economic condition of farmers and provide year-round income and employment to them. Agriculture in Himachal is characterized by presence of large number of small and marginal farmers. The wet zone is bestowed upon with plenty of rainfall congenial for vegetable production. Also, hilly area of the state is famous for production of high-quality vegetables which are major driving force behind diversifying cereal-based cropping systems with high value vegetables. Therefore, to increase income of small households, alternative cropping systems suited to the region for efficient utilization of resources need to be selected for higher system productivity, economic returns and benefit cost ratio.

Material and Methods

Experimental site

A field investigation on diversification of rice – wheat cropping system was carried out in the year 2017-18 under All India Coordinated Research Project to evaluate productivity, profitability and energy auditing of diversified cropping systems at Bhadiarkar research farm of department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The research site was located at latitude of 32°04′ N and longitude of 76°35′ E and at an elevation of 1100 m amsl in the Palam valley of Kangra region.

Soil and Climate

Soil of experimental farm was silty clay loam in texture, slightly acidic (pH 5.5) with high organic carbon (0.95%), available nitrogen (295.12 kg/ha), phosphorus (68.58 kg/ha) and potassium (123.35 kg/ha) at the start of investigation. The total rainfall recorded was 2851mm from June 2017-June 2018. The minimum and maximum temperature varied from 3.06 – 20.78 and 15.71 – 32.89 during the cropping period. The climate of region is classified as humid sub-tropical with cool winters and mild summers.

Treatment details

The experiment was laid out in randomized block design with eight treatments (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) which were replicated four times. All the crops were provided with full recommended dose of fertilizes. All the intercultural operations were according to recommended package of practices for the region. The varieties, seed rate and fertilizer doses for each crop is given in table 1.Economic yield of all the crops were converted to rice grain equivalent yield (RGEY) as per the price of the respective crop at a local market and was calculated as follows-

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

Land use efficiency (LUE) was measured by dividing actual duration of crop sequence with 365 and expressed as percentage.Energy input (MJ/ha) was calculated by summing up all the energy expenditures used for raising the component crops. Energy output (MJ/ha) was determined by adding the energy equivalents (MJ) for main and by products of crops.

$$E_0 = \{\sum(M_y * E_m)\} + \{\sum(B_y * E_b)\}$$

E_0 is the energy output
M_y and B_y are the economic and by-product yield, respectively
E_m and E_b are energy equivalents for main crop and by-products, respectively

$$\text{Energy use efficiency, EUE} = \frac{\text{Energy Output (MJ/ha)}}{\text{Energy Input (MJ/ha)}}$$

$$\text{Energy productivity} = \frac{\text{Grain Output (kg/ha)}}{\text{Energy Input (MJ/ha)}}$$

Results and Discussion

Rice grain equivalent yield, productivity, land use efficiency and duration

The rice equivalent yield (RGEY) was recorded highest in rice – palak – cucumber (table 2) which was followed by okra – radish – onion and turmeric – pea – summer squash which might be due to high market price of vegetables compared to cereals and also high cropping intensity than cereal-based system. Lowest RGEY was recorded from traditional rice – wheat system (Jat *et al*., 2012) which was 2.6 times less than rice – palak – cucumber. Productivity also followed almost similar trend as rice equivalent yield. Maximum productivity was observed in rice – palak – cucumber sequence because of higher production and market price of cucumber. Tandel *et al*. (2014) and Kachroo *et al*. (2014) also reported similar results where maximum rice grain equivalent yield and productivity was observed from diversified vegetable-based sequence compared to cereal-based system. Total duration and land utilization efficiency was maximum for turmeric – pea – summer squash system which was followed by rice – wheat and rice – pea – summer squash. Lowest land use efficiency was recorded from rice – broccoli – radish and rice – palak – cucumber sequence (table 2).

Table 1: Varieties, seed rate and fertilizer doses of all the crops

Sequence	Crop	Variety	Seed rate (kg/ha)	Fertilizer dose		
				N	P2O5	K2O
Kharif						
T_1	Rice	HPR-2143	15	90	20	40
T_2	Rice	HPR-2143	15	90	20	40
T_3	Okra	P-8	15	75	25	55
T_4	Turmeric	Palam pitamber	2250	30	15	60
T_5	Rice	HPR-2143	15	90	20	40
T_6	Rice	HPR-2143	15	90	20	40
T_7	Rice	HPR-2143	15	90	20	40
T_8	Colocasia	Local	2000	75	25	50
Rabi						
T_1	Wheat	HPW-155	100	120	60	30
T_2	Pea	Palam Priya	75	25	30	60
T_3	Radish	Japanese white	8	100	25	35
T_4	Pea	Palam Priya	75	25	30	60
T_5	Lettuce	Avej wonder	0.5	60	20	40
T_6	Palak	Pusaharit	30	74	25	30
T_7	Broccoli	Palam samridhi	0.5	150	50	55
T_8	Pea + Coriander	Palampriya+Local	75+10	25	30	60
Summer						
T_1	-	-	-	-	-	-
T_2	Summer squash	Pusaalankar	8	100	25	55
T_3	Onion	Nasik red	10	125	37	60
T_4	Summer squash	Pusaalankar	8	100	25	55
T_5	Potato + Coriander	Kufrijyoti + Local	2250 + 10	120	40	60
T_6	Cucumber	Palam sanjog	10	100	25	60
T_7	Radish	Marvel white	4	100	25	35
T_8	-	-	-	-	-	-

Table 2: Rice grain equivalent yield, LUE and productivity of rice-based cropping systems

	Cropping sequence	Biological yield (kg/ha)	RGEY (kg/ha)	Duration (days)	LUE (%)	Productivity (kg/ha/day)
T_1	Rice – Wheat	4072 + 2273	6259	96 + 196 (292)	80.00	21.44
T_2	Rice – Pea – Summer squash	3598 + 2273 + 7292	13163	96 + 132 + 54 (282)	77.26	46.68
T_3	Okra – Radish – Onion	1098 + 5398 + 13636	14025	63 + 83 + 123 (269)	73.70	52.14
T_4	Turmeric – Pea – Summer squash	2794 + 1610 + 7008	13506	131 + 132 + 54 (317)	86.85	42.61
T_5	Rice – Lettuce – Potato + Coriander	3930 + 3409 + 8523 + 379	12547	96 + 58 + 119 (273)	74.79	45.96
T_6	Rice – Palak – Cucumber	3409 + 1420 + 11648	16477	96 + 113 + 50 (259)	70.96	63.62
T_7	Rice – Broccoli – Radish	2841 + 2367 + 3598	7599	96 + 103 + 59 (258)	70.68	29.46
T_8	Colocasia – Pea + Coriander	8144 + 1894 + 237	10630	131 + 133 (264)	72.33	40.26
	CD		1737			6.61

This was due to presence of more fallow period between harvest and sowing of successive crop. These cropping systems need more intensification to get more profit per unit area per unit time. Among the crops, wheat crop remained in field for longest followed by pea, turmeric and onion while cucumber, summer squash, lettuce and radish covered the field for very short duration i.e for less than 60 days.

Energy pattern

Energy pattern of different rice-based cropping systems were evaluated (table 3). Rice – lettuce – potato + coriander cropping system utilized maximum amount of energy which is attributed to labour intensive nature of potato crop and high cropping intensity of this system. This sequence was followed by turmeric – pea – summer squash and rice – broccoli – radish. However, rice – wheat sequence utilized the lowest amount of energy. Similar results were reported by Sharma *et al*. (2004). In case of energy output, rice – pea – summer squash system was reported to had significantly higher energy output followed by rice – wheat, rice – broccoli – radish, rice – lettuce – potato + coriander, colocasia – pea + coriander, rice – palak – cucumber, turmeric – pea – summer squash and least for okra – radish – onion (127.71). Net energy was also recorded maximum for rice – pea – summer squash system followed by rice – wheat. This was due to more output of energy as compared to energy use in these systems. Least net energy was from okra – radish – onion sequence.

The energy use efficiency was recorded maximum in rice – pea – summer squash. However, this sequence was at par with rice – wheat system. This was due to production of maximum energy with low energy input in this system. Similar results were also reported by Kacharoo *et al (2012).* Significantly lower energy efficiency was observed in okra – radish – onion which was at par with turmeric – pea – summer squash. Among all the cropping systems, rice – lettuce – potato + coriander was found to be most productive (9.95 kg/MJ) followed by Colocasia – pea + coriander whereas traditional rice – wheat system was reported to be least productive (0.64 kg/MJ).

Table 3:Energy pattern of different rice-based cropping systems

	Cropping systems	Energy input (MJ/ha)	Energy output (MJ/ha)	Net Energy (MJ/ha)	Energy Efficiency	Energy productivity
T_1	Rice – Wheat	23478.37	240113.64	216635.27	10.23	0.64
T_2	Rice – Pea – Summer squash	26513.69	280421.40	253907.71	10.58	1.49
T_3	Okra – Radish – Onion	29505.84	127712.12	98206.28	4.33	1.90
T_4	Turmeric – Pea – Summer squash	33780.22	159308.71	125528.49	4.72	1.16
T_5	Rice – Lettuce – Potato + Coriander	39804.19	205118.37	165314.18	5.15	9.95
T_6	Rice – Palak – Cucumber	27857.43	168522.73	140665.30	6.05	1.84
T_7	Rice – Broccoli – Radish	33102.41	215250.95	182148.54	6.50	0.88
T_8	Colocasia – Pea + Coriander	26616.72	197500.00	170883.28	7.42	6.14
	CD	-	28814.98	28814.98	0.98	0.06

Economic analysis

It is evident from table 4 that maximum cost for cultivation of crops was involved in turmeric – pea – summer squash system (₹ 168 040/ha) followed by rice – lettuce – potato + coriander and okra – radish – onion. However, least cost was involved in rice – wheat sequence. Rice – palak – cucumber system generated highest gross and net returns (₹ 344 488 and 219 828/ha, respectively) which was followed by rice – pea – summer squash and okra – radish – onion. Lowest gross returns were obtained from rice – wheat system (₹ 163 542/ha) whereas net returns were lowest from rice – broccoli – radish (₹ 80 163/ha) followed by rice – wheat (₹ 80163/ha). Similar results were reported by Prasad and Urkurkar (2010). Benefit cost ratio followed the similar trend being highest from rice – palak – cucumber system (5.64) and lowest from rice – wheat (1.88). Returns and benefit cost ratio was higher from the systems including vegetables compared to cereal-based system. These results corroborate the findings of Prasad (2016). Moreover, all the cropping systems are intensified than rice – wheat system. Rice – palak – cucumber cropping system generated maximum income (848.76 ₹/ha/day) mainly because of higher production which ultimately fetch more returns from cucumber. This system was followed by rice – pea – summer squash and okra – radish – onion whereas rice – broccoli – radish (176.78 ₹/ha/day) and rice – wheat (274.53 ₹/ha/day) were least profitable. Economic efficiency of rice – palak – cucumber was recorded 380% and 209% higher over rice – broccoli – radish and rice – wheat system. Prasad *et al*. (2013) and Ray *et al*. (2016) also reported similar results in rice-based cropping system.

Table 4: Economic analysis of various rice-based cropping systems

	Cropping sequence	Cost of cultivation	Returns (₹/ha)		B:C	Profitability (₹/ha/day)
			Gross	Net		
T_1	Rice – Wheat	82014	163542	80163	1.88	274.53
T_2	Rice – Pea – Summer squash	127646	285914	156903	4.06	556.39
T_3	Okra – Radish – Onion	130003	282395	152392	2.91	566.51
T_4	Turmeric – Pea – Summer squash	168040	275846	107806	2.67	340.08
T_5	Rice – Lettuce – Potato + Coriander	162534	266004	93075	3.07	340.93
T_6	Rice – Palak – Cucumber	123295	344488	219828	5.64	848.76
T_7	Rice – Broccoli – Radish	121222	168196	45609	1.04	176.78
T_8	Colocasia – Pea + Coriander	129373	224091	94718	1.58	358.78
	CD		35295	35295	0.29	134.26

Conclusion
From the research it can be concluded that rice – palak – cucumber cropping sequence resulted in higher rice grain equivalent yield, economic and production efficiency, net and gross returns and benefit cost ratio whereas energy efficiency and energy output were recorded highest from rice – pea – summer squash system. Inclusion of legume crop in system was found to increase dry matter production and yield of succeeding crop i.e summer squash. Land use efficiency was maximum from turmeric – pea – summer squash which utilized the land for maximum period. Overall, it can be concluded that vegetable-based systems are superior in almost all aspects over traditional rice – wheat system. So, it is advisable to farmers to substitute cereal-based system with diversified crops so as to provide additional sources of revenue, making farming more resilient, promoting a diverse ecosystem for the long-term viability of the farm, sustainable production and for better resource use efficiency.

Conflict of interest
The authors declare that they have no conflict of interest.

References

Hedge, D.M., Tiwari, S.P. and Rai, M. (2003). Crop diversification in Indian agriculture. *Agricultural Situation in India,*351-354.

Jat, H.S., Kumar, V., Kakraliya, S.K., Abdallah, A.M., Datta, A., Choudhary, M., Gathala, M.K., McDonald, A.J., Jat, M.L. and Sharma, P.C. (2021). Climate-smart agriculture practices influence weed density and divesity in cereal-based agri-food systems of western Indo-Gangetic plains. *Scientific Reports,* 11, 15901.

Jat, R.A., Dungrani, R.A., Arvadia, M.K. and Sahrawat, K.L. (2012). Diversification of rice (*Oryza sativa* L.) based cropping systems for higher productivity, resource-use efficiency and economic returns in South Gujarat of India. *Archives of Agronomy and Soil Science,* 58(6), 561-572.

Kachroo, D., Thakur, N.P., Kaur, M., Kumar, P., and Sharma, R. (2012). Productivity and energetic of rice (*Oryza sativa*) based cropping systems under sub-tropical condition of Jammu. *Indian Journal of Agronomy,* 57: 117-121.

Kachroo, D., Thakur, N.P., Kaur, M., Kumar, P., Sharma, R. & Khajuria, V. (2014). Diversification of rice-based cropping system for enhancing productivity and employment. *Indian Journal of Agronomy,* 59, 21-25.

Lohan, S.K., Jat, H.S., Yadav, A., Sidhu, H.S., Jat, M., Choudhary, M., Peter, J.& Sharma, P. (2017). Burning issues of paddy residue management in north-west states of India. *Renewable and Sustainable Energy Reviews,* 81, 693-706.

Prasad, A. (2016). Diversification of existing rice–based cropping system for sustainable productivity under assured irrigation condition for Chhattisgarh plains. *International Journal of Multidisciplinary Education and Research,* 1(3), 85-88.

Prasad, D., and Urkurkar, J.S. (2010). Economic evaluation of rice based cropping sequences in plain areas of Chhattisgarh. *Journal of Soils and Crops*, 20: 229-232.

Prasad, D., Yadava, M.S.& Singh, C.S. (2013). Diversification of rice-based cropping systems for higher productivity, profitability and resource-use efficiency under irrigated ecosystem of Jharkhand. *Indian Journal of Agronomy,* 58, 264-270.

Ray, M., Roy, D.C.&Zaman, A. (2016). Evaluation of rice (*Oryza sativa*)-based cropping systems for increasing productivity, resource use efficiency and energy productivity in coastal West Bengal. *Indian Journal of Agronomy,* 61(2), 131-137.

Samui, R., Kundu, A., Mazumdar, D., Mani, P.&Sahu, P. (2004). Diversification of rice (*Oryza sativa*)-based cropping system in new alluvial zone of West Bengal. *Indian Journal of Agronomy,* 49,71-73.

Sarkar, S. (2015). Management practices for enhancing fertilizer use efficiency under rice-wheat cropping system in the Indo-Gangetic Plains. *Innovare Journal of Agricultural Science,* 3(2), 5–10.

Sharma, R.P., Pathak, S.K., Haque, M.& Raman, K.R. (2004). Diversification of traditional rice (*Oryza sativa*) based cropping system for sustainable production in South Bihar alluvial plains. *Indian Journal of Agronomy,* 49(4), 218-222.

Tandel, B.M., Patel, N.N. &Tandel, Y.N. (2014). Economic production on rice based vegetable cropping system. *Indian Journal of Agronomy,* 79, 233-236.