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Research Paper

Influence of diversification on productivity, profitability and efficiency of rice (*Oryza sativa*)-based cropping systems under irrigated condition

A.K. PATRA[1], L.M. GARNAYAK[2], K.N. MISHRA[3] AND A.K. MOHANTY[4]

All-India Coordinated Research Project on Integrated Farming Systems, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha 751 003

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ABSTRACT

A long-term field experiment was conducted during 2006–07 to 2012–13 at Bhubaneswar, Odisha under irrigated medium land condition, to evaluate the production potential and economics of 10 rice (*Oryza sativa* L.)-based cropping systems. Rice–tomato (*Solanum lycopersicum* L.)–cowpea [*Vigna unguiculata* (L.) Walp.] and rice–maize (*Zea mays* L.)–okra [*Abelmoschus esculentus* (L.) Moench] cropping systems recorded significantly higher rice-equivalent yield (24.24 and 22.75 t/ha respectively) than other systems evaluated, the relative production efficiency being 140 and 122% over the existing rice–groundnut (*Arachis hypogaea* L.) system. The rice–groundnut system recorded the least rice-equivalent yield (9.75 t/ha). Land-use efficiency (LUE) of rice–tomato–cowpea system was the highest (85.8%), followed by that of rice–groundnut–cucumber (*Cucumis sativus* L.) (83.8%) and rice–French bean (*Phaseolus vulgaris* L.)–sesame (*Sesamum indicum* L.) (81.9%). Rice–tomato–cowpea gave the highest gross and net returns of ₹277,276 and 166,776/ha respectively, followed by rice–maize–okra system with gross and net returns of ₹256,210 and 150,210/ha respectively. These two systems also recorded higher benefit: cost ratio (2.51 and 2.42) with 257 and 222% relative economic efficiency over the rice–groundnut system. The cropping systems which included the legumes like groundnut, cowpea and French bean improved soil organic carbon content by 15.9 to 21.7% over the initial value of 0.69%. The cropping systems having cowpea as a summer crop increased the available N content by 8.5 to 13.8%; however, the available P and K content in soil decreased in all the systems after completion of 7 cropping cycles, though the depletion in K was more pronounced than that of P.

Key words: Crop diversification, Economics, Production efficiency, Rice-based cropping system, System productivity

Rice–groundnut is a predominant cropping system in coastal Odisha under irrigated ecosystem. However, farmers grow various field crops and short-duration vegetables in small patches after rice with limited irrigations. A third crop often fails due to non-availability of water. The winter crops mostly govern the rice-equivalent yield of the systems, because rice is the base crop and contribution of summer crop is often marginal (Bastia *et al.,* 2008). Hence, the selection of the second crop is most important, as it decides the overall productivity and profitability of the system. Thus, crop diversification during winter (*rabi*) and summer seasons plays a significant role in augmenting the farm income per unit area by integrating small–duration, high-value crops with high water-and nutrient-use efficiency (Pramanik and Ravisankar, 2007). Inclusion of vegetables in the rice-based cropping systems has been suggested for higher productivity and profitability (Sharma *et al.,* 2007; Kachroo *et al.,* 2014). Therefore, an experiment was designed to study the overall productivity and profitability, besides land and nutrient use efficiency under different rice-based cropping systems with crop diversification for irrigated ecosystems.

[1]**Corresponding author Email:** alokpatra2000@yahoo.co.in
[1]Professor (Agronomy), [2]Dean, College of Agriculture; [3]Professor (Soil Sciences), [4]Principal Scientist (Agronomy), Regional Research and Transfer Technology Station, Chiplima, Odisha 768 025

MATERIALS AND METHODS

A long-term (7 years) field experiment was conducted from 2006–07 to 2012–13 at Central Research Station, Odisha University of Agriculture and Technology, Bhubanehswar, Odisha (20° 26' N, 85° 81' E, 34 m above mean sea-level) under irrigated medium-land condition having hot humid climate with mean annual rainfall of 1,482 mm. The annual mean maximum and minimum temperatures were 31.5 and 22.3°C, respectively. The soil was sandy loam, having *p*H 5.7, medium organic carbon 0.69%, available N, P and K of 312, 15.7 and 189 kg/ha respectively. The experiment was laid out in randomized block design with 10 treatments of rice-based cropping systems (detailed in Table 2) and replicated thrice. Varieties and hybrids which were popular with the local farmers for their yield potential and low infestation of insect-pests and diseases were used. The varieties of different crops and their duration in the field, recommended fertilizer dose and planting spacing are given in Table 1. Rainy-season (*kharif*) rice was sown in the nursery in the last week of June, and after its harvesting in the last week of October the subsequent crops were sown as per the optimum sowing time recommended for the region. In winter (*rabi*) season, maize crop was harvested for green cob. All the crops were grown successfully with recommended packages of practices. The crops were irrigated optimally as and when required. Plant-protection measures were taken as and when required.

Crop yields were recorded at the end of each season and rice-equivalent yield (REY) was computed at the end of each cropping cycle. System yield was obtained by adding REY of component crops and price from seventh cycle were used for all the years. Total field duration of a cropping system expressed in percentage of 365 days was taken as the land-use efficiency (LUE) of the system. Apparent nutrient-use efficiency (ANUE) was calculated by dividing the rice-equivalent yield of the system with the total quantity of the nutrients (N-P-K) applied to the system. System productivity of different rice-based cropping systems was obtained dividing the system yield by 365 and was expressed in kg REY/ha/day. Production efficiency was calculated dividing the system yield by total duration of the system and was expressed in kg REY/ha/day (Tomar and Tiwari, 1990). Crop profitability in term of ₹/ha/day was calculated by net monetary returns of the system divided by total duration of the crops in that rotation (Kachroo *et al*., 2014). The profitability of the system was calculated by dividing the net returns (₹/ha) in a system by 365 days (Kachroo *et al*., 2014). Sustainable yield index (SYI) and sustainable value index (SVI) were calculated as per Singh *et al.* (1990). Relative productivity efficiency and relative economic efficiency were calculated as per Urkurkar *et al.*, (2008).

For economic analysis (cost of cultivation and gross return) cost of inputs and price of outputs were used from seventh cycle (2012–13) for all the years. Statistical analyses were carried out using standard methodology of randomized block design. Soil samples were drawn at initial and at the end of seventh cropping system cycle from a depth of 0–15 cm from each treatment. Soil organic carbon, N, P and K contents were analysed using standard procedures (Jackson, 1973).

RESULTS AND DISCUSSION

System yield and productivity

Rice–tomato–cowpea and rice–maize–okra cropping systems showed significantly higher mean rice-equivalent yield (REY) than other rice-based cropping systems (Table 2) and this was mainly owing to the better contribution of winter crops to the system REY Kachroo *et al*. (2014) and Bastia *et al*. (2008) also recorded higher system yields with vegetables as winter or summer crops. The existing rice–groundnut system recorded the least REY. Rice–*toria* (*Brassica rapa* L. var. toria)–cowpea and rice–French bean–sesame also recorded low system yield, mainly due to low yield of *toria* and sesame respectively.

The highest system productivity was recorded with rice–tomato–cowpea and rice–maize–okra systems (Table 3). These 2 cropping systems also registered the highest production efficiency. Rice–groundnut, rice–*toria*–cowpea

Table 1. Crop varieties and their average duration in the field, and crop-wise recommended fertilizer dose applied and spacing of crops

Season	Crop	Variety	Duration (days)	Fertilizer dose (kg/ha) N	P	K	Planting spacing (cm × cm)
Rainy season (*kharif*)	Rice	‘Hiranmayee’	127	80	17.5	33	20 × 10
Winter season (*rabi*)	Maize	‘Navjyot’	90	80	17.5	33	50 × 30
	Toria	‘Parbati’	69	60	13.2	25	30 × 10
	Groundnut	‘Smruti’	117	20	17.5	33	25 × 10
	Tomato	‘Utkal Kumari’	113	100	22.0	33	50 × 40
	Radish	‘Chetki long’	61	80	17.5	33	30 × 10
	French bean	‘Selection 9’	74	80	17.5	33	50 × 10
Summer	Cowpea	‘Utkal Manika’	73	30	12.2	25	45 × 15
	Okra	‘Utkal Gaurav’	72	80	17.5	33	50 × 30
	Bitter gourd	‘Nakhara local’	66	80	17.5	33	100 × 100
	Cucumber	‘Summer Queen’	62	80	17.5	33	100 × 100
	Sesame	‘Uma ‘	98	60	13.2	25	30 × 10

and rice–French bean–sesame cropping systems recorded lower production efficiency.

Land-use efficiency

Land use-efficiency (LUE) of rice–tomato–cowpea system was the highest, followed by rice–groundnut–cucumber system and rice–French bean–sesame (81.9%). Other three-crop sequences showed LUE in the range of 73.2–79.5% (Table 3). It was the lowest for rice–groundnut system. As rice is the common rainy-season crop in all the systems and summer crops having almost similar duration (except sesame), the LUE was governed mostly by duration of the winter crops. Groundnut and tomato occupied the field for maximum period (117 and 113 days respectively) and hence the LUE of the systems having groundnut and tomato were high. Cropping system not only illustrates the current land use but also reflects how the land-use pattern has changed over the time (Gangwar and Ram, 2005).

Monetary returns and economic viability

Rice–tomato–cowpea and rice–maize–okra systems gave higher returns than other cropping systems. Rice–tomato–cowpea gave the highest gross and net returns of ₹277,276 and 166,776/ha, respectively, followed by rice–maize–okra system with gross and net returns of ₹256,210 and 150,210/ha, respectively (Table 3). Rice–maize–cowpea was next in order with respect to gross and net returns. Maize sold as green cobs and vegetables like tomato, okra and cowpea fetched better market price, besides being high yielders, which has contributed to higher net returns of the systems comprising these crops. Bastia *et al*. (2008) also concluded that inclusion of vegetables and maize (for green cob purpose) as winter (*rabi*) crop in the rice-based cropping system were remunerative. Rice–groundnut, rice–groundnut–cucumber, rice–French bean–bitter gourd (*Momordiaca charantia* L.) and rice–french bean–sesame were the systems with low net returns, in the range of ₹41,087 to 65,871/ha.

Rice–tomato–cowpea and rice–maize–okra systems showed higher crop profitability and system profitability (Table 3). Rice–groundnut exhibited the lowest crop and system profitability, followed by rice–groundnut–cucumber. Rice–tomato–cowpea and rice–maize–okra systems also revealed higher benefit: cost ratio (2.51 and 2.42). Similar results were also recorded by Bastia *et al*. (2008) and Kachroo *et al*. (2012) with inclusion of maize and vegetables in rice-based cropping systems at Bhubanehswar and Jammu respectively.

Relative efficiency

Relative efficiency of different cropping systems were worked out in respect to the total productivity and economics over existing rice–groundnut cropping system (Table 3). The highest positive relative production efficiency was found in rice–tomato–cowpea, followed by rice–maize–okra. Similarly, the relative economic efficiency was found highest in rice–tomato–cowpea, followed by rice–maize–okra (222%), which indicated their efficiency in improving the productivity relatively over existing rice–groundnut system. On the other hand, rice–groundnut–cucumber, rice–*toria*–cowpea and rice–French bean–bitter gourd systems were not much remunerative over the existing rice–groundnut system as the relative

Table 2. Average yields, year-wise rice-equivalent yield (REY) and sustainable yield index of diversified rice-based cropping systems (t/ha)

Cropping system	Crop yields (7 years mean)			Rice-equivalent yield								SYI
	Kharif	*Rabi*	Summer	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	Mean	
Rice–groundnut	4.21	2.26	-	11.33	9.78	10.32	9.45	9.37	8.31	9.66	9.75	0.33
Rice–maize–cowpea	4.22	39025*	3.87	18.70	17.83	18.20	20.48	20.22	17.55	17.81	18.68	0.49
Rice–maize–okra	4.24	39445*	7.47	26.00	23.49	26.10	22.05	22.65	19.30	19.69	22.75	0.56
Rice–*toria*–okra	4.35	1.11	7.46	16.05	16.11	20.46	15.09	14.52	10.11	12.77	15.02	0.38
Rice–*toria*–cowpea	4.28	1.08	4.36	9.96	9.89	12.21	13.39	13.78	9.71	11.50	11.49	0.36
Rice–French bean–bitter gourd	4.29	5.79	3.15	12.42	13.67	16.66	17.66	17.60	12.36	13.91	14.90	0.43
Rice–groundnut–cucumber	4.25	2.40	3.56	14.18	12.87	12.90	16.48	15.75	12.20	13.87	14.03	0.41
Rice–tomato–cowpea	4.41	22.28	3.69	25.51	30.08	35.94	22.73	22.40	16.89	18.94	24.64	0.56
Rice– radish–sesame	4.13	22.10	1.08	11.14	13.92	19.41	18.23	14.81	10.36	12.31	14.31	0.37
Rice–French bean–sesame	4.18	5.84	0.94	11.57	13.55	16.75	16.44	13.38	10.01	11.27	13.28	0.38
SEm±	–	–	–	0.86	0.46	0.30	0.86	0.53	0.35	1.14	0.46	
CD (P=0.05)	–	–	–	2.57	1.38	0.88	2.56	1.58	1.04	3.41	1.37	

*Number of green cobs/ha; SYI, sustainable yield index; Sale price (₹/t): rice grain, 11,000; *toria*, 25000; French bean, 12,000; groundnut, 27,000; bitter gourd, 15,000; cowpea, 12,000; cucumber, 12,000; okra, 12,000; radish, 3,500; sesame, 32,000; tomato, 8,000; maize, ₹2.5/green cob

Table 3. LUE, ANUE, system productivity and economics of rice-based diversified cropping systems (mean of 7 years)

Cropping system	System duration (days)	LUE (%)	ANUE (kg REY/kg NPK applied)	System productivity (kg REY/ha/day)	Production efficiency (kg REY/ha/day)	Relative production efficiency (%)	Cost of cultivation (×10³ ₹/ha)	Gross returns (×10³ ₹/ha)	Net returns (×10³ ₹/ha)	Benefit: cost ratio	Crop profitability (₹/ha/day)	System profitability (₹/ha/day)	Relative economic efficiency (%)	SVI
Rice–groundnut	244	66.8	48.5	26.7	39.9	-	72.0	113.1	41.1	1.57	168	113	-	0.27
Rice–maize–cowpea	290	79.5	56.9	51.2	64.4	82.3	86.5	211.2	124.7	2.44	430	342	167.0	0.37
Rice–maize–okra	289	79.2	58.1	62.3	78.7	122.0	106.0	256.2	150.2	2.42	520	412	221.8	0.71
Rice–*toria*–okra	268	73.4	41.8	41.1	56.0	46.5	97.5	171.1	73.6	1.75	275	202	57.7	0.33
Rice–*toria*–cowpea	268	73.4	38.8	31.5	42.9	12.1	78.0	132.4	54.4	1.70	203	149	16.6	0.23
Rice–French bean–bitter gourd	267	73.2	38.1	40.8	55.8	45.3	106.5	169.7	63.2	1.59	237	173	35.4	0.27
Rice–groundnut–cucumber	306	83.8	42.3	38.5	45.9	36.9	106.5	160.2	53.7	1.50	175	147	15.0	0.31
Rice–tomato–cowpea	313	85.8	69.9	67.5	78.7	140.4	110.5	277.3	166.8	2.51	533	457	257.2	0.67
Rice– radish–sesame	286	78.4	39.8	39.2	50.0	39.6	69.0	163.3	94.3	2.37	330	258	102.1	0.48
Rice–French bean–sesame	299	81.9	37.0	36.4	44.4	29.6	86.0	151.9	65.9	1.77	220	180	41.1	0.24

LUE, Land-use efficiency; ANUE, apparent nutrient-use efficiency; REY, rice-equivalent yield; SVI, sustainable value index

economic efficiency were only 15.0, 16.6 and 35.4% respectively. Kachroo *et al*. (2014) also reported that 3 crops including a vegetable in a rice-based cropping system recorded higher relative production and economic efficiency than rice–wheat system.

Sustainable indices

Sustainable yield index (SYI) and sustainable value index (SVI) were worked out and presented in Table 2 and Table 3 respectively. Rice–maize–okra and rice–tomato–cowpea systems recorded higher sustainable yield index. Rice–groundnut cropping system recorded the lowest SYI. Among the 3-crop sequences rice–*toria*–cowpea, rice–radish (*Raphanus sativus* L.)–sesame and rice–French bean–sesame systems registered lower SYI. Similarly, rice–maize–okra and rice–tomato–cowpea recorded higher sustainable value index. Rice–French bean–sesame and rice–groundnut systems recorded the lower SVI. Bastia *et al*. (2008) also reported that rice-based cropping systems with a vegetable crop in winter or summer had higher SYI than the 2 crop sequence rice–groundnut.

Soil fertility and apparent nutrient-use efficiency

The soil *p*H did not show any difference among various cropping systems from the initial *p*H. The initial soil organic carbon content was 0.69% and after 7 years of cropping it ranged from 0.69 to 0.84% in different systems (Table 4). The cropping systems which included the legumes like groundnut, cowpea and French bean improved soil organic carbon content by 15.9 to 21.7% over the initial value.

After 7 years cropping cycle, the available N content increased in all the cropping systems except rice–maize–okra and rice–*toria*–okra systems over the initial value of 312 kg/ha. The cropping systems having cowpea as a summer crop increased the available N content by 8.5 to 13.8%. This was mainly because cowpea symbiotically fixed the atmospheric nitrogen in the soil and also left huge quantity of crop residue in the form of roots and leaves in the soil. However, the available P and K content in soil decreased after completion of 7 cropping cycles, though the depletion in K was more pronounced than that of P. The maximum decrease (12%) in available P content was noticed under rice–groundnut system from the initial value of 15.7 kg/ha. The available K content decreased by 23 to 35% from the initial values of 189 kg/ha, the highest decrease was recorded with rice–maize–okra cropping system.

Higher apparent nutrient-use efficiency was realized with the rice–tomato–cowpea (69.9 kg REY/kg NPK applied), followed by rice–maize–okra (58.1 kg REY/kg NPK applied) which correlates the higher REY in these 2

Table 4. Changes in soil fertility status after seven years of cropping cycle under rice-based diversified cropping systems

Cropping system	*p*H	Organic carbon (%)	Available nutrients (kg/ha)		
			N	P	K
Rice–groundnut	5.63	0.72	321	13.8	123
Rice–maize–cowpea	5.70	0.81	339	15.0	144
Rice–maize–okra	5.60	0.70	310	14.1	121
Rice–*toria*–okra	5.50	0.69	302	14.3	126
Rice–*toria*–cowpea	5.73	0.84	350	15.9	145
Rice–French bean–bitter gourd	5.60	0.81	335	15.1	137
Rice–groundnut–cucumber	5.57	0.72	318	14.6	130
Rice–tomato–cowpea	5.70	0.84	355	15.6	142
Rice– radish–sesame	5.60	0.74	328	14.7	124
Rice–French bean–sesame	5.80	0.81	338	15.6	136
Initial	5.72	0.69	312	15.7	189

systems (Table 3). The lower ANUE was recorded with rice–French bean–sesame, rice–french bean–bitter gourd and rice–radish–sesame cropping systems.

Thus, it can be concluded that rice–tomato–cowpea and rice–maize–okra were the most productive, remunerative and efficient cropping systems under irrigated condition, and needs to be promoted for adoption in place of existing rice–groundnut system.

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