



Crop diversification for enhancing productivity, profitability and resource use efficiency of rice (*Oryza sativa*)-based systems in red and lateritic soils of eastern region

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Received: 29 June 2020; Accepted: 05 April 2022

ABSTRACT

A field experiment was conducted at agricultural farm, Institute of Agriculture, Visva-Bharati, West Bengal to identify most productive, remunerative and resource use efficient rice (*Oryza sativa* L.)-based cropping systems in red and lateritic soil during 2014–15 and 2015–16. Pooled data of two years field experiments revealed that highest productivity of rice was achieved from legume involved system, viz. rice-potato-green gram (4.81 t/ha) followed by rice-yellow sarson-green gram (4.67 t/ha) and rice-lentil-okra (4.64 t/ha) which were at par with each other. Highest system rice equivalent yield (SREY) was found in rice-baby corn-elephant foot yam (31.89 t/ha/yr) which was at par with rice-french bean-baby corn (30.99 t/ha/yr). Rice-baby corn-elephant foot yam system achieved significantly higher system gross return (₹4,22,467/ha) and net return (₹2,69,557/ha) over other systems. However, significantly higher system return per rupee investment was obtained from rice-lentil-okra (₹3.12). Significantly higher system production efficiency/SPE (129.14 kg/ha/day) and higher employment potential (345 man days/ha/yr) was found in rice-french bean-baby corn. Highest land use efficiency (LUE) was in rice-lentil-elephant foot yam system (94.5%) followed by rice-baby corn-elephant foot yam (86.3%) and rice-potato-sesame (73.9%). Rice-french bean-baby corn also showed highest system energy output (1344.14 GJ/ha), energy output:input ratio (43.47), energy output efficiency (4.99 GJ/ha/day) and highest energy productivity (6448.35 kg REY/GJ). This was similar with rice-yellow sarson-baby corn sequence. Hence, inclusion of vegetables (french bean, baby corn, elephant foot yam) in rice-based cropping systems enhanced the productivity, profitability, energy use efficiency and employment potential over traditional cropping sequences like rice-potato-green gram and rice-potato-sesame in red and lateritic soil of eastern region.

Keywords: Crop diversification, Energetics, Rice equivalent yield, System economics, System productivity

With the changing agricultural scenario, there has been a gradual change in cropping pattern in favour of high value short duration remunerative crops like boro paddy, potato, vegetables, fruits etc against pulses, coarse cereals, sugarcane etc. Farmers are now interested in short duration high value cash crops like summer and winter vegetables (okra, cucurbitaceous vegetables, tomato, french bean, brinjal, chilli) to generate income in the family to raise their overall livelihood (Ray *et al.* 2012). Crop diversification would fulfil the basic needs for cereals, pulses, tuber crops, oilseeds and vegetables, regulate farm income, stand with weather aberrations, control price fluctuations, ensure balanced food supply, conserve natural resources, reduce chemical fertilizer and pesticide load, ensure environmental safety and create employment opportunity (Gill and Ahlawat 2006). The horizontal or vertical diversification is now a

days relevant under small holder production systems and is having the potential for increasing the production and economics due to high cropping intensity through addition of low volume high value crops over the existing cropping systems. In the era of shrinking resource base of land, water and energy, resource use efficiency is an important aspect for considering the suitability of a cropping system to increase overall productivity (Anderson 2005, Chitale *et al.* 2011 and Sharma *et al.* 2014). Diversified systems require increased use of energy input. Yield of different crops can be increased up to 30% by using optimal level of energy input. Efficient use of energy is one of the most important indicators of crop performance.

Hence, an attempt was made to identify and evaluate most productive, resource use efficient and remunerative location specific rice (*Oryza sativa* L.)-based cropping system for red and lateritic soils with a view to utilize resources judiciously to maximize safe return to the environment.

MATERIALS AND METHODS

A field experiment was conducted at Agricultural farm

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(situated at 23°39' N latitude, 87°42' E longitude at an elevation of 58.9 m amsl), Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal during rainy (*khariif*), winter (*rabi*) and summer seasons of 2014–15 and 2015–16. Soil of the experimental site was sandy loam in texture, acidic in nature (pH 5.18), low in organic carbon (0.44%), available nitrogen (132.13 kg N/ha) and phosphorus (25.13 kg P₂O₅/ha) and medium in available potassium (107.15 kg K₂O/ha). Total annual rainfall at experimental site was 514.65 mm during 2014–15 and 1566.40 mm during 2015–16 cropping season. The experiment, consisted of ten cropping systems, was laid out in Randomized Block Design where each treatment was replicated thrice. Treatments were T₁, Rice-yellow sarson-baby corn; T₂, Rice-yellow sarson-green gram; T₃, Rice-potato-green gram; T₄, Rice-potato-sesame; T₅, Rice-french bean-baby corn; T₆, Rice-french bean-okra; T₇, Rice-baby corn-sesame; T₈, Rice-baby corn-elephant foot yam; T₉, Rice-lentil-elephant foot yam and T₁₀, Rice-lentil-okra. All the crops (*khariif*, *rabi* and summer) in sequences were raised following recommended package of practices. For comparison between crop sequences, the yields of *rabi* and summer crops were converted into rice-equivalent yield (REY) obtained from yield of rice (first crop) + yield of *rabi* crops × price of *rabi* crops + yield of summer crops × price of summer crops/price of rice on prevailing market price basis. Economics were calculated on the basis of prevailing market price of various produce and by products for both the years. Land use efficiency (LUE)

was calculated by dividing total field duration of cropping sequences by 365 days multiplying with 100 and expressed in percentage. System productivity in rice-based cropping systems was obtained by addition of rice-equivalent yields of component crops in sequence. System production efficiency (SPE) was calculated by dividing the system productivity by total duration of the system and was expressed in kg/ha/day. Energy input of a crop was calculated by adding the product of quantity of various inputs (seeds, fertilizer, labour, farm yard manure) required with their energy equivalents, expressed in GJ/ha (Tuti *et al.* 2012). Energy output of a crop was calculated by adding the product of the quantity of economic yield (grain) and crop residue (straw, stover, stick) with their energy equivalents (Hadi *et al.* 2012). Energy output of a system was obtained by adding the energy output of component crops and was expressed in GJ/ha. Experimental data over two years were pooled and analysed statistically using F test at 5% level of probability following standard statistical methods (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Productivity: Among various rice-based cropping systems, rice-french bean-okra showed highest rice equivalent yield (18.92 t/ha) which was at par with rice-baby corn-elephant foot yam (18.65 t/ha) and significantly higher than other cropping systems (Table 1) on pooled data basis. The higher rice equivalent yield in rice-french bean-

Table 1 Productivity of main and component crops, rice equivalent yield (REY), system rice equivalent yield (SREY), system production efficiency (SPE), land use efficiency (LUE) and employment potential of different cropping sequences (pooled data of 2 years)

Cropping system	Main crop (rice) yield (t/ha)	<i>Rabi</i> crop yield (t/ha)	REY <i>rabi</i> crop (t/ha)	Summer crop yield (t/ha)	REY summer crop (t/ha)	REY (t/ha)	SREY (t/ha/yr)	SPE (kg/ha/day)	LUE (%)	Employment potential (man days/ha/yr)
Rice-yellow sarson-baby corn	4.24	1.71	3.20	17.73	5.95	9.15	23.68	98.66	65.75	287
Rice-yellow sarson-green gram	4.67	1.76	3.30	1.12	3.50	6.79	7.55	31.44	65.75	216
Rice-potato-green gram	4.81	22.70	9.22	1.27	3.95	13.18	28.78	112.84	69.86	225
Rice-potato-sesame	4.30	21.32	8.66	0.83	1.87	10.53	26.45	97.96	73.97	214
Rice-french bean-baby corn	4.47	8.54	8.00	17.99	6.04	14.04	30.99	129.14	65.75	345
Rice-french bean-okra	4.43	9.56	8.96	10.63	9.96	18.92	24.61	102.55	65.75	340
Rice-baby corn-sesame	4.35	17.38	5.83	0.83	1.68	7.52	22.57	88.49	69.86	273
Rice-baby corn-elephant foot yam	4.25	17.39	5.84	10.25	12.81	18.65	31.89	92.44	86.30	310
Rice-lentil-elephant foot yam	4.63	1.09	3.41	10.80	13.50	16.91	16.52	45.89	94.52	225
Rice-lentil-okra	4.64	1.12	3.50	10.90	10.22	13.72	16.66	65.34	73.97	265
SEm±	0.142	0.206	0.112	0.164	0.193	0.250	0.325	1.194	-	-
CD (P=0.05)	0.422	0.611	0.332	0.488	0.574	0.743	0.967	3.548	-	-

REY, rice equivalent yield; SREY, system rice equivalent yield; SPE, system production efficiency; LUE, land use efficiency.

okra system might be attributed to higher yield potential, market price and efficient utilization of time and space as evidenced from the findings of (Kumar *et al.* 2019).

Rice-baby corn-elephant foot yam system exhibited the highest system rice equivalent yield (SREY)/ system productivity (31.89 t/ha/yr) on pooled data basis (Table 1) which was at par with rice-french bean-baby corn system (30.99 t/ha/yr) but significantly higher than other rice-based cropping systems. Significantly higher system productivity was achieved in rice-potato-green gram (28.78 t/ha/yr) as compared to rice-potato-sesame (26.45 t/ha/yr). Rice-yellow sarson-baby corn and rice-french bean-okra as well as rice-lentil-elephant foot yam and rice-lentil-okra were similar with each other in respect of system productivity. The lowest system productivity was obtained from rice-yellow sarson-green gram (7.55 t/ha/yr). In view of increasing demand, crops like french bean, baby corn, elephant foot yam were introduced in rice based cropping systems which produced higher yield and fetched higher return in comparison to other conventional crops like sesame, yellow sarson, potato etc. Improvement in the productivity was due to higher biological yield and higher market values of the newly introduced crops like french bean, baby corn, elephant foot yam etc. Similar findings were also reported by (Khanda *et al.* 2005, Bastia *et al.* 2008, Chitale *et al.* 2011, Mishra *et al.* 2013, Sharma *et al.* 2014 and Baishya *et al.* 2016).

System production efficiency (SPE) and Land use efficiency (LUE): Rice-french bean-baby corn sequence showed significantly higher system production efficiency (129.14 kg/ha/day) over other cropping sequences and also exhibited higher employment potential (345 man days/ha/yr). Among different rice-based cropping systems, rice-lentil-elephant foot yam exhibited highest land use efficiency (94.5%) owing to the longest duration of crop sequences. This was followed by rice-baby corn-elephant foot yam system (86.3%). Kumar *et al.* (2015c) opined that intensification through inclusion of short duration vegetables and pulses or oilseeds in the system increased LUE. Higher land use efficiency indicated longer duration of crops in a calendar year as evidenced from the findings of Parsed *et al.* (2013).

System economics: Crop diversification had significant influence on system economics, viz. gross return, net return and return per rupee investment of various rice-based cropping systems (Table 2). Among the cropping systems, rice-baby corn-elephant foot yam exhibited the highest gross return (₹422467 /ha) and net return (₹269557 /ha) on pooled data basis which was significantly higher than all other cropping systems. Significantly highest return per rupee investment was achieved by rice-lentil-okra system (₹3.12) when compared with other cropping systems. This might be attributed to variation in yield, cost of cultivation

Table 2 System economics and energy use efficiencies as influenced by different rice-based cropping systems (pooled data of 2 years).

Treatment	System economics				Energy use efficiencies				
	Gross return (₹/ha)	Cost of cultivation (₹/ha)	Net return (₹/ha)	Return per rupee invested (₹)	Energy input (GJ/ha)	Energy output (GJ/ha)	Energy output: input ratio (GJ/ha)	Energy output efficiency (GJ/ha/day)	Energy productivity (kg REY/GJ)
Rice-yellow sarson-baby corn	272422	104554	167868	2.61	31.37	1320.85	42.11	4.96	6085.90
Rice-yellow sarson-green gram	207130	78990	128140	2.63	23.3	307.49	13.20	1.26	576.94
Rice-potato-green gram	307200	129637	177563	2.37	35.39	306.40	8.66	1.19	908.52
Rice-potato-sesame	241503	123830	117673	1.95	38.37	265.32	6.91	0.98	755.72
Rice-french bean-baby corn	364045	135188	228857	2.70	30.92	1344.14	43.47	4.99	6448.35
Rice-french bean-okra	376416	126227	250189	2.99	26.11	177.00	6.78	0.69	3948.12
Rice-baby corn-sesame	237514	103395	134119	2.30	29.85	1236.92	41.44	4.58	852.75
Rice-baby corn-elephant foot yam	422467	152910	269557	2.77	38.46	1324.87	34.45	4.85	3907.50
Rice-lentil-elephant foot yam	348398	122704	225694	2.84	30.87	375.42	12.16	1.33	3738.60
Rice-lentil-okra	297615	95599	202016	3.12	22.54	367.74	16.31	1.38	3750.02
SEm±	4487.75	-	4487.75	0.04	-	29.128	0.509	0.108	43.061
CD (P=0.05)	12888.07	-	12888.07	0.12	-	86.533	1.511	0.321	127.927

Selling price (₹/t): Rice grain, ₹16000; Rice straw, ₹500 (grain ₹16/kg, straw ₹0.50/kg), Yellow sarson seed, ₹30000/t; Yellow sarson stick, ₹500/t; Potato, ₹6500/t; French bean, ₹15000/t; Baby corn, ₹0.50/piece; Baby corn green fodder, ₹1000/t; Lentil seed, ₹50000/t; Lentil stick, ₹500/t; Green gram seed, ₹50000/t and stick, ₹500/t, Sesame seed, ₹36000/t and stick, ₹500/t, Elephant foot yam, ₹20000/t, Okra, ₹15000/t.

and market prices of economic produce of component crops in cropping systems. This was in conformation with the findings of Porpavai *et al.* (2011) and Kumar *et al.* (2019) where economic returns increased over traditional system with inclusion of vegetable crops in sequences. Moreover, legumes were potentially important to diversify cereal based mono cropping into cereal-legume sequences which had nutrient cycling advantages. Similar results were also reported by (Saroach *et al.* 2005, Walia *et al.* 2011, Choudhary *et al.* 2013 and Prasad *et al.* 2013).

Energetics: Among different rice-based cropping systems, rice-baby corn-elephant foot yam showed highest total energy input (38.46 GJ/ha) followed by rice-potato-sesame (38.37 GJ/ha) and rice-potato-green gram (35.39 GJ/ha) presented in Table 2. The higher need of energy in these cropping systems was due to higher energy required for seed and fertilizers in growing potato, baby corn and elephant foot yam crops. On pooled data basis, rice-french bean-baby corn showed the highest system energy output (1344.14 GJ/ha), energy output:input ratio (43.47), energy output efficiency (4.99 GJ/ha) and energy productivity (6448.35 kg REY /GJ). This was comparable with rice-yellow sarson-baby corn. Higher energy output in this cropping system was due to higher crop yields in sequences. Similar findings were reported by Alluvione *et al.* (2011) and Kachroo *et al.* (2012) on energy production by various rice-based cropping systems.

Inclusion of vegetables (french bean, baby corn, elephant foot yam) in rice-based cropping systems enhanced the productivity, profitability, energy use efficiency and employment potential over traditional cropping sequences like rice-potato-green gram and rice-potato-sesame in red and lateritic soil of eastern region.

REFERENCES

- Alluvione F, Moretti B, Sacco D and Grignani C. 2011. EUE (Energy use efficiency) of cropping systems for a sustainable agriculture. *Energy* **36**(7): 4468–81.
- Anderson R I. 2005. Are some crops synergistic to following crops? *Agronomy Journal* **97**(1):7–10.
- Bastia D K, Garnayak L M and Barik T. 2008. Diversification of rice (*Oryza sativa*)-based cropping systems for higher productivity resource-use efficiency and economics. *Indian Journal of Agronomy* **53**(1): 22–26.
- Baishya A, Gogoi B, Hazarika J, Hazarika J P, Bora A S, Das A K, Borah M and Sutradhar P. 2016. Maximizing system productivity and profitability through crop intensification and diversification with rice (*Oryza sativa*)-based cropping systems in acid soils of Assam. *Indian Journal of Agronomy* **61**(3): 274–80.
- Chitale S, Sarawgi S K, Tiwari A and Urkurkar J S. 2011. Assessment of productivity and profitability of different rice (*Oryza sativa*)-based cropping systems in Chhattisgarh plains. *Indian Journal of Agronomy* **56**(4): 305–10.
- Choudhary V K, Kumar P S, Sarkar S K and Yadav J S. 2013. Production potential, economic analysis and energy auditing for maize-vegetable based cropping systems in Eastern Himalayan region, Arunachal Pradesh. *Indian Journal of Agricultural sciences* **83**(1): 110–15.
- Gill M S and Ahlawat I P S. 2006. Crop diversification-its role towards sustainability and profitability. *Indian Journal of Fertilisers* **2**(9):125–38.
- Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research*, 2nd edn, pp. 139–240. John Wiley and Sons, New York.
- Hadi M R H S. 2012. Energy efficiency of potato crop in major production regions of Iran. *International Journal of Agriculture and Crop Science* **4**(2): 51–53.
- Kachroo D, Thakur N P, 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* **53**(1):18–21.
- Khanda C M, Mandal B K and Garnayak L M. 2005. Productivity and economics of different rice-based cropping sequences as influenced by integrated nutrient management. *Oryza* **42**(1): 48–51.
- Kumar R, Kumar M, Kumar A and Pandey A. 2015c. Productivity, profitability, nutrient uptake and soil health as influenced by establishment methods and nutrient management practices in transplanted rice (*Oryza sativa*) under hill ecosystem of North East India. *Indian Journal of Agricultural Sciences* **85**(5): 634–39.
- Kumar M, Kumar R, Rangnamei K L, Das A, Meena K L and Rajkhowa D J. 2019. Crop diversification for enhancing the productivity for food and nutritional security under the Eastern Himalayas. *Indian Journal of Agricultural Sciences* **89**(7): 1157–61.
- Mishra M M, Mohanty M, Gulati J L M and Nanda S S. 2013. Evaluation of various rice (*Oryza sativa*)-based crop sequences for enhanced productivity, profitability and energy efficiency in eastern plateau and hills zone of India. *Indian Journal of Agricultural Sciences* **83**(12):1279–84.
- Porpavai S, Devasenapathy P, Siddeswaran K and Jayaraj T. 2011. Impact of various rice-based cropping systems on soil fertility. *Journal of Cereals and Oilseeds* **2**(3): 43–46.
- Prasad D, Yadav M S and Singh C S. 2013. Diversification of rice (*Oryza sativa*)-based cropping systems for productivity, profitability and resource-use efficiency under irrigated ecosystem of Jharkhand. *Indian Journal of Agronomy* **58**(3): 264–70.
- Ray M, Samanta B, Haldar P, Chatterjee S and Khan D K. 2012. Economic characterization of predominant farming systems in West Bengal, India. *American Journal of Agriculture and Forestry* **1**(3): 40–7.
- Saroach K, Bhargava M and Sharma J J. 2005. Diversification of existing rice (*Oryza sativa*)-based cropping systems for sustainable productivity under irrigation conditions. *Indian Journal of Agronomy* **50**(2): 86–88.
- Sharma R P, Dutta, S K and Ghosh M. 2014. Diversification of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping for sustainable production in south Bihar alluvial plains. *Indian Journal of Agronomy* **59**(2): 191–99.
- Tuti M D, Prakash V, Pandey B M, Bhattacharya R, Mahanta D, Bisht J K, Mina M K, Mina B L, Kumar N, Bhatt J C and Srivastva A K. 2012. Energy budgeting of colocasia-based cropping systems in the Indian sub-Himalayas. *Energy* **45**(9): 986–93.
- Walia S S, Gill M S, Bhushan B, Phutela R P and Aulakh C S. 2011. Alternate cropping systems to rice (*Oryza sativa*)-wheat (*Triticum aestivum*) in Punjab. *Indian Journal of Agronomy* **56**(1): 20–27.