Indian Journal of Agronomy **61** (2): 131–137 (June 2016)

Research Paper

Evaluation of rice (*Oryza sativa*)-based cropping systems for increasing productivity, resource-use efficiency and energy productivity in coastal West Bengal

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Received : November 2015; Revised accepted : March 2016

ABSTRACT

A field experiment was conducted during 2011–13 at farmers' field of Kakdwip in the district South 24 Parganas of West Bengal to assess productivity, profitability, resource-use efficiency including energy value under coastal saline zone with 6 different rice (*Oryza sativa* L.)–based cropping systems, viz. rice–greengram [*Vigna radiata* (L.) Wilczek], rice–sunflower (*Helianthus annuus* L.), rice–sunflower + greengram, rice–okra [*Abelmoschus esculentus* (L.) Moench], rice–rice and rice–*khasari* (*Lathyrus sativus* L.) (as *utera*). The highest rice-equivalent yield was recorded in rice–okra (33.6 t/ha) cropping system. Higher productivity, net returns and profitability also recorded in rice–okra system followed by rice–sunflower. However, higher benefit: cost ratio was obtained from rice–okra system (2.03) followed by rice–*khasari* (1.85) and the lowest from rice–greengram (1.52) system. Rice–okra system showed better land-utilization efficiency (69.1%) followed by rice–sunflower than the other systems. Rice–okra system also showed higher irrigation water-use efficiency (1,416.3 kg/ha-cm) and employment generation (475 man-days) than the other systems. Total input, output and net energy produced in the systems were in order of rice–okra > rice–rice > rice–sunflower > rice–sunflower+greengram > rice–greengram > rice–*khasari*. Rice–okra system was the most efficient in term of energy productivity (0.45 kg/MJ). Energy-use efficiency was the highest in rice–*khasari* followed by rice–sunflower + greengram and rice–greengram. The rice–okra cropping system proved the most remunerative cropping system in the coastal saline zone of West Bengal.

Key words **:** Coastal saline zone, Cropping systems, Energetic, Productivity, Profitability, Rice

Indian economy largely depends on agriculture and allied sector. As a concomitant of growth, the share of agriculture and allied sector in India's gross domestic product (GDP) declined to 13.9% in 2013–14 from 14.6% in 2009–10 (Government of India, 2014). Till now, foodgrain based cropping systems, viz. rice–wheat (10.5 m ha), rice–rice (5.9 m ha) and coarse grain-based systems (10.8 m ha) are the major contributors to national food basket in India (Gangwar and Prasad, 2005) wherein about 30 important cropping systems have been identified (Yadav *et al.*, 1998). Out these systems, rice + wheat is the highest contributor and together shares 65% of national foodgrain production (Gangwar and Prasad, 2005).

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The National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) has classified our country into 21 zones in the agro-ecological maps with six ecosystems, viz. arid, semi-arid, sub-humid, humid, and coastal and island ecosystems. However, there are 6 distinct agro-climatic sub-regions in West Bengal and they are i) the Northern hilly zone, ii) the Terai-Teesta flood plain, iii) the Gangetic flood plain, iv) the Coastal flood plain, v) the Vindhya old flood plain and vi) the undulating Lateritic sub-regions of the Eastern Plateau Region. Of the 6 agro-climatic regions, the Coastal flood plain is vulnerable and most fragile zone, comprising whole south 24 Parganas district and part of North 24 Parganas, and East Midnapore districts of West Bengal. Coastal flood plain spreads over 10,158.2 km^2 in the above 3 districts and this is 11.5% of the total area of the state. Globally, coastal land and water comprise 8% of the Earth's surface. The coastal flood plain comprises watersheds, marshes, flora and fauna, coastal and freshwater, island and forest. The average minimum and maximum temperature prevails in this area are 22°C and 34°C with average annual rainfall of 1,950 mm and humidity level of 85% and is prone to tidal wave and cyclones. This area also represents lowland agro-ecosystem with heavy-textured saline soils, limited availability of irrigation water and very low cropping intensity (134%) as compared to state average of 185%. Conventionally, farmers grow high-yielding varieties of rice during the wet season and use to keep their land fallow in dry season (*rabi* and summer) except marginally growing some low-water requiring crops like greengram and *lathyrus* or *khasari* using residual moisture or life-saving irrigation. Water harvested in small tanks is the only source of irrigation during dry period. Though the adjacent Kolkata metropolitan city provides good market of the agricultural produces, farmers cannot harness this opportunity due to their limited resources and marginal holdings. As a whole, agriculture is becoming non-economic and non-viable proposition imposing increasing numbers of related population into the lap of dire poverty. Crop diversification has been recognized as an effective strategy for achieving the objectives of food security, nutritional security, income growth, poverty alleviation, employment generation and judicious use of land and water resources, sustainable agricultural development and environmental improvement. Diversification of cropping system with food crops like potato, oilseed and vegetables is necessary for obtaining higher yield and return, maintenance of soil health, protection of environment and meeting up daily requirement of human and livestock (Samui *et al*., 2004). Inclusion of legumes in the cropping system increases soil-fertility status (Upadhyay *et al.,* 2011). By and large a number of soil and climatic parameters decide cropping system of a region, which determine overall agro-ecological setting for nourishment and appropriateness of a crop or set of crops for cultivation. Choice of crop or cropping system is further narrowed down by several forces regarding infrastructure facilities, socio-economic factors and technological development which are operating interactively at micro-level. Potential productivity and monetary benefit act as guiding principles for a particular crop/cropping system, at farmers' level.

In general, in the process of technology assessment farmers' concern like their resources, social and economic aspect as well as their perception were often ignored, particularly in case of the resource-poor farmers. As a result the potential yield and profitability of a crop/cropping system remains far behind from that of actual. Farmers' Participatory Research (FPR) emphasizes the process that enables a local farmer to evolve and promote improved agricultural technologies to the field. Considering this fact, a participatory research was conducted to assess the influence of rice-based cropping systems on productivity, profitability and resource efficiency at farmer field in fragile coastal flood plains.

MATERIALS AND METHODS

The field experiment was conducted with 6 rice-based cropping systems, viz. rice–greengram, rice–sunflower, rice–sunflower + greengram, rice–okra, rice–rice and rice–*lathyrus* (this as *utera* crop) 2011–12 and 2012–13. Twelve farmers were selected from 3 different villages, spread in the Kakdwip block of the district South 24 Parganas of West Bengal adopted by All India Coordinated Research Project (AICRP) on Integrated Farming Systems, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur. These farmers' fields lie between 21°50.068' N to 22°06.975' N and 88°11.858' E to 88°19.653' E with an average altitude of 8.19 m above mean sea-level in coastal saline flood plain. The soils were characterized as silty clay loam with *p*H 5.45 (4.45–6.99), electrical conductivity 0.59 (0.15–1.95) dS/m, organic carbon 0.72 (0.58–0.82)%, available N 140.50 (111.1–186.6) kg/ha, P 48.1 (39.9–59.8) kg/ha, available K 305.8 (281.5–324.7) kg/ha and annual rainfall of 1,626 cm and 1,667 cm in the year 2011–12 and 2012–13 respectively. Crop sowing and harvesting window period, recommended fertilizer doses and variety of different crops under all cropping systems are given in Table 1. Recommended doses of N, P and K were applied to different crops through urea, single superphosphate and muriate of potash respectively. In every system rainy season (*kharif*) rice was grown under rainfed condition and the dry season crops were given irrigation only at critical growth stages. Need-based intercultural and plant-protection measures were adopted for different crops. All the 6 cropping systems were allotted in each of the farmer's field taking a block of 150 m^2 area, i.e. the area of each cropping system at every farmer's plot was 25 m^2. The trials were conducted at same site during the entire period of study and each farmer's field was treated as 1 replication. Statistical analysis of the recorded data was done using SPSS software, IBM Inc. 2009 and critical difference (CD) was computed at 5% level of probability (P=0.05). Economic yield of component crops was taken into account over the year and converted into rice-equivalent yield (REY) based on prevailing market of the produces for each cropping system to compare the various systems. The cost of cultivation was calculated on the basis of prevailing market price of different inputs. Productivity efficiency in term of kg/ha/day was calculated by dividing the total production of the cropping system by 365 days and profitability in term of ₹/ha/day was obtained by dividing the net returns of the cropping system by total duration of the same (Devasenapathy *et al*., 2008). Benefit: cost ratio of a system was expressed as net returns per rupee spent. Land-use efficiency was calculated as per Tomar and Tiwari (1990):

Land use efficiency (LUE) = (Sum of duration of component crops/365) × 100%

Irrigation requirement was calculated by multiplying the number and area of irrigation with the depth of irrigation given to all the component crops of a particular cropping system and amount of irrigation water was determined by adding the irrigation given to the component crops of the cropping system. Irrigation water-use efficiency (kg/ha-cm) of a particular cropping system was calculated by dividing the total yield of the cropping system by its irrigation requirement. Employment generation (man-days/ha) was calculated by adding the number of labour required in various agronomic activities of the component crops of the cropping systems.

Energy parameters of cropping systems were calculated using the energy equivalents as given by Devasenapathy *et al.* (2008) and expressed as MJ/ha. System-input energy was calculated by adding the energy requirements for seed, fertilizer, organic manures, diesel for irrigation, land preparation (fuel + machinery), human labour, plant protection agro-chemicals etc. used in that cropping systems. System output energy was determined by summation of energy produced by total grains or fruits and byproducts such as straw, dried plants etc. of all the component crops of the system. Energy-use efficiency (EUE) and energy productivity (Kg/MJ) were calculated as:

$$\text{EUE} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}$$

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

RESULTS AND DISCUSSION

Productivity

Rice-equivalent yield (REY) of rice–okra cropping system was the highest in both the years, whereas significantly lowest REY was recorded from rice–*lathyrus* cropping system (Table 2). Pooled analysis of 2 years data also revealed that rice–okra cropping system gave the highest REY being significantly higher than that of rest of the cropping systems. This might be owing to the fact that okra as follower crop of rice gave vegetable biomass production with better market price, whereas *lathyrus* or *khasari* gave low yield as it was cultivated as *utera* crop.

So far as the yields of component crops are concerned, significantly higher *kharif* rice yield was obtained from rice–okra cropping system in both the years (Table 2). Rice yield was significantly higher owing to residual effects of high doses of fertilizer and organic manure applied to okra might have caused benefits for rice. Ray *et al.* (2009) and Samui *et al.* (2004) also observed similar trend in their studies of cropping system with potato and okra. Year-wise yield of other component crops, i.e. greengram, sunflower, *boro* rice and *khasari* are also shown in Table 2.

Rice–okra system revealed significantly the highest production efficiency followed by rice–sunflower, rice–rice, rice–greengram + sunflower, rice–greengram and rice– *khasari* (Table 3).

Profitability

The cost of production and net return of *kharif* season crop (rice) was not significant, whereas that of *rabi* and summer crops were significant in different cropping systems, as revealed from the results of pooled analysis of data. Production cost for rice–okra cropping system was significantly the highest followed by rice–rice, rice–sunflower, rice–greengram + sunflower, rice–greengram and significantly lowest in rice–*lathyrus* (Table 2). It was primarily to the fact that okra required higher number of labour, higher volume of fertilizers, plant-protection chemicals, irrigation etc. as compared to the other component crops. Singh *et al.* (2013) also reported that the rice–lentil and rice–pea crop sequence required far less cost of cultivation in comparison to rice–Frenchbean or rice–mustard sequence. Rice–okra crop sequence was found the most remunerative to the farmers with net return of ₹120,220/ha and it was mainly owing to okra which fetched high market price besides having high production. Similar result was also reported by Jat *et al.* (2012) in rice–fenugreek–okra cropping system owing to inclusion of okra in the system. Kumar *et al.* (2008) also recorded the highest net returns owing to inclusion of vegetable crops in rice-based cropping system. The next in order were the rice–sunflower, rice–sunflower + greengram, rice–rice, rice–*lathyrus*, and the lowest from rice–greengram cropping system (Table 2).

Significantly the highest benefit: cost ratio was recorded in rice–okra system followed by rice–*lathyrus*, rice–sunflower, rice–sunflower + greengram, rice–rice and rice–greengram. This was primarily owing to inclusion of okra in the crop sequence which gave very high returns. Mandal *et al.* (2002) reported similar trend where soybean–wheat crop sequence gave the highest net returns. The similar result was also reported by Pramilarani *et al.* (1998) in black clay soil in southern India. Significantly higher profitability of ₹330/ha/day was recorded in rice–okra system as compared to the lowest of ₹74/ha/day in rice–greengram system (Table 3).

Table 1. Agronomic practices of different crops of the crop sequences

Cropping system	Parameters	2011–12		2012–13	
		Kharif	*Rabi*/Summer	*Kharif*	*Rabi*/Summer
Rice–greengram	Sowing window	Last week of June	Second fortnight of January	Last week of June	Second fortnight of January
	Harvesting window	Last week of November	Second fortnight of April	Last week of November	Second fortnight of April
	Fertilizer dose (N : P_2O_5 : K_2O)	80 : 40 : 40	20 : 40 : 40	80 : 40 : 40	20 : 40 : 40
	Variety	'IET 5656'	'Local Selection'	'IET 5656'	'Local Selection'
	Irrigation no.	0	1	0	1
Rice–sunflower	Sowing window	Last week of June	First fortnight of January	Last week of June	First fortnight of January
	Harvesting window	Last week of November	First fortnight of May	Last week of November	First fortnight of May
	Fertilizer dose	80 : 40 : 40	80 : 40 : 40	80 : 40 : 40	80 : 40 : 40
	Variety	'IET 5656'	'GK 2002'	'IET 5656'	'GK 2002'
	Irrigation no.	0	2	0	2
Rice–sunflower + greengram (2:4)	Sowing window	Last week of June	First fortnight of January	Last week of June	First fortnight of January
	Harvesting window	Last week of November	First fortnight of May	Last week of November	First fortnight of May
	Fertilizer dose (N : P_2O_5 : K_2O)	80 : 40 : 40	80 : 40 : 40	80 : 40 : 40	80 : 40 : 40
	Variety	'IET 5656'	'GK 2002'/ 'Local Selection'	'IET 5656'	'GK 2002'/'Local Selection'
	Irrigation no.	0	2	0	2
Rice–okra	Sowing window	Last week of June	First fortnight of January	Last week of June	First fortnight of January
	Harvesting window	Last week of November	Second fortnight of May	Last week of November	Second fortnight of May
	Fertilizer dose (N : P_2O_5 : K_2O)	80 : 40 : 40	80 : 40 : 40	80 : 40 : 40	80 : 40 : 40
	Variety	'IET 5656'	'Pankaj'	'IET 5656'	'Pankaj'
	Irrigation no	0	3	0	3
Rice–rice	Sowing window	Last week of June	first week of January	Last week of June	First week of January
	Harvesting window	Last week of November	Last week of April to first week of May	Last week of November	Last week of April to first week of May
	Fertilizer dose (N : P_2O_5 : K_2O)	80 : 40 : 40	120 : 60 : 60	80 : 40 : 40	120 : 60 : 60
	Variety	'IET 5656'	'IET 4786'	'IET 5656'	'IET 4786'
	Irrigation no.	0	6	0	6
Rice–*khasari* (*utera* crop)	Sowing window	Last week of June	Second fortnight of Nov.	Last week of June	Second fortnight of Nov.
	Harvesting window	Last week of November	End of March-mid April	Last week of November	End of March-mid April
	Fertilizer dose (N : P_2O_5 : K_2O)	80 : 40 : 40	DAP spray 30 kg/ha	80 : 40 : 40	DAP spray 30 kg/ha
	Variety	'IET 5656'	'BioL'	'IET 5656'	'BioL'
	Irrigation no.	0	0	0	0

DAP, Diammonium phosphate

Table 2. System rice-equivalent yield, component crops yield and economics of rice-based cropping systems (pooled data of 2 years)

Cropping system	Component crop yield (t/ha)				System rice-equivalent yield (t/ha)			Cost of production (× 10³ ₹/ha)	Net returns (× 10³ ₹/ha)	Benefit: cost ratio
	First crop		Second crop							
	2011–12	2012–13	2011–12	2012–13	2011–12	2012–13	Pooled			
Rice–greengram	4.6	4.5	0.9	0.9	9.3	8.6	9.0	53.3	27.0	1.52
Rice–sunflower	4.6	4.6	1.7	1.6	13.6	10.6	12.1	59.6	45.0	1.76
Rice–sunflower + greengram	4.7	4.6	0.8 (0.4)	1.0 (0.4)	11.1	9.5	10.3	59.1	42.5	1.72
Rice–okra	4.8	4.7	18.0	18.2	39.3	27.8	33.6	118.2	120.2	2.03
Rice–rice	4.7	4.6	5.4	5.2	11.1	10.2	10.6	72.9	40.7	1.56
Rice–*khasari*	4.7	4.7	0.9	0.9	8.1	7.7	7.9	41.2	34.5	1.85
SEm±	0.04	0.02	-	-	0.25	0.23	0.24	2.17	2.11	0.03
CD (P=0.05)	0.10	0.07	-	-	0.71	0.65	0.66	6.06	5.91	0.07

Data in parentheses represent the yield of greengram

Resource-use efficiency

Significantly higher land-utilization efficiency (LUE) was recorded in rice–okra and the least in rice–*lathyrus* (Table 3). Rice was the common crop grown during *kharif* in all the cropping systems; it is the *rabi*/summer crop of the cropping systems that governed the land utilization efficiency. The LUE of rice–okra was recorded the highest because the rice–okra crop sequence occupied the field for maximum period (252 days) compared to other cropping systems. Jat *et al.* (2012) also reported the significantly higher LUE in rice–fenugreek–okra cropping sequence. Requirement of irrigation water was higher in rice–rice cropping system followed by rice–okra, rice–sunflower, rice–sunflower + greengram, rice–greengram and no irrigation water was applied in rice–*lathyrus* cropping system. But irrigation water-use efficiency was the highest in rice–okra, followed by rice–greengram, rice–sunflower, rice–sunflower + greengram, rice–rice. Jat *et al.* (2012) also reported the highest water-use efficiency in rice–fenugreek–okra system followed by rice–onion–cowpea. Employment generation was recorded the highest in rice–okra (475 man-days/ha) owing to involvement of more number of human labour for management and harvesting of okra. Similarly, higher employment generation in rice–potato+wheat–greengram was reported by Prasad *et al.* (2013) owing to higher labour involvement in harvesting of potato than other crops. The lowest employment generation was recorded in rice–*lathyrus* (223 man-days/ha) as this system required less human labour (Table 3).

Energetics

Total input energy requirement was the lowest in rice–*lathyrus* and rice–greengram systems due to low input requirements of component pulse crops. The cropping systems having crops like okra, *boro*/summer paddy, sunflower had significantly higher total input energy. The input energy for rice–okra, rice–rice, rice–sunflower and rice–sunflower+greengram are given in Table 4. Total energy output of the produces in rice–okra system was significantly higher than the other 5 cropping systems and the lowest in rice–*lathyrus* (Table 4). It was due to the fact that okra being a vegetable crop, gave higher biomass yield than the other component crops of rice. The results revealed that rice–okra system with the highest input energy and yield gave the highest energy productivity, whereas rice–rice system recorded the lowest (Table 4). Mandal *et al.* (2002) observed that soybean–wheat crop sequence gave the highest energy productivity over soybean–chickpea and soybean–mustard owing to its higher input energy and grain yield.

Energy-use efficiency (EUE), in terms of total output energy/total input energy, was significantly higher in rice–

Table 3. Productivity and resource-use efficiency of rice-based cropping systems (pooled data of 2 years)

Cropping system	Productivity (kg/ha/day)	Land-use efficiency (%)	Profitability (₹/ha/day)	Irrigation requirement (cm)	Irrigation water-use efficiency (kg/ha-cm)	Employment generation (man-days/ha)
Rice–greengram	24.5	60.6	74	2.8	1318.3	303
Rice–sunflower	33.1	67.5	123	13.9	881.0	320
Rice–sunflower + greengram	28.3	67.5	116	13.8	771.2	311
Rice–okra	91.9	69.1	330	23.6	1416.3	475
Rice–rice	29.1	67.4	112	33.7	315.9	340
Rice–*khasari*	21.7	55.8	95	0	0	223
SEm±	0.86	0.23	5.72	0.19	55.69	-
CD (P=0.05)	2.40	0.65	16.00	0.53	155.89	-

Table 4. Energy input-output relationship of different cropping systems (pooled data of 2 years)

Cropping systems	System input energy ($\times 10^3$ MJ/ha)	System output energy ($\times 10^3$ MJ/ha)	System net energy ($\times 10^3$ MJ/ha)	Energy productivity (kg/MJ)	Energy-use efficiency (EUE)
Rice–greengram	37.2	223.8	186.6	0.24	6.05
Rice–sunflower	48.8	268.9	220.1	0.25	5.51
Rice–sunflower + greengram	40.6	247.0	206.4	0.26	6.08
Rice–okra	74.4	434.2	359.8	0.45	5.84
Rice–rice	58.3	342.7	284.4	0.18	5.88
Rice–*khasari*	31.6	214.7	183.2	0.25	6.80
SEm±	0.38	2.69	2.70	0.003	0.06
CD (P=0.05)	1.05	7.54	7.56	0.01	0.17

lathyrus cropping system followed by rice–sunflower + greengram than other crop sequences (Table 4). It was owing to the fact that legumes require much less energy than other crops (Walia *et al.*, 2014). Mandal *et al.* (2002) also observed that cropping system with legumes (soybean–chickpea) gave higher EUE than soybean–wheat and soybean–mustard crop sequence.

It was concluded that rice–okra system recorded higher yield, productivity, net returns, benefit: cost ratio, input and output energy than the other 5 cropping systems. Rice–okra system also showed the highest employment generation, better land use efficiency and irrigation water-use efficiency than the other 5 cropping systems. Hence rice–okra cropping system was the most remunerative cropping system in the fragile coastal saline zone of West Bengal.

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