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Productive and Profitable Rice-based Cropping Systems for Coastal Plains of Kerala

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The production potential and economics of rice-based cropping sequences for coastal plains of Kerala were investigated as part of the ongoing All India Co-ordinated Research Project on Integrated Farming Systems (ICAR) being implemented in the Integrated Farming System Research Station (IFSRS) of Kerala Agricultural University located at Karamana, Thiruvananthapuram, during *Kharif, Rabi* and summer seasons of 2019-2020. The experiment was laid out in a randomized block design with eleven treatments *i.e.*, CS_1 : rice - fallow - fallow, CS_2 : rice - rice - fallow, CS_3 : rice - *dhaincha* - cowpea, CS_4 : (rice + *dhaincha*) - rice - green gram, CS_5 : rice - cassava - amaranthus, CS_6 : rice - cassava - cowpea, CS_7 : rice - para grass - fodder cowpea, CS_8 : rice - fodder cowpea - fodder maize, CS_9 : rice - okra - culinary melon, CS_{10} : rice - okra - yard long bean and CS_{11} : rice - rice - amaranthus, all replicated thrice. Among the cropping sequences, the productivity in terms of rice equivalent yield (28.93 t ha^{-1}) and system productivity (0.079 t ha^{-1} day^{-1}) was highest for CS_{10} : rice - okra - yard long bean. The maximum gross returns (₹ 901865 ha^{-1}) and net returns (₹ 545705 ha^{-1}) were also found to be highest for CS_{10} : rice - okra - yard long bean. However, B: C ratio was highest for CS_9 : rice - okra - culinary melon (2.64) followed by CS_{10} : rice - okra - yard long bean (2.53).

(***Key words:*** *Coastal plain, Cropping system, Kerala, Productivity, Rice, Rice equivalent yield, System productivity*)

Rice is the staple food for the largest number of people on earth. India produced a total of 102.04 million tonnes of rice during 2018-19 (GOI, 2020). In recent years, despite its significance, the performance of rice is decreasing in Kerala. During the past two decades, numerous farmers have been opting for crops of their choice and converting paddy fields for other crops, which resulted in a reduction in the cultivated area from 6.78 lakh ha in 1985-86 to 1.98 lakh ha in 2018-19 (FIB, 2021). The greatest challenge in rice farming is to make it a remunerative venture. The high cost of labour (₹ 950 man day^{-1}) and the non-availability of agricultural labour during critical operations like transplanting, weeding harvesting, etc., make paddy cultivation a less remunerative option for the farmers. In addition to this, over the past years due to excessive rainfall, floods and other abiotic and biotic stresses, there were incidences of complete failure of the monocropped rice. Under these circumstances, growing a different, more remunerative and climate-resilient second or third crop could make the sequence more resilient thereby reducing the associated risks. The vital role of a highly intensive crop sequence is well recognized to meet the growing demand of ever increasing population. In the present era, intensive cropping which is not only highly productive and profitable but also stable over time has greater importance.

Inclusion of high yielding, short-duration and disease-resistant grain legumes and vegetable crops into the existing rice-based cropping system could improve the productivity and economic viability of the system (Jat *et al*., 2012). Raising pulses during summer is likely to improve the productivity of the succeeding rice crop by improving the soil health (Mishra *et al*., 2013) Pulses can fix atmospheric nitrogen (Kamble *et al*., 2017) and enhance the physical, chemical and biological properties of soil (Aschi *et al*., 2017; Prajapati *et al*., 2017; Huthily *et al*., 2020). Triple cropping systems involving legumes were found to be the most suitable system for flood-prone lowlands of North Bihar (Roy *et al*., 2011).

Inclusion of short duration cassava varieties like Sree Vijaya, Sree Jaya, Vellayani Hraswa and Kalpaka appeared promising for cultivation in rice fallows and the rice - pulse - short duration cassava sequence proved to be feasible (Suja *et al*., 2010). Tuber crops owing

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to their high biological efficiency in productivity and nutritional status can supplement the cereals (Naskar and Ravi, 2011).

Kerala falls in the West coast plains and ghat region agro-climatic zone. Rice - rice -fallow and rice - fallow - fallow are the major rice-based cropping systems in the coastal agro-ecosystem of Kerala (John *et al*., 2014). The introduction of remunerative crops can enhance the productivity of the rice-based cropping systems. Hence, the present study was undertaken to identify rice-based cropping systems suited to the coastal agro-ecosystems in terms of yield and economics.

MATERIALS AND METHODS

The study was conducted as part of the All India Co-ordinated Research Project on Integrated Farming Systems (ICAR) being implemented in the Integrated Farming System Research Station (IFSRS) of Kerala Agricultural University located at Karamana, Thiruvananthapuram, Kerala during *Kharif, Rabi* and summer seasons of 2019-2020. The experimental site, which falls under the agro-climatic zone - West coast plains and ghat region, is located at 8° 28′ 25″ N latitude and 76° 57′ 32″ E longitudes and an altitude of 5 m above mean sea level. A warm humid tropical climate existed over the experimental site. The rainfall received during *Kharif* (May to September 2019) was 1172.2 mm, while during *Rabi* (October 2019 to January 2020) was 519.8 mm, and during summer (February to May 2020) was 622.2 mm.

During the *Kharif* season, the maximum temperature varied between 27.5°C and 34.5°C, while the minimum temperature varied between 22°C and 29°C. During the Rabi season, the maximum temperature varied between 26°C and 33.5°C, while the minimum temperature varied between 21°C and 27°C and during the summer season the maximum temperature varied between 31.5°C and 38°C while the minimum temperature varied between 21°C and 29°C. The soil of the experimental site was acidic in reaction (pH - 5.80), medium in available nitrogen (288.1 kg ha^{-1}), medium in available phosphorus (36.8 kg ha^{-1}) and low in potassium status (137.7 kg ha^{-1}). The experiment was laid out in randomized block design with eleven cropping sequences *i.e*., CS_1 : rice - fallow - fallow, CS_2 : rice - rice - fallow, CS_3 : rice - *dhaincha* (*Sesbania aculeata*) - cowpea, CS_4 : (rice + *dhaincha*) - rice - green gram, CS_5 : rice - cassava - amaranthus, CS_6 : rice - cassava - cowpea, CS_7 : rice - para grass - fodder cowpea, CS_8 : rice - fodder cowpea - fodder maize, CS_9 : rice - okra - culinary melon, CS_{10} : rice - okra - yard long bean and CS_{11} : rice - rice - amaranthus replicated thrice. The plot size was 6 x 6 m. The details of crop, variety, spacing, seed rate, crop duration, doses of manures and fertilizers applied are abridged in Table 1. The recommended agronomic packages of practices of the state were followed for raising different crops (KAU, 2016). Rice was transplanted after puddling the land and the component crops were planted on raised beds and furrows while cassava was planted on mounds. The *Kharif* and *Rabi* crops were rainfed and received sufficient water from the South West and North East monsoon rains. During summer, only life-saving irrigation was given to the crops as the fields were lowlands having a high water table and received sufficient moisture through capillary action. The cropping sequences were evaluated to study the performance in terms of yield and economics.

During the first cropping season (*Kharif*), rice grains were harvested, threshed, dried, winnowed, air dried and their weight recorded and expressed as t ha^{-1}. *Dhaincha* plants were incorporated into the rice field 10 weeks after sowing of the rice crop in (rice + *dhaincha*) - rice - green gram cropping sequence. In the second cropping season (*Rabi*), tubers of cassava were harvested at maturity and tuber yield was recorded. Green fodder yield of para grass and fodder cowpea were recorded. The fruits of okra and culinary melon, yard long bean pods, cowpea and green gram seeds were harvested as and when these attained maturity and recorded. Harvest of amaranthus crop at maturity, but prior to bolting (40 days after sowing) was done by uprooting the plants. Since the fodder cowpea variety raised was single cut, a single harvest was done when the plants just started flowering (45 days after sowing). Fodder maize cuttings were taken 60 days after planting.

For comparison between crop sequences the yield of all the crops was converted into rice equivalent yield (REY) on a price basis as in Eq. (1) (Lal *et al*., 2017).

$$\text{REY} = \sum \frac{Yi\ Pi}{P(p)} \qquad \ldots (1)$$

Where, REY denotes rice equivalent yield; Y_i =

Table 1. *Details of crop, variety, spacing, seed rate, crop duration, doses of manures and fertilizers applied in the experiment*

Crop	Variety	Spacing	Seed rate	Duration	Fertilizers and manures applied
Rice	Uma	*Kharif* – 20 x 15 cm *Rabi* – 20 x 10 cm	60 kg ha^{-1}	120 days	N:P:K - 90:45:45 kg ha^{-1} FYM - 5 t ha^{-1}
Dhaincha	Local	Nil	25 kg ha^{-1}	63 days	-
Cowpea	Anaswara	25 x 15 cm	20 kg ha^{-1}	55 days	N:P:K - 20:30:10 kgha^{-1} FYM - 20 t ha^{-1}
Green gram	CO-8	Nil	20 kg ha^{-1}	60 days	N:P:K - 20:30:30 kg ha^{-1} FYM - 20 t ha^{-1}
Cassava	Vellayani Hraswa	90 x 90 cm	one sett per mound	6 months	N:P:K - 50:50:100 kg ha^{-1} FYM - 12.5 t ha^{-1}
Amaranthus	Arun	Solid row planting with 20 cm between rows	2 kg ha^{-1}	44 days	N:P:K - 100:50:50 kg ha^{-1} FYM - 50 t ha^{-1}
Para grass	Local	60 x 60 cm	27000 slips ha^{-1}	63 days	N:P:K - 80:30:30 kg ha^{-1} FYM - 40 t ha^{-1}
Fodder cowpea	CO-8	30 x 15 cm	40 kg ha^{-1}	45 days	N:P:K - 25:60:30 kg ha^{-1} FYM - 10 t ha^{-1}
Fodder maize	African Tall	30 x 15 cm	40 kg ha^{-1}	72 days	N:P:K - 120:60:40 kg ha^{-1} FYM - 10 t ha^{-1}
Okra	Salkeerthi	60 x 30 cm	8.5 kg ha^{-1}	88 days	N:P:K - 110:35:70 kg ha^{-1} FYM - 20 t ha^{-1}
Culinary melon	KAU Vishal	2 x 1.5 m	4 seeds per pit	89 days	N:P:K - 70:25:25 kg ha^{-1} FYM - 20 t ha^{-1}
Yard long bean	Vellayani Jyothika	2 x 2 m	4 kg ha^{-1}	96 days	N:P:K - 20:30:10 kg ha^{-1} FYM - 20 t ha^{-1}

yield of different crops; P_i = price of respective crops and P(p) = price of rice. The stability index (SI) for individual crops and sequences was computed using the following formula as used by Gangwar *et al*. (2006):

$$SI = \frac{Y - S}{Ymax} \quad \dots (2)$$

Where, Y is the average yield of crop in sequence over a period of year and locations and S is the standard deviation of the yield of a crop in a period of year and Ymax is the maximum yield of a crop in a certain year. Here, the stability index in terms of the REY of the system was computed. The system productivity (t ha^{-1} day^{-1}) was calculated by dividing the rice equivalent yield by 365. Similarly, the profitability in terms of ₹ ha^{-1} day^{-1} was worked out by dividing the average net returns over years by 365. The cost of cultivation of different crops was calculated based on the various operations performed and materials used for raising the crops including the rental value of the land. Returns were calculated using the prevailing market prices of different crops in the year 2019-2020. The market prices of the crops were obtained from the farm guide price during the year 2019-2020. The benefit: cost (B:C) ratio for different sequences was calculated by dividing the gross returns by the cost of cultivation in the system. The data generated were statistically analysed using analysis of variance (ANOVA) for Randomized Block Design (Cochran and Cox, 1965). Wherever significant differences among treatments were observed, CD values at 5% level of significance were calculated for comparison of means.

RESULTS AND DISCUSSION

Rice yield

During the first cropping season (*Kharif*), rice grain yield was significantly higher in CS_{10} : rice - okra - culinary melon cropping system (5.02 t ha^{-1}) which was on par with all other treatments except CS1: : rice - fallow - fallow (3.46 t ha^{-1}) and CS_2 : rice - rice -fallow

(3.58 t ha^{-1}) cropping sequences which were significantly less and on par (Table 2). The increase in rice grain yield could be due to diversification through crop rotations of cover crops, nitrogen-fixing crops and carry-over effect of manures and fertilizers applied to the vegetable crops and tubers included in the sequences. Prasad *et al*. (2013) reported that legumes, when grown in the summer season, could increase the grain and straw yield of succeeding rice crop due to the residual effect of nutrients used for growing potatoes during *Rabi* and the beneficial effect of legumes grown in the summer season.

Rice equivalent yield

The productivity in terms of REY (28.93 t ha^{-1}) and system productivity (0.079 t ha^{-1} day^{-1}) was the highest for rice - okra - yard long bean as compared to all other crop sequences studied (Table 3). Intensification and the inclusion of a vegetable crop and a legume during the *Rabi* and summer seasons contributed to the higher system productivity. John *et al*. (2013) reported that the highest average annual rice equivalent was obtained in the sequence rice - rice - amaranthus followed by rice - rice - sweet potato in rice-based cropping systems of southern Kerala. Rice-bitter gourd system was observed to have the highest system yield (49.88 ± 4.34 t ha^{-1} yr^{-1}) followed by rice-potato-ridge gourd (37.78 ± 2.77 t ha^{-1} yr^{-1}) and rice-potato-pumpkin (36.84 ± 2.04 t ha^{-1} yr^{-1}) systems and the lowest was recorded in the rice-fallow-fallow system (< 5 t ha^{-1} yr^{-1}) in a study conducted at the coastal parts of West Bengal (Ray *et al*., 2020). The system yields of rice- vegetable systems were high due to the higher selling price of vegetable crops and the overall yield of their economic products.

Stability index

The sequence involving CS$_6$: rice - cassava - cowpea was found to be maximum stable having a stability index of 0.95 (Table 3). This was followed by the sequence CS$_4$: (Rice + *dhaincha*) - rice - green gram (0.94). This could be due to the high compatibility of cassava and cowpea to be grown in sequence with rice as documented by Adeniyan *et al*. (2011). Short duration cassava varieties performed well in systems involving vegetable and grain cowpea (Suja and Sreekumar (2015). Walia *et al*. (2014), based on a study conducted in the central plain zone region of Punjab, recorded a maximum stability index of 0.99 in rice - green pea - summer moong bean, rice - green pea and rice - green pea - summer mash sequences.

In this study, rice - okra - yard long bean sequence had the lowest stability index. However, this was due to the very low yield of okra (3.26 t ha^{-1}) produced during the year 2017-18, which was a consequence of heavy shoot and fruit borer attack. If the yield of 2017 –18, would not have been considered, rice - okra - yard long bean would have the highest stability index.

Table 2. *Economic yield (t ha^{-1}) of different cropping systems*

Cropping system	Economic yield (t ha^{-1})		
	Kharif	*Rabi*	*Summer*
Rice - fallow - fallow	3.46	-	-
Rice - rice - fallow	3.58	2.06	-
Rice - *dhaincha* - cowpea	4.14	9.72	0.34
(Rice + *dhaincha*) - rice - green gram	4.30	2.64	0.98
Rice - cassava - amaranthus	4.61	15.84	6.42
Rice - cassava - cowpea	4.93	18.21	0.30
Rice - para grass - fodder cowpea	4.46	6.94	26.62
Rice - fodder cowpea - fodder maize	4.42	24.43	20.32
Rice - okra - culinary melon	5.02	12.34	7.35
Rice - okra - yard long bean	4.82	12.60	4.40
Rice - rice - amaranthus	4.37	2.59	6.53
CD (p≤0.05)	0.686	-	-

Table 3. *Rice equivalent yield, system productivity and stability index of the different cropping systems*

Cropping system	REY (t ha^{-1})			System REY (t ha^{-1})	System productivity (t ha^{-1} day^{-1})	Stability index
	Kharif	*Rabi*	*Summer*			
Rice - fallow - fallow	3.46	-	-	3.46	0.0095	0.87
Rice - rice - fallow	3.58	2.49	-	6.08	0.0167	0.68
Rice - *dhaincha* - cowpea	4.14	0.49	0.34	4.97	0.0136	0.73
(Rice + *dhaincha*) - rice - green gram	4.30	3.21	1.63	9.14	0.0250	0.94
Rice - cassava -amaranthus	4.62	10.61	6.42	21.65	0.0593	0.89
Rice - cassava - cowpea	4.94	12.19	0.30	17.44	0.0477	0.95
Rice - para grass - fodder cowpea	4.46	0.49	2.66	7.61	0.0208	0.83
Rice - fodder cowpea - fodder maize	4.42	2.44	2.03	8.89	0.0243	0.88
Rice - okra - culinary melon	5.02	16.42	4.92	26.36	0.0722	0.44
Rice - okra - yard long bean	4.82	16.76	7.35	28.93	0.0792	0.42
Rice – rice - amaranthus	4.37	2.59	6.53	13.47	0.0369	0.92
CD ($p\leq0.05$)	0.686	1.083	0.629			

Market price (₹ kg^{-1}): Rice: 30, *Dhaincha*: 150, Cowpea: 30, Green gram: 50, Cassava: 20, Amaranthus: 30, Para grass: 2, Fodder cowpea: 3, Fodder maize: 3, Okra: 40, Culinary melon: 20, Yard long bean: 50.

Economics

The system providing the maximum net returns and profitability is considered as economically significant. Significantly higher net return and B:C ratio were obtained in the sequences CS_9 : rice - okra - culinary melon (₹ 5.1 lakhs ha^{-1}, 2.64) and CS_{10} : rice - okra - yard long bean (₹ 5.45 lakhs ha^{-1}, 2.53) which were on par (Table 4). Maximum profitability was obtained from the sequence, CS_{10} : rice - okra - yard long bean (₹ 1495.08 ha^{-1} day-1) followed by CS_9 : rice - okra - culinary melon (₹ 1397.72 ha^{-1} day^{-1}). The next best sequence was rice - cassava - amaranthus (₹ 3.11 lakhs ha^{-1}, 1.85). Prasad *et al*. (2011) reported that vegetable-based cropping sequences showed more production efficiency, gross and net returns than other cropping sequences. Rice - cassava - *dhaincha* when grown over an extensive area is expected to perform well as cassava produces a higher and stable yield (John *et al*., 2013). Saha *et al*. (2019) reported that intensification

Table 4. *Economics of the different cropping systems*

Cropping system	Gross return (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio	Profitability (₹ ha^{-1} day^{-1})
Rice - fallow - fallow	125861	89040	36821	1.41	100.87
Rice - rice - fallow	204167	178080	26087	1.15	71.47
Rice - *dhaincha* - cowpea	175796	217870	-42073	0.81	-115.26
(Rice + *dhaincha*) - rice - green gram	298785	226384	72401	1.32	198.35
Rice - cassava - amaranthus	678343	367290	311053	1.85	852.2
Rice - cassava - cowpea	555282	367290	187992	1.51	515.04
Rice - para grass - fodder cowpea	256139	150255	105884	1.70	290.09
Rice - fodder cowpea - fodder maize	295037	150255	144782	1.96	396.66
Rice - okra - culinary melon	821809	311640	510169	2.64	1397.72
Rice - okra - yard long bean	901865	356160	545705	2.53	1495.08
Rice - rice - amaranthus	404580	289380	115200	2.51	315.61
CD ($p\leq0.05$)	46375.1		46375.1	0.198	

of rice-based system with vegetable crops like potato and spinach increased profitability compared to the farmer's practice of rice - fallow - fallow in salt-affected coastal zones of Bangladesh due to their better salinity tolerance.

Among the cropping sequences, the productivity in terms of rice equivalent yield (28.93 t ha^{-1}) and system productivity (0.079 t ha^{-1} day^{-1}) was highest for CS_{10} : rice - okra - yard long bean. The maximum gross returns (₹ 9,01,865 ha^{-1}) and net returns (₹ 5,45,705 ha^{-1}) were also found to be highest for CS_{10} : rice - okra - yard long bean. However, B:C ratio was highest for CS_9 : rice - okra - culinary melon (2.64) followed by CS_{10} : rice - okra - yard long bean (2.53). Thus, considering the production, net return and profitability, it may be concluded that CS_{10} : rice - okra - yard long bean is the most remunerative rice-based cropping system for marginal farmers to improve their livelihood followed by CS_9 : rice - okra - culinary melon in the coastal ecosystem of Kerala. More detailed studies to generate information on the influence on soil health, CO_2 sequestration, GHG emission and climate resilience are needed in the future.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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