



Assessment of productivity and profitability of different rice (*Oryza sativa*) based cropping systems in Chhattisgarh plains

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ABSTRACT

Experiments were conducted for 6 years (from 2003-04 to 2008-09) at Raipur to evaluate the production potential, economic viability and competence of 7 rice (*Oryza sativa* L.) based cropping systems under Chhattisgarh plains agro-climatic conditions. The cropping systems were rice-wheat [*Triticum aestivum* (L.) emend Fiori and Paol]- fallow; rice-mustard [*Brassica juncea* (L.) Czern and Coss]- green manure (GM); rice-coriander (*Coriandrum sativum* L.) - green gram [*Vigna radiata* (L.) Wilczek]; rice- table pea (*Pisum sativum* L.)- maize (*Zea mays* L.) (fodder); rice – brinjal (*Solanum melongena* L.) - green manure; rice- onion (*Allium cepa* L.)- green manure and rice – potato (*Solanum tuberosum* L.) – cowpea [*Vigna unguiculata* (L.) Walp]. Sunhemp (*Crotalaria juncea*) was grown as green manure. The highest total productivity was obtained under rice–potato–cowpea system (22.29 t/ha) while rice-brinjal-GM gave the highest net return (₹ 98,252 /ha) and benefit: cost ratio (2.40). However, the rice-potato-cowpea cropping sequence provided most employment (554 days). Least number of irrigations (12) with lowest quantity of water was required under rice-onion-GM, however, maximum irrigation water use efficiency was recorded under rice-brinjal-GM (235.46 kg/ha/cm water). Rice-wheat-fallow and rice-onion-GM recorded the highest sustainability index (0.84). Rice-potato-cowpea sequence was found to be most appropriate system in terms of profit as well as sustainability over the years.

Key words: Diversification, Profitability, Rice equivalent yield, Rice-potato-cowpea, Sustainability

Chhattisgarh is relatively underdeveloped with regards to agricultural productivity, rural employment and economic status as compared to most of the Indian states. During *kharif*, growing of rice is a tradition and is widely accepted depending upon farmers socio-economic conditions. However, in *rabi*, there are fewer options for the stakeholders to take a profitable and/or suitable crops. Under these circumstances, they generally follow rice – wheat, rice – mustard and rice – winter vegetables under partially or assured irrigation and rice – fallow, rice – utera (*Lathyrus*, chickpea and linseed) under rainfed situation. Any modification to the existing system with a tendency to decline the productivity of rice crop will neither be sustainable nor acceptable to the farming community unless and until it is stable over the time, maintains the soil health and sustains the environment in one hand and could also meet the daily requirements of human and animals (Samui *et al.*, 2004). Oilseeds and pulses including vegetables and fodder are receiving more attention owing to their higher prices. Diversification of existing cropping systems through these crops of diverse nature can change the eco-

nomics of the cropping sequences and may be a good proposition to break the monotony of the system. Hence, introduction of new high yielding and more profitable crop(s) in this area is vital. This will not only enhance the socio-economic conditions of the farmers by providing employment for longer duration but also enable them to exploit the upcoming marketing and processing infrastructure in this area. Besides, inclusion of vegetables, oilseeds or pulses could have effect on weed dynamics and sustaining the productivity. Therefore, an experiment was carried out to evaluate production potential and economic viability of different rice based cropping sequences including oilseed, pulses and vegetables.

MATERIALS AND METHODS

Field experiments were conducted on different rice based cropping systems under irrigated conditions between 2003-04 to 2008-09 on the same location at Indira Gandhi Krishi Vishwavidyalaya, Raipur under All India Coordinated Research Project on Integrated Farming Systems to evaluate and identify the promising need based cropping system for crop diversification and intensification in Chhattisgarh. The soil (*Inceptisol*) was silty clay in

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texture and neutral in reaction, medium in organic carbon (5.2 g/kg), low in available N (243 kg/ha), medium in available P (20.2 kg/ha) and high in available K (240 kg/ha). Seven cropping sequences were followed with 'Indira Sugandhit Dhan-1' rice in rainy season as the base crop. The cropping systems *viz.* rice-wheat ('GW 273') – fallow as check; rice-mustard ('Pusa Bold') – green manure (GM); rice-coriander ('Pant Dhaniya') – green gram ('HUM-1'); rice-table pea ('Arkil') – maize (fodder); rice – brinjal ('Hybrid Nisha') – GM; rice- onion ('Nasik Red') – GM and rice – potato ('Kufri Chipsona for first two years and K. Badshah' for later four years) – cowpea ('Gomati') were tested in balanced incomplete block design replicated thrice with a plot size of 10.0 X 7.0 m. Green manuring of 40 days old crop was done *insitu* with Sunhemp (*Crotalaria juncea*). Recommended dose of N, P and K were supplied through urea, single super phosphate/diammonium phosphate and muriate of potash. The total rainfall received was 1524, 1106, 1576, 979, 1529 and 840 mm during 2003-04, 2004-05, 2005-06 2006-07, 2007-08 and 2008-09 respectively. The experiment was conducted under irrigated condition as per recommended practices for different crops.

The yield obtained from winter and summer crops was converted into rice equivalent yield. The profitability of the systems was calculated by dividing the net returns (Rs/ha) in a sequence by 365 days. The relative productivity Efficiency (RPE) and relative economic efficiency (REE) were calculated by using following formula (Ururkar *et al.*, 2006).

$$\text{Relative Productivity Efficiency (\%)} = \frac{\text{TP of diversified CS} - \text{TP of existing CS}}{\text{TP of existing CS}} \times 100$$

$$\text{Relative Economic Efficiency (\%)} = \frac{\text{NR of diversified CS} - \text{NR of existing C.S.}}{\text{NR of existing CS}} \times 100$$

TP - Total productivity, CS- Cropping systems, NR - Net return, existing CS – existing cropping system i.e. Rice-wheat-fallow

Production efficiency was obtained dividing the total productivity of a system (in terms of rice yield equivalent) by total duration of that system (Tomar and Tiwari, 1990). Total duration of the system includes period required for field preparation and seeding. The irrigation water use efficiency was calculated dividing the total productivity by total irrigation water used by the crops in a particular sequence. Employment generation efficiency was determined dividing the total mandays employment for the system by 365 days and expressed in percentage. Sustainability yield index (SYI) was calculated as per the

formula suggested by Wanjari *et al.* (2004). Due to yearly variation in price of crops, the total productivity in terms of rice equivalent yield and total net return of ending year i.e. 2008-09 was only presented in the study considering with the farm gate prices for different crops for this particular year. Soil samples were analyzed for different parameters by following the standard procedures for organic carbon (Walkley and Black method), available nitrogen (alkaline permanganate method), available phosphorus (0.5 M sodium bicarbonate extractable) and available potassium (ammonium acetate extract). Weed density and dry weight of weeds was recorded by placing a quadrat of 0.50 x 0.50 m (0.25m²) size randomly at three places in each plot.

RESULTS AND DISCUSSION

System productivity and economic viability

Maximum total productivity (22.29 t/ha) in terms of rice yield equivalent was recorded in rice-potato-cowpea cropping system than other systems over the years (Table 1). This system produced additional yield of 150% over established cropping system i.e. rice-wheat-fallow (9.08 t/ha), 152% over rice-tablepea-maize (f) and 168% over rice-mustard-GM cropping systems. Higher productivity of rice-potato-cowpea system was owing to the replacement of wheat with high value and high priced potato in the system along with cowpea as a vegetable crop in summer. The yield advantage of rice-potato-cowpea over other rice based vegetable systems was 35% over rice-coriander (leaf)-green gram, 17% over rice –brinjal – GM and 36% over rice – onion – GM. Rice based systems with field crops *viz.* rice –wheat – fallow, rice-mustard-GM and rice-table pea-maize (f) produced almost similar rice equivalent yield with each other and these cropping systems remained significantly lower than those systems which included vegetables and cash crops follow rice. Saroch *et al.* (2005) also reported more productivity by replacing wheat in rice-wheat system with vegetables.

Though, maximum productivity was obtained under rice – potato – cowpea system, rice – brinjal – GM was identified to be distinctly superior and more economically viable in terms of net returns (₹98,252/ ha) and benefit: cost ratio (2.40) than other systems. The higher cost involved in potato seed and other interculture operations increased the cost of cultivation of rice – potato – cowpea system. Thus, rice-potato-cowpea system was second in rank in order of economic returns and was closely followed by rice – onion – GM. Cropping systems comprising vegetables like brinjal, onion and cowpea registered higher REY and contributed to higher net returns of the systems (Bastia *et al.*, 2008).

Table 1. Rice equivalent yield (REY) and economics of different rice based cropping systems (mean of six years)

Cropping system	Actual yield of individual crop and total productivity (t/ha) in terms of REY												Mean of six years		
	2003-04		2004-05		2005-06		2006-07		2007-08		2008-09		TP (t/ha) (REY)	Total net return ($\times 10^3$ ₹/ha)	B:C ratio
	Actual yield (t/ha)	TP (t/ha)	Actual yield (t/ha)	TP (t/ha)	Actual yield (t/ha)	TP (t/ha)	Actual yield (t/ha)	TP (t/ha)	Actual yield (t/ha)	TP (t/ha)	Actual yield (t/ha)	TP (t/ha)			
T ₁ Rice- Wheat- Fallow	5.07 3.65 -	10.13	4.78 3.53 -	9.33	8.10	5.62 2.57 -	9.67	4.73 2.97 -	9.68	4.51 2.10 -	7.55	9.08	39.4	1.40	
T ₂ Rice- Table pea- Maize (f)	4.97 0.80 18.00	8.33	5.80 6.21 27.80	11.00	7.77	5.52 1.05 22.22	8.01	4.81 0.68 21.20	9.62	4.51 0.41 21.06	8.23	8.83	81.9	2.04	
T ₃ Rice- Mustard- GM	5.13 1.12 -	7.89	5.27 1.11 -	8.29	7.90	6.13 0.81 -	8.69	5.39 1.39 -	9.49	4.92 0.91 -	7.45	8.29	24.6	0.61	
T ₄ Rice- Coriander (leaf)- Green gram	4.88 5.06 0.73	12.86	5.63 9.31 0.87	13.87	14.91	0.79 5.75 10.43	16.74	5.22 12.68 0.55	18.91	4.77 18.05 0.65	21.40	16.45	33.5	1.27	
T ₅ Rice - Brinjal- GM	4.88 8.81 -	10.39	5.60 30.41 -	14.29	26.47	5.75 36.48 -	21.39	5.24 36.29 -	19.75	4.77 43.75 -	21.78	19.00	98.3	2.40	
T ₆ Rice- Onion- GM	4.86 14.35 -	13.69	5.16 20.40 -	15.71	17.95	5.50 19.95 -	16.90	5.22 15.76 -	17.82	4.71 15.37 -	15.81	16.32	78.4	1.96	
T ₇ Rice- Potato- Cowpea SEM± CD (P=0.05)	5.07 10.32 5.12 - -	16.97	5.45 15.78 4.80 - -	21.13	23.51	5.51 22.17 3.52 - -	27.03	5.16 16.60 8.56 - -	23.01	4.67 17.73 9.16 - -	22.06	22.29	91.0	1.38	

Farm gate price of produce (₹/t): Rice 9,000/-, wheat 13,000/-, Mustard 25,000/-, Coriander 7,000/-, Field pea 30,000/-, Brinjal 3,500/-, Onion 6,500/-, Potato 6,500/-, Cowpea 4,500/-, Green gram 30,000/-, Maize (f) 1,000/-

Employment and production efficiency

The rice-potato-cowpea cropping sequence was found to be the most preferable in terms of providing employment coupled with better economic return. This sequence employed maximum number of man-days (554) in a year and showed highest employment generation efficiency (152.3%) as compared with other sequences (Table 2). Similar findings were also noted by Rautray (2005) under rainfed rice – based cropping systems from lower Assam. The production efficiency was also maximum in rice – potato – cowpea (68.98 kg/ha/day) cropping sequence closely followed by rice – brinjal – GM (60.47 kg/ha/day). These two systems also gave higher values of profitability (249.42 and 269.18 Rs/ha/d respectively). The lowest production efficiency (28.07 kg/ha/day) was noted in rice-mustard-GM as well as in rice – tablepea – maize (f) (28.38 kg/ha/day) sequence mainly due to less total productivity of these cropping sequences (Sharma *et al.*, 2004).

Irrigation – water use efficiency was the highest with rice-brinjal-GM cropping sequence (235.46 kg/ha/cm), followed by rice-potato-cowpea (214.91 kg/ha cm) and rice-onion-GM (207.06 kg/ha cm). Rice-potato-cowpea needed most irrigation water (103.7 ha-cm) due to higher

water requirement of potato and cowpea at short intervals. Kumar *et al.*, (2008) also reported the higher irrigation water use efficiency coupled with higher values of profitability with rice-potato and rice-onion cropping sequences. Irrigation water requirement of cereal-cereal (57.9 ha-cm) and cereal-oilseed cropping sequence (48.3 ha-cm) was found to be the lowest as compared to cereal – vegetable sequences. But this was not reflected in higher efficiency due to lesser quantum of productivity levels of wheat and mustard in terms of rice yield equivalent in cropping system mode.

Relative efficiency of the systems

Rice- potato- cowpea cropping system had higher positive values in respects of relative productivity efficiency, RPE (245.4%) and relative economic efficiency, REE (131.2%) over rice-wheat cropping system. The rice – vegetable systems particularly rice – brinjal – GM and rice- onion- GM were also found viable in terms of relative productivity and relative economic efficiency.

Sustainability

Based on six years analysis, systems having field crops are found to be more stable in terms of productivity. Rice

Table 2. Production efficiency, sustainability, profitability, employment generation, employment generation efficiency, irrigation and irrigation water use efficiency of different rice based cropping systems (average of six years)

Cropping system	Production efficiency (kg/ha/day)	Sustainable yield index	Sustainable economic index	Profitability (₹/ha/day)	Employment generation (mandays)	Employment generation efficiency (%)	Number of irrigation (No.)	Irrigation water (cm)	Irrigation water use efficiency (kg/ha-cm water)
Rice- wheat- fallow	34.6	0.84	0.88	107.89	290	80	7.7	57.9	156.8
Rice-table pea -maize (f)	28.4	0.20	0.67	67.28	420	115	10.5	78.8	112.0
Rice- mustard -GM	28.1	0.82	0.75	91.84	264	72	6.3	48.3	171.6
Rice-coriander (leaf)- green gram	52.6	0.73	0.69	224.33	411	113	11.2	82.0	200.6
Rice –brinjal-GM	60.4	0.50	0.67	269.18	401	110	12.8	80.7	235.4
Rice –onion-GM	51.4	0.84	0.80	214.71	402	110	11.0	78.8	207.0
Rice-potato- cowpea	68.9	0.70	0.72	249.42	554	152	14.5	103.7	214.9

Table 3. Chemical properties after completion of 6th cycle as influenced by different cropping systems

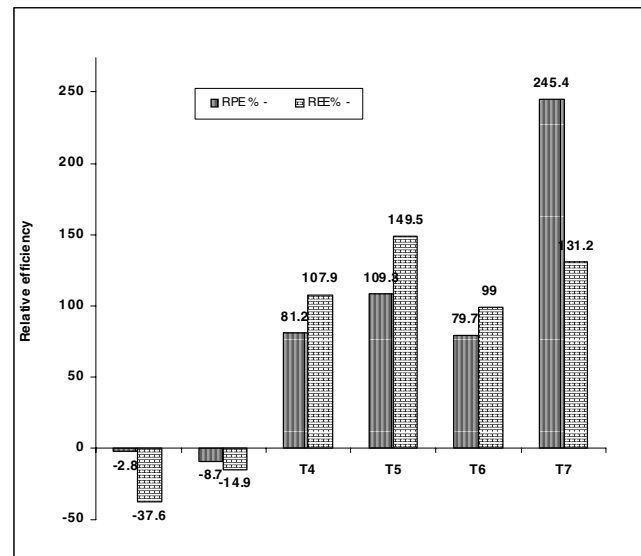
Cropping Systems	pH	EC (dS/m)	OC (g/kg)	N (kg/ha)	P(kg/ha)	K(kg/ha)
Rice-wheat-fallow	7.52	0.22	5.0	241	19.3	223
Rice-table pea-maize (F)	7.43	0.23	5.4	244	19.5	251
Rice-mustard-GM	7.27	0.28	5.2	247	18.7	236
Rice-coriander(leaf)-green gram	7.48	0.21	5.3	250	20.1	244
Rice-brinjal-GM	7.22	0.28	5.5	246	22.9	249
Rice-onion-GM	7.19	0.29	5.7	279	25.5	284
Rice-potato-cowpea	7.53	0.22	5.9	277	24.7	269
Initial	6.90	0.23	5.2	243	20.2	240
SEm±	0.5	0.03	0.15	7	0.8	8
CD (P=0.05)	NS	NS	0.40	19	2.1	21

– wheat – fallow (0.84) followed by rice – mustard – GM system (0.82) recorded higher sustainability among all the systems. Interestingly, rice – onion – GM showed appreciably high sustainability (0.84) revealing the consistency of producing higher yields over the years and found to be more compatible next crop after rice. While, in order of merit, the other systems consisting green vegetables e.g. rice-potato- cowpea system and rice – brinjal – GM, exhibited lesser stability index of 0.70 and 0.50, respectively. On the otherhand, rice – tablepea – maize (f) system showed yearly deviation in yield of table pea and resulted in lowest (0.20) sustainability. Stability with respect to total net return followed the similar trend. In fact, fluctuations in market prices of green vegetables over the years have mainly governed the quantum of total productivity in terms of RYE and returns from that system (Table 2). The sustainability in terms of total productivity and economics observed to be lowered down when more than two crops particularly vegetables were included in the system in a cycle. Though, the RPE and REE of rice – mustard was negative and/or much less than rice – vegetable systems, it still has a place due to higher sustainability yield index (stability) of this system was higher than those of rice vegetable systems (Table 2 and Fig. 1). Gangwar *et al.* (2004) also noted higher stability of field crops in cereal-cereal or cereal-oilseed cropping sequences.

Soil fertility status

The soil organic carbon (OC) remained unchanged in rice-mustard-GM and rice-tablepea-maize (f) and increased from 5.3 to 5.9 g/kg (rice-potato-cowpea) as compared to initial (5.2 g/kg of soil) under all the cropping sequences except rice-wheat-fallow (5.0 g/kg) where legume/GM was not included. Rice-wheat-fallow cropping system was observed to have a negative impact on soil organic carbon and soil N status. This system failed to maintain the initial soil organic C status. Organic carbon

content and available N, P and K status of soil increased by 14.0, 15.7, 32.1 and 27.3% in rice – onion – GM system, respectively, owing to the use of balanced application of fertilizer along with green manuring and incorporation of legumes in cropping sequence as compared to rice-wheat-fallow sequence (Table 3). The favourable soil conditions brought by the inclusion of cowpea/green manure helped in build-up soil. Lesser soil status of P (18.7 kg/ha) in rice – mustard – GM system might be due to higher uptake of P by mustard crop. Soil pH and electrical conductivity remained unaffected due to continuous use of fertilizers and intensive cropping.



T₁: Rice-wheat-fallow (existing cropping system), T₂: Rice-mustard-GM, T₃: Rice-Tablepea-maize (f), T₄: Rice-coriander (leaf) -greengram; T₅: Rice-brinjal-GM, T₆: Rice-onion-GM, T₇: Rice-potato-cowpea

Fig. 1. Relative production efficiency (RPE, %) and relative economic efficiency (REE, %) of different rice based cropping systems over existing cropping system (mean over)

Table 4. Total weed population and total dry matter of weeds under different cropping systems during *rabi* season

Cropping system	Total weed population (No./m ²)						Total dry matter of weeds (g/m ²)					
	2006-07		2007-08		2008-09		2006-07		2007-08		2008-09	
	A	B	A	B	A	B	A	B	A	B	A	B
Rice – wheat – fallow	160.6	190.0	166.1	157.0	155.2	150.2	7.5	240.7	8.2	247.3	10.2	220.8
Rice – table pea – maize (f)	166.6	140.3	172.1	145.8	188.5	160.5	7.6	184.8	8.1	191.4	12.1	200.0
Rice – mustard – GM	176.5	151.5	182.0	204.1	174.1	204.1	7.7	203.8	9.5	271.6	10.8	281.4
Rice – coriander (leaf) – green gram	188.4	215.1	177.4	185.5	166.2	170.8	9.0	285.8	8.0	219.2	10.7	256.2
Rice – brinjal-GM	105.4	103.1	110.9	108.6	90.7	110.1	4.9	122.6	5.4	129.2	7.8	130.8
Rice – onion –GM	56.7	80.7	62.2	86.2	55.5	90.3	2.5	92.9	3.1	99.5	5.5	88.8
Rice – potato – cowpea	46.6	80.1	52.1	85.6	48.7	87.8	2.5	75.8	3.0	82.4	7.7	90.8

A – 30 DAS, B – 60 DAS

Studies on weeds

The weeds became a major problem during *rabi* under irrigated conditions. The predominant weed species observed in the experimental field during *rabi* season were *Melilotus indica*, *Chenopodium album*, *Echinochloa colona*, *Cynodon dactylon*, *Eleusine indica*, and *Anagallis arvensis*. Among all these weeds, *Melilotus indica* had highest population and made up to 60% of total weed population. Mustard and coriander were highly infested by weeds at 60 DAS. This was due to slow growth of both the crops during initial stage and wider spacing particularly in mustard. Lower weed population and dry matter of weeds in rice – brinjal – GM, rice – onion – GM and rice – potato – cowpea cropping sequences was due to repeated intercultural operations in vegetables which did not provide conducive environment for weed growth (Tripathi and Singh, 2008). However, no definite trend of crop diversification was observed on weed population and dry weight in rice-mustard, rice – coriander and rice – tablepea over the years (Table 4). Rice – potato – cowpea sequence was found to be the most appropriate system in terms of profit as well as sustainability over the years. Inclusion of peri-urban crops like brinjal, potato and onion during post rainy season followed by green gram or cowpea during summer could be a better option to fulfill the daily needs of urban population and to fetch higher economic returns. Owing to their long-term sustainability, existing rice-wheat and rice- mustard- GM systems can be suitable for farmers with limited resources.

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