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Cropping system analysis for agricultural sustainability, productivity, economy and land use efficiency of different rice based cropping systems in Chhattisgarh plains

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Abstract
A field experiment was conducted at the Research-cum instructional farm, College of Agriculture, Raipur (C.G.) during 2020-21 and 2021-22. The experiment was laid out in randomized block design consists three replications with ten treatments of rice based cropping systems were i.e. rice(MTU 1010)-wheat-green manure; rice(MTU 1010)-chickpea-fallow; rice(Dubraj)-garden pea-cowpea(veg.); rice(Devbhog)-cowpea(veg.)-moong; rice(Zinco rice)-mustard-moong; rice(Protazin)-french bean-groundnut; rice (Badshah bhog)-berseem-sorghum; rice(Vishnubhog)-oat-pearl millet; rice(Hybrid US 312)-sweet corn-tomato+coriander(1:1); rice(Hybrid Arize Gold)-cabbage-sweet corn+cowpea(veg.)(1:1). The results revealed that maximum total productivity of the system in terms of REY was recorded under rice((Hybrid US-312)-sweet corn-tomato+coriander (1:1) cropping sequence in both the years (242.7 and 247.7 q ha^{-1}). The highest production efficiency and economic efficiency were registered in rice (Hybrid US-312)-sweet corn-tomato+coriander (1:1) cropping system as compare to other rice based cropping systems during both theyears and on mean basis. Land utilization efficiency was recorded maximum under rice (Badshah bhog) -berseem-sorghum cropping system during both the years and on mean basis. Maximum total cost of cultivation, total gross returns and total net returns were registered under rice (Hybrid US-312)-sweet corn-tomato+coriander (1:1) cropping system (Rs 181245 ha^{-1}, Rs 193674 ha^{-1} and Rs 187460 ha^{-1} respectively) on the mean basis. B:C ratio (3.02, 2.64) was registered maximum under rice (MTU 1010) – chickpea – fallow cropping system during the first year and on mean basis. However, during the second year the maximum B:C ratio (2.38) was under rice(Protazin)- french bean – groundnut cropping.

Keywords: Rice-based cropping systems, cropping system analysis, agricultural sustainability

Introduction
India is the second largest producer and consumer of rice in the world. In India, rice had a share of 35.26 per cent in area and 40.02 per cent in total food grain production in India (2020-21). India is also a major exporter of rice exporting around 14.37 million tonnes of rice (2020-21), according to the Agricultural and Processed Food Products Export Development Authority (APEDA). State like Chhattisgarh where traditionally rice and rice-based farming systems are practiced, rice is grown on an area of 3893.46 ha with a productivity of 3864 kg ha^{-1} (Anonymous 2025) [1]. The rice in Chhattisgarh is mainly grown by transplanting under puddled field and direct seeding through seed drill and broadcasting of seeds on un-puddled field and there after beushening. The growing of second crops after rice is a concern due to field preparation, proper crop establishment method, shortage of moisture specially at upper soil layer and poor germination and thus cropping intensity is very low. In a particular agro-climatic and resource condition, the identification of most suitable crop sequence is based on its productivity, stability, land use efficiency as well as production efficiency and its performance is chiefly judged in terms of productivity and net return. Nevertheless, understanding of production and land use efficiency provide an additional base for identification of a better and efficient crop sequence for a particular area. For assured success, workable and socially acceptable technologies are to be essentially used. The alternative cropping system so developed may be

practiced to enhance sustainability of existing system**.** The diversification of cropping system is necessary to get higher yield and return, to maintain soil health by including pulses, sustain environment and meet daily requirement of human and animals with growing vegetables, pulses and fodders as well as more remunerative crops like tomato, chilli, potato and onion which receive higher income due to increased demand. In the state, majority of farm families rear animals with rice farming, but they face problem of green fodder availability throughout the year. Most of the previous research concentrated either on a particular cropping system (e.g., rice-wheat system) or on the adaptability of specific crop-based cropping systems under different land situations. There is a need for a comprehensive evaluation of various cropping systems with regards to productivity, profitability, land use etc to evaluate alternative cropping system through crop diversification and intensification. In view of the above, the present investigation was undertaken to study the cropping system analysis for agricultural sustainability, productivity, economy and land use efficiency of rice based cropping systems in Chhattisgarh plains.

Materials and Methods

A field experiment was conducted at Research cum Instructional farm of College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur during *kharif* season of 2020-21 and 2021-22. In the present investigation, ten treatments consisting of different rice-based cropping systems were taken to identify the most efficient cropping systems of Chhattisgarh for family nutrition, soil health, fodder and income generation for integrated farming systems of Chhattisgarh plains. Rice was taken as base crop during *kharif* with ten different cropping systems followed during *rabi* and *summer*. The experiment was laid out in randomized block design with three replications. The ten rice based cropping systems i.e. rice(MTU 1010)-wheat-green manure; rice(MTU 1010)-chickpea-fallow; rice(Dubraj)-garden pea-cowpea(veg.); rice(Devbhog)-cowpea(veg.)-moong; rice(Zinco rice)-mustard-moong; rice(Protazin)-french bean-groundnut; rice(Badshah bhog)-berseem-sorghum; rice(Vishnubhog)-oat-pearl millet; rice(Hybrid US 312)-sweet corn-tomato+coriander(1:1) and rice(Hybrid Arize Gold)-cabbage-sweet corn+cowpea(veg.)(1:1) were taken. The soil of the experimental site was sandy-clay-loam in texture of pH 7.2, EC 0.22 dsm^{-1}, 0.51% OC and available N, P and K 243.3, 13.5 and 258.5 kg ha^{-1} in soil, respectively. To compare performance of different cropping systems, rice equivalent yield (REY) were calculated on price basis.

Results and Discussion

Total productivity in terms of rice equivalent yield (REY)

Crops of diversified nature performed quite differently when grown in a system. One system having higher productivity and revenue in one season may not be profitable during next season. To have a clear picture of diversified cropping system, yields of *kharif* rice, different *rabi* and summer crops were converted into rice equivalent yield (REY) of respective crops and the total productivity of all three seasons in terms of system productivity are presented in terms of REY in Table 1.

The winter and summer crops mostly governed the REY of the system. Maximum total productivity (242.7 and 247.7 respectively) of the system in terms of REY was recorded under rice((Hybrid US-312)-sweet corn-tomato+coriander (1:1) cropping sequence in both the years. Further, rice (Hybrid Arize Gold)- cabbage – sweet corn + cowpea (1:1) system stood next in order of merit and produced appreciably higher total productivity (183.5 and 203.9 respectively). Rice (Hybrid US-312)-sweet corn-tomato+coriander (1:1) gave higher total productivity over existing cropping systems of rice(MTU 1010)-chickpea- fallow cropping system. As regards to soil health point of view rice (Dubraj)- garden pea – cowpea recorded higher total productivity over rice (Devbhog) – cowpea – moong cropping system, in terms of family nutrition cropping system rice(Protazin)- french bean – groundnut was better over rice(Zinco rice)-mustard-moong. While, in respect to fodder production rice (Badshah bhog)- berseem– sorghum was better over rice(Vishnu bhog-oat-pearl millet.

1. Production efficiency (kg ha^{-1} day^{-1})

Data pertaining to production efficiency is presented in Table 2. The maximum production efficiency (75.8, 77.4 and 76.6, respectively) was recorded under rice(Hybrid US-312)-sweet corn-tomato+coriander (1:1) cropping sequence in both the years and on mean basis. Whereas the lowest production efficiency was recorded under rice(Vishnu bhog)-oat-peral millet. From this result it is clear that the rice((Hybrid US-312)-sweet corn-tomato+coriander (1:1) cropping sequence can be a better option over all the other cropping system as it has maximum potential of producing yield within a given time period. Kalita *et al*., (2015) [7] suggested that the effect on system productivity efficiency was significant.

2. Economic efficiency (Rs ha^{-1} day^{-1})

The economic efficiency (Table 2) was recorded maximum (866.6, 813.4 and 840.0, respectively) under rice(Hybrid US-312)-sweet corn-tomato+coriander (1:1) cropping sequence in both the years and on mean basis followed by rice (Hybrid Arize Gold)- cabbage – sweet corn + cowpea (1:1) cropping system presented in Table. Similarly, the lowest economic efficiency was recorded under rice(Vishnu bhog)-oat-pearl millet cropping system. Economic efficiency in cropping systems is a measure of how well a cropping system performs based on the inputs and outputs of the system and this result shows that the rice(Hybrid US-312)-sweet corn-tomato+coriander (1:1) cropping sequence is highly economically efficient.

3. Land use efficiency (%)

The data regarding LUE is presented in (Table 2) and it was recorded maximum (97.8, 95.9 and 96.8, respectively) under rice(Badshah bhog)-berseem-sorghum cropping system. Likewise, the minimum LUE was recorded under rice(MTU 1010)-chickpea-fallow cropping system.

4. Economics

The data presented in Table 3 shows maximum total cost of cultivation of the system (Rs 181245 ha^{-1}, Rs 193674 ha^{-1} and Rs 187460 ha^{-1} respectively) was recorded under rice (Hybrid US-312)-sweet corn-tomato+coriander(1:1) cropping systems during both the years and on mean basis, respectively followed by rice (Hybrid Arize Gold)- cabbage – sweet corn + cowpea (1:1) cropping system(Rs 166669 ha^{-1}, Rs 178692 ha^{-1} and Rs 172681 ha^{-1} respectively). The lowest cost of cultivation (Rs 55471 ha^{-1}, Rs 58126 ha^{-1} and Rs 56799 ha^{-1}) was recorded in green manure under rice(MTU 1010)-chickpea-fallow cropping systems during both the years and on mean basis. This might be due to fallow in cropping system during summer season.

The data on highest total gross return (Table 3) of the system (Rs 497551 ha^{-1}, Rs 449897 ha^{-1} and Rs 473724 ha^{-1} respectively) was recorded under rice (Hybrid US-312)-sweet corn-tomato+coriander(1:1) cropping systems during both the

years and on mean basis, respectively followed by rice (Hybrid Arize Gold)- cabbage – sweet corn + cowpea (1:1) cropping system(Rs 420680 ha^{-1}, Rs 319120ha^{-1} and Rs 369900 ha^{-1} respectively). The total gross return of the system (Rs 116365ha^{-1}, Rs 96830 ha^{-1} and Rs 106598 ha^{-1}) was recorded in green manure under rice(Vishnu bhog)-oat-pearl millet cropping systems during both the years and on mean basis.

The data (Table 3) on highest total net return of the system (Rs 316306 ha^{-1}, Rs 265804 ha^{-1} and Rs 291055 ha^{-1} respectively) was recorded under rice (Hybrid US-312)-sweet corn-tomato+coriander(1:1) cropping systems during both the years and on mean basis, respectively followed by rice (Hybrid Arize Gold)- cabbage – sweet corn + cowpea (1:1) cropping system (Rs 254011 ha^{-1}, Rs 218259 ha^{-1} and Rs 236135 ha^{-1} respectively). The total net return of the system (Rs 43110ha^{-1}, Rs 22336 ha^{-1} and Rs 32723 ha^{-1}) was recorded in green manure under rice(Vishnu bhog)-oat-pearl millet cropping systems during both the years and on mean basis.

The data on (Table 3) maximum B:C ratio (3.02, 2.64) of the system was recorded under rice(MTU 1010)-chickpea-fallow cropping systems during the first year and on mean basis. During the second year the maximum total B:C ratio was recorded under rice (Protazin)-french bean-groundnut cropping system. Similary, the minimum total B:C ratio (1.59. 1.28, 1.44) was recorded under rice(Vishnu bhog)-oat-pearl millet cropping systems during both the years and on mean basis respectively.

Table 1: Rice equivalent yield (REY) and total productivity of *kharif*, *rabi*, summer season as influenced by different rice based cropping system

Treatments	REY(q ha^{-1}) 2020-21			TP	REY(q ha^{-1}) 2021-22			TP
	Kharif	*Rabi*	Summer		*Kharif*	*Rabi*	Summer	
T_1 Rice (MTU 1010)-Wheat- *Dhaincha*	43.3	32.8	8.7	84.8	42.8	25.9	9.4	78.1
T_2 Rice (MTU 1010)-Chickpea-Fallow	45.1	44.5	0.0	89.6	42.5	24.8	0.0	67.4
T_3 Rice (Dubraj)-Garden pea-Cowpea (veg.)	45.2	54.0	21.7	120.9	43.8	41.7	14.9	100.4
T_4 Rice (Devbhog)-Cowpea (veg.)-Moong	49.9	33.3	22.0	105.2	50.1	23.5	22.3	95.9
T_5 Rice(Zinco rice)-Mustard-Moong	48.5	32.2	22.6	103.2	45.4	24.5	21.0	90.9
T_6 Rice (Protazin)-French bean-Groundnut	49.5	46.6	29.5	125.5	51.4	29.9	39.3	120.6
T_7 Rice (Badshah bhog)-Berseem-Sorghum	26.0	33.9	16.2	76.1	22.5	26.6	12.1	61.2
T_8 Rice (Vishnu bhog)-Oat-Pearl millet	25.2	20.1	17.0	62.3	20.4	16.0	13.1	49.5
T_9 Rice (Hybrid US-312)-Sweet corn-Tomato+Coriander (1:1)	58.2	115.7	68.8	242.7	45.5	127.2	74.9	247.7
T_{10} Rice (Hybrid Arize Gold)-Cabbage-Sweet corn+Cowpea (veg) (1:1)	60.2	99.7	23.7	183.5	54.2	94.3	55.5	203.9
SEm±	1.3	4.0	0.3	2.9	1.6	4.2	2.9	2.8
CD (P=0.05)	3.8	11.9	0.8	8.8	4.9	12.5	8.6	8.2

Table 2: Production efficiency, economic efficiency, and land use efficiency of the system as influenced by different rice based cropping systems

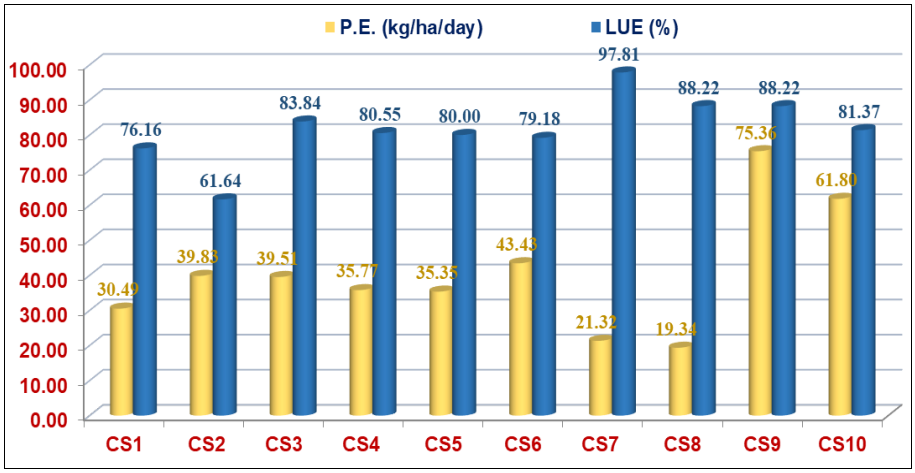
Treatments	Production efficiency (kg ha^{-1} day^{-1})			Economic efficiency (Rs ha^{-1} day^{-1})			Land use efficiency (%)		
	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean
T_1 Rice (MTU 1010)-Wheat- *Dhaincha*	30.5	28.1	29.3	247.8	216.5	232.1	78.9	76.2	77.5
T_2 Rice (MTU 1010)-Chickpea-Fallow	39.8	29.9	34.9	306.6	200.6	253.6	63.0	61.6	62.3
T_3 Rice (Dubraj)-Garden pea-Cowpea (veg.)	39.5	32.8	36.2	371.0	282.0	326.5	85.2	83.8	84.5
T_4 Rice (Devbhog)-Cowpea (veg.)-Moong	35.8	32.6	34.2	314.7	282.6	298.6	83.6	80.5	82.1
T_5 Rice (Zinco rice)-Mustard-Moong	35.3	31.1	33.2	301.1	252.7	276.9	87.7	80.0	83.8
T_6 Rice (Protazin)-French bean-Groundnut	43.4	41.7	42.6	382.3	377.6	379.9	82.2	79.2	80.7
T_7 Rice (Badshah bhog)-Berseem-Sorghum	21.7	17.5	19.6	162.0	96.3	129.1	97.8	95.9	96.8
T_8 Rice (Vishnu bhog)-Oat-Pearl millet	19.3	15.4	17.4	118.1	61.2	89.7	90.4	88.2	89.3
T_9 Rice (Hybrid US-312)-Sweet corn-Tomato+Coriander(1:1)	75.8	77.4	76.6	866.6	813.4	840.0	87.7	87.7	87.7
T_{10} Rice (Hybrid Arize Gold)-Cabbage-Sweet corn+Cowpea (veg) (1:1)	61.8	68.7	65.2	695.9	619.3	657.6	82.2	81.4	81.8
S.Em±	0.9	1.8	0.9	-	-	-	-	-	-
CD(P=0.05)	2.9	5.5	2.8	-	-	-	-	-	-

Table 3: System economics of different rice based cropping systems

Treatments	Cost of cultivation (Rs ha^{-1})			Gross return (Rs ha^{-1})			Net return (Rs ha^{-1})			B:C ratio		
	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean
T_1 Rice (MTU 1010)-Wheat- *Dhaincha*	67902	71354	69628	158338	148901	153620	90436	79017	84727	2.33	2.09	2.21
T_2 Rice (MTU 1010)-Chickpea-Fallow	55471	58126	56799	167389	130655	149022	111918	73211	92565	3.02	2.25	2.64
T_3 Rice (Dubraj)-Garden pea-Cowpea (veg.)	90448	93471	91960	225876	194623	210250	135428	102942	119185	2.50	2.08	2.29
T_4 Rice (Devbhog)-Cowpea (veg.)-Moong	81596	84353	82975	196457	185969	191213	114861	103131	108996	2.41	2.20	2.31
T_5 Rice (Zinco rice)-Mustard-Moong	82927	85997	84462	192838	176412	184625	109910	92257	101084	2.33	2.05	2.19
T_6 Rice (Protazin)-French bean-Groundnut	94910	98352	96631	234454	233960	234207	139544	137812	138678	2.47	2.38	2.43
T_7 Rice (Badshah bhog)-Berseem-Sorghum	83024	85921	84473	142161	119397	130779	59137	35126	47132	1.71	1.39	1.55
T_8 Rice (Vishnu bhog)-Oat-Pearl millet	73254	75755	74505	116365	96830	106598	43110	22336	32723	1.59	1.28	1.44
T_9 Rice (Hybrid US-312)-Sweet corn-Tomato+Coriander(1:1)	181245	193674	187460	497551	449897	473724	316306	265804	291055	2.75	2.32	2.54
T_{10} Rice (Hybrid Arize Gold)-Cabbage-Sweet corn+Cowpea (veg) (1:1)	166669	178692	172681	420680	319120	369900	254011	218259	236135	2.52	1.79	2.16

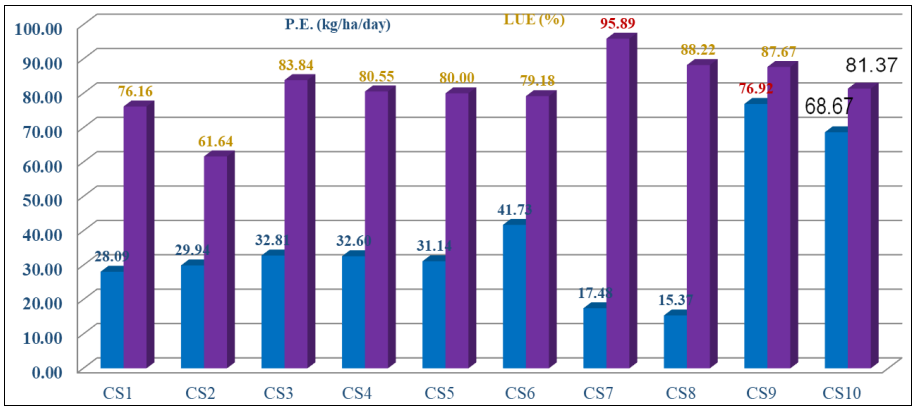
*Price of produce (Rs/q) year 2020-21: Rice- 1868, Scented rice- 2242, Wheat-1925, Chickpea– 4875, Sweetcorn – 2000, Garden pea – 1500, Mustard – 4425, French bean – 1800, Cabbage – 1000, Cowpea -1000, Berseem fodder-100, Oat fodder-100, Dhaincha – 50, Ground nut – 5275, Tomato –800, Coriander (green)-1500, Moong- 7196, Sorghum (f) -100, Pearl millet (f) – 100, Cowpea -1000, Sweetcorn – 2250

*Price of produce (Rs/q) year 2021-22: Rice- 1940, Scented rice- 2425, Wheat-2015, Chickpea – 5230, Sweetcorn – 2250, Garden pea – 1800, Mustard – 5050, French bean – 1800, Cabbage – 1000, Cowpea -1100, Berseem fodder-100, Oat fodder-100, Dhaincha – 50, Ground nut – 5550, Tomato –800, Coriander (green)-1700, Moong- 7275, Sorghum (f) -100, Pearl millet (f) – 100, Cowpea -1100, Sweetcorn – 2250



*CS1- Rice-wheat-dhaincha, CS2- Rice-chickpea-fallow, CS3- Rice-garden pea-cowpea, CS4-Rice-cowpea-green gram,
CS5- Rice mustard-green gram, CS6- Rice-french bean-groundnut, CS7-Rice-berseem-sorghum (f), CS8- Rice-oat-pearl millet (f),
CS9-Rice-sweetcorn-Tomato+coriander (1:1), CS10-Rice-cabbage-sweet corn+cowpea (1:1)

Fig 1: Pattern of Land use efficiency & Production efficiency during 2020-2021 of various cropping systems



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CS5- Rice mustard-moong, CS6- Rice-french bean-groundnut, CS7-Rice-berseem-sorghum (f), CS8- Rice-oat-pearl millet (f),
CS9-Rice-sweetcorn-Tomato+coriander (1:1), CS10-Rice-cabbage-sweet corn+cowpea (1:1)

Fig 2: Pattern of Land use efficiency & Production efficiency during 2021-2022 of various cropping systems

Conclusion

Cropping systems involving hybrid rice under rice(Hybrid US-312 - sweet corn-tomato+coriander(1:1) cropping systems are highly productive in terms of rice equivalent yield (REY), economic efficiency, production efficiency and land use efficiency. Also these are suitable for higher return. The present research addresses the problems arise by continuous growing of rice-wheat or rice chickpea cropping system. This study has also emphasized the necessity of detailed study on nutrient balance, pest dynamics, energy efficiency of existing systems and new systems for long term sustainability.

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