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Diversification of Rice-rice (*Oryza sativa* L.) cropping systems for productivity, profitability and resource use efficiency in Tunga Bhadra Project Command Area

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ABSTRACT
A field experiment was carried out in farmer's field near Agriculture Research Station, Siruguppa in Karnataka during kharif and rabi seasons of 2014-15 to evaluate productivity, profitability and resource use efficiency of rice (Oryza sativa L.) based cropping system in Tunga Bhadra Project Command Area. The experimental site was medium fertile deep black soil belong to the order vertisol with soil pH (8.01), EC (0.54 dS m^{-1}), available nitrogen (240.80 kg ha^{-1}), P_2O_5 (22.90 kg ha^{-1}) and K_2O (347.49 kg ha^{-1}). The experiment comprised of seven sequential cropping systems viz., Rice-maize, Rice-sorghum, Rice-chickpea, Rice-sesame, Maize-chickpea, Cotton-sesame and Rice-rice which were evaluated. These treatments were laid out in completely randomized block design with three replications. Data on yield of each crop was recorded and statistically analyzed. Cost of cultivation of each crop was worked out and income of crop yields was calculated on prevailing market prices. The experimental results revealed that significantly higher rice equivalent yield (REY) was recorded in cotton-sesame cropping system (13117 kg ha^{-1}). Whereas, significantly higher system productivity was recorded with maize-chickpea cropping system (35.94 REY kg ha^{-1} day^{-1}) and it was significantly superior over existing rice-rice (26.89 REY kg $ha^{-1}day^{-1}$) cropping systems. Rice-rice cropping system accounted for highest land use efficiency (78.36 %) and it was followed by cotton-sesame (71.23 %). Significantly highest production efficiency (56.67 kg REY ha^{-1} day^{-1}) and apparent nutrient productivity (35.60 kg REY kg^{-1} nutrient applied) were recorded with maize-chickpea as against the other cropping systems. The gross returns were higher in cotton-sesame and maize-chickpea cropping systems of ₹ 220813 ha^{-1} and ₹ 203988 ha^{-1}, respectively with net profit ₹ 166328 ha^{-1} and ₹ 148803 ha^{-1}, and benefit cost ratio of 4.05 and 3.70 respectively. The cotton-sesame and maize-chickpea crop sequences are more productive, profitable and remunerative as they fetched more net returns per unit area for time invested, and can be a better cropping systems in place of rice-rice for the farmers of the Tunga Bhadra Project area of Karnataka for higher profitability.
Key words*: Rice equivalent yield, System productivity, Land use efficiency, Production efficiency, Relative economic efficiency, Employment generation.*

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INTRODUCTION

Rice (*Oryza sativa* L.), occupies a pivotal place in Indian agriculture. It is the staple food for about 70 per cent of population and a source of livelihood for about 120-150 million rural households. It accounts for about 43 per cent of total food grain production and 55 per cent of cereal production in the country. Rice is a primary energy source or high calorie food and it contains less protein than wheat. The protein content of milled rice is usually 6-7 per cent. The by-products of rice milling are used for various purposes. Rice bran is used as cattle and poultry feed. Rice hulls can be used in manufacturing of insulation materials, cement and card board and as a litter in poultry keeping. Besides, rice straw is also used to feed cattle [14]. In India, rice is cultivated over an area of 43.95 million hectares with a production of 106.54 million tonnes. In Karnataka, it is grown in an area of 1.42 million hectares with an annual production of 3.5 million tonnes [1].

Mono cropping of rice or rice-rice cropping system has led to several environmental hazards viz., soil salinity and alkalinity problems, besides methane emission from the rice field also led to environmental problems. To overcome these deleterious effects an alternate cropping system or crop diversification is need of the hour. Crop diversification and intensification of rice-based or alternate cropping system for rice-rice system to enhance the productivity per unit resource is very pertinent. Crop diversification shows lot of promises in alleviating problems viz., water scarcity, excess use of nitrogenous fertilizer, soil deterioration etc., besides, fulfilling basic needs for cereals, pulses, oilseeds, vegetables and also regulating farm income, withstanding weather aberrations, controlling price fluctuation, ensuring balanced food supply, conserving natural resources, reducing the chemical fertilizer and pesticide loads, ensuring environmental safety and creating employment opportunity [4]. In this context, efforts are being made to promote diversification of rice based cropping sequence or development of an alternate cropping systems to rice-rice in our country as well as Tunga Bhadra Project area with cereals, legumes and oil seed crops for sustaining the productivity and meet out demand for vegetables, pulses and oilseeds. Therefore, keeping all these points in view, the present investigation was carried out to studies the economic feasibility of alternate sequential cropping systems to rice-rice (*Oryza sativa* L.) in Tunga Bhadra Project area.

MATERIAL AND METHODS

A field experiment was carried out in farmer's field near Agriculture Research Station, Siruguppa in Karnataka during *kharif* and *rabi* seasons of 2014-15 to "Diversification of Rice-Rice (Oryza sativa L.) cropping systems for productivity, profitability and resource use efficiency in Tunga Bhadra Project Command Area". The experimental site was medium deep black soil belong to the order *vertisol* with soil pH (8.01), EC (0.54 dS m^{-1}), available nitrogen (240.80 kg ha^{-1}), P_2O_5 (22.90 kg ha^{-1}) and K_2O (347.49 kg ha^{-1}). The experiment comprised of seven sequential cropping systems viz., T_1: Rice-maize, T_2: Rice-sorghum, T_3: Rice-chickpea, T_4: Rice-sesame, T_5: Maize-chickpea, T_6: Cotton-sesame and T_7: Rice-rice. These cropping system were laid out in completely randomized block design with three replications. Recommended fertilizer to each crop was applied at the appropriate time in the form of urea, diammonium phosphate and muriate of potash at the time of sowing and subsequent N was applied as per the package of practice. Healthy seedlings of paddy were transplanted in the paddy plots, whereas cotton and maize seeds were dibbled. At each spot two seeds were dibbled up to 4 to 5 cm deep in the seed lines of maize, cotton, sorghum and chickpea. Whereas, sesame at 2 to 3 cm deep by following the specified row and plant spacing. The details of each crop varieties, date of sowing, quantity of fertilizer applied, spacing adopted, date of harvest and plot size of each treatment are tabulated in Table 1. All agronomical packages of practices were followed to raise the crops in different cropping s. Economic yields of component crops were converted into rice-equivalent yield (REY), taking into account the prevailing market prices of different crops in the cropping sequences. The above values were computed as per the following formula given by [17].

$$\text{REY (kg ha}^{-1}\text{)} = \frac{\text{(YCC X MPCC) + yield of main crop (kg ha}^{-1}\text{)}}{\text{Price of main crop (₹ ha}^{-1}\text{)}}$$

Whereas, YCC= Yield of component crop (kg ha^{-1}) and MPCC=Market price of component crop (₹ ha^{-1}). System productivity values in terms of kg REY $ha^{-1}day^{-1}$ were worked out for the total production by means of rice equivalent yield in a crop rotation divided by year duration. Production efficiency was expressed as the ratio of system productivity in kg REY/ha to total duration of the system in days [10]. Total field duration of a cropping system expressed in percentage of 365 days was taken as the land use efficiency, LUE [16]. Land-use efficiency was obtained by taking total duration of crops in an individual crop rotation divided by 365 days. Apparent nutrient productivity was calculated by dividing the equivalent yield of the system by the total quantity of nutrient used. Cost of cultivation, gross returns and returns were calculated in terms of ₹ ha^{-1}, benefit cost ratio was calculated by dividing gross returns by cost of cultivation. Relative economic efficiency (REE) is comparative measure of economic gains over the existing system. The following method was used to calculate the REE and expressed as percentage.

$$\text{REE (\%)} = \frac{A\text{-}B}{B} \times 100$$

Whereas, A = Net returns of diversified system (₹ ha^{-1}), B = Net returns of existing system (₹ ha^{-1}). Crop profitability (₹ $ha^{-1}day^{-1}$) is calculated by dividing net returns with duration of the crop, whereas system profitability (₹ $ha^{-1}day^{-1}$) is calculated by dividing net returns with duration of the year. Employment generation of the system (man day's) was computed with number of days of employment generated throughout the year by following cropping system. Employment generation efficiency (%) was calculated by number of days of employment generated throughout the year divided by number of days in a year (365) multiplied by 100 for a cropping system. The data of each crop season were statistically analyzed separately. Fisher's method of analysis of variance was applied for analysis and interpretation of the data as given by [9]. The level of significance used in 'F' test was at p = 0.05. Critical difference values were calculated whenever 'F' was significant. In other cases, values of standard error of means have been provided [5].

RESULTS AND DISCUSSION

Rice equivalent yield and System Productivity

Among different cropping systems cotton-sesame produced significantly higher rice equivalent yield (13117 kg ha^{-1}) compared to rest of the cropping systems (Table. 2). The yield varied from 9.32 to 33.60 per cent over existing rice-rice cropping system (9816 REY kg ha^{-1}). Whereas, minimum rice equivalent yield was noticed with rice-sesame system (8342 REY kg ha^{-1}). Significantly higher system productivity was registered with maize-chickpea cropping system (35.94 REY kg ha^{-1}day^{-1}) due to its superior grain yield of both maize and chickpea also attributed to less crop duration of the system. Further it was significantly superior over rice-sesame (22.85 REY kg ha^{-1}day^{-1}), rice-sesame (24.17 REY kg ha^{-1} day^{-1}) and existing rice-rice (26.89 REY kg ha^{-1}day^{-1}) cropping systems. These results are in conformity with finding of [11] who reported that inclusion of legume during summer/*rabi* in rice based cropping system resulted in an increased in productivity and profitability. The higher rice equivalent yield indicate that the residual advantage of a legume crop on the succeeding maize besides contribution in total system productivity. In the present study, similarly, rice-maize and rice-chickpea cropping systems are ranked second and third, respectively with system productivity. This might be due to higher production potential of maize along with the good market price of chickpea and rice that yielded better grain yield than rest other cropping systems. The chickpea in maize-chickpea and rice-chickpea cropping system also markedly contributed to the system productivity, besides enhancing the productivity of succeeding crops and consequently resulted in higher crop equivalent yield and system productivity which was almost equal to the conventional rice-rice cropping system. Similar findings are also reported by [12].

Land use efficiency

Among different cropping systems rice-rice cropping system accounted for highest land use efficiency (78.36 %) and it was followed by cotton-sesame (71.23 %) cropping system (Table.3). It was mainly attributed to rice and cotton crops in respective sequences because these crops occupied the field for about 148 and 170 days, respectively than other treatments led to achieve higher land use efficiency. The lowest land use efficiency (58.08 %) was recorded in maize-chickpea cropping system indicated that it has the scope to include one more short duration crop like greengram or chickpea for soil fertility restoration. These results are in conformity with findings of [18] and [19].

Production efficiency

Significantly superior production efficiency was recorded with maize-chickpea (56.67 kg REY ha^{-1}day^{-1}) compared to other cropping systems. The next best performed cropping systems were cotton-sesame, rice-maize and rice-chickpea (50.45, 44.90 and 44.53 kg REY ha^{-1} day^{-1}, respectively). It was attributed to higher crop equivalent yield which in turn led to harness the higher production efficiency of the system. Similar findings have also been reported by [7]. In the present study production efficiency of maize-chickpea, cotton-sesame, rice-maize and rice-chickpea was 65.12, 46.99, 30.80 and 29.74 per cent, respectively higher than the prevailing rice-rice cropping system. [8] also reported that higher productivity and profitability through inclusion of vegetables and pulses in rice based cropping system.

Apparent nutrient use productivity

Maize-chickpea cropping system registered significantly higher apparent nutrient productivity (35.60 kg REY kg^{-1} nutrient applied) over other cropping systems. The next best cropping system was found to be cotton-sesame cropping system (32.79 kg REY kg^{-1} nutrient applied). These results are also in line with findings of [2]. In the present investigation, this higher apparent nutrient productivity might be due to high crop equivalent yield per unit of nutrient applied. The apparent nutrient use productivity of cotton-sesame and maize-chickpea was 100.42 and 117.60 per cent, respectively higher than the existing rice-rice cropping system (Table 3).

Effect of cropping systems on economics

Economics is the ultimate criteria for acceptance and wider adoption of any technology and, cropping system technology is also no exception to this. Among different indicators of economic efficiency in any production system, a net return has greater impact on the practical utility and acceptance of the technology by the farmers.

In the present study eeconomics of the different cropping systems showed that the higher cost of cultivation was noticed in rice-rice cropping system (₹ 63980 ha^{-1}) compared to rest of the cropping systems and it was at par with rice-maize cropping system (₹ 62219 ha^{-1}). The inclusion of rice and maize in the *rabi* under rice based cropping systems increased the total variable cost due to usage of more fertilizer and human labour engagement. These results are in line with finding of [3]. In the present study, the gross returns were higher in cotton-sesame (₹ 220813 ha^{-1}) because of higher value of produce and it was followed by maize-chickpea (₹ 203988 ha^{-1}) cropping system (Table 3). Further highest net profit (₹ 166328 ha^{-1}) was noticed with cotton-sesame cropping system and this was mainly attributed to higher gross returns and minimum cost of cultivation. These results are in conformity with the findings of [6]. In the present study, the next best performed cropping systems in terms of net returns were maize-chickpea (₹ 148803 ha^{-1}) and rice-maize (₹ 132389 ha^{-1}). The lowest profit was recorded under rice-sesame (₹ 89826 ha^{-1}) cropping system, whereas the minimum income was registered with traditional rice-rice system (₹ 103945 ha^{-1}). With regards to benefit cost ratio, it was highest in case of cotton-sesame cropping system (4.05) mainly due to higher price of cotton and sesame and less cost of production. The other best performed cropping systems are maize-chickpea (3.70) and rice-maize (3.13) cropping systems. This was mainly due to less cost of production, more yield and higher prices of chickpea and maize crops. In the present study significantly lowest benefit cost ratio was recorded with prevailing rice-rice cropping system (2.62), this was mainly attributed to higher cost of production.

Economic profitability and efficiency

Crop profitability and system profitability varied significantly among different cropping systems. During *kharif* the significantly higher crop profitability observed with cotton in cotton-sesame (₹ 827.80 ha^{-1}day^{-1}) compared to rest of the cropping systems (Table. 4). Significantly lower crop profitability was recorded with rice (₹ 404.59 ha^{-1}day $^{-1}$) in rice-sorghum cropping system. During *rabi* chickpea recorded significantly higher crop profitability in maize-chickpea cropping system (₹ 728.01 ha^{-1}day $^{-1}$) and was comparable with maize-chickpea (₹ 719.22 ha^{-1}day^{-1}) and maize in rice-maize (₹ 688.83 ha^{-1}day $^{-1}$) cropping systems. Significantly lower crop profitability was obtained with cotton in cotton-sesame (₹ 284.47 ha^{-1}day $^{-1}$) cropping system. Whereas, existing rice-rice system registered the crop profitability of ₹306.13 ha^{-1}day^{-1}.

Significantly higher system profitability was obtained with cotton-sesame (₹ 456.69 ha^{-1} day^{-1}) compared to rest of the cropping systems. The system profitability advantage varied from 12.02 to 85.56 per cent over maize-chickpea (₹ 407.68 ha^{-1}day^{-1}) and rice-sesame (₹ 246.10 ha^{-1} day^{-1}) cropping systems, respectively. Similar results were also reported by [13]. Profitability depends on the duration of crop and net returns of the system. There was positive correlation between the net returns and system profitability. Highest net returns in cotton-sesame cropping system attributed to higher system profitability.

TABLE 1: DETAILS OF CROP VARIETIES, SPACING, RECOMMENDED DOSE OF FERTILIZER, CROP MATURITY DURATION, CROPPING DURATION AND HECTARE FACTOR USED FOR THE EXPERIMENT

Sequence cropping system	Crop	Season	Varieties	Spacing (cm)	Recommended dose of fertilizers (N, P_2O_5 and K_2O kg ha^{-1})	Crop maturity duration (days)	Total cropping duration (Days)	Hectare conversion factor
Rice-maize	Rice	*Kharif*	BPT-5204	20 x 10	150:75 :75	148	253	494.07
	Maize	*Rabi*	NK-6240	60 x 20	150:75:37.5	105		833.33
Rice-sorghum	Rice	*Kharif*	BPT-5204	20 x 10	150:75 :75	148	253	494.07
	Sorghum	*Rabi*	NSH-18	45 x 15	100:75:40	105		694.44
Rice-chickpea	Rice	*Kharif*	BPT-5204	20 x 10	150:75 :75	148	241	494.07
	Chickpea	*Rabi*	JG-11	30 x 10	25:50:00	93		541.12
Rice-sesame	Rice	*Kharif*	BPT-5204	20 x 10	150:75 :75	148	238	494.07
	Sesame	*Rabi*	DSS-9	30 x 15	25:50: 25	90		566.89
Maize-chickpea	Maize	*Kharif*	NK-6240	60 x 20	150 :75:37.5	112	212	833.33
	Chickpea	*Rabi*	JG-11	30 x 10	25: 50:00	100		541.12
Cotton-sesame	Cotton	*Kharif*	AJITH-155	90 x 60	150:75:75	170	260	771.60
	Sesame	*Rabi*	DSS-9	30 x 15	25:50: 25	90		566.89
Rice-rice	Rice	*Kharif*	BPT-5204	20 x 10	150:75 :75	148	286	494.07
	Rice	*Rabi*	Gangavathi sona	20 x 10	150:75 :75	138		494.07

TABLE 2: CROP YIELD, RICE EQUIVALENT YIELD (REY), SYSTEM PRODUCTIVITY, STRAW/HAULM/STOVER/STALK YIELD AND HARVEST INDEX AS INFLUENCED BY DIFFERENT CROPPING SYSTEMS

Sequence cropping system	Crop yield (kg ha^{-1})		REY (kg ha^{-1})		REY (kg ha^{-1})	System productivity (kg REY ha^{-1}day^{-1})	Straw/haulm/stover/stalk yield (kg ha^{-1})		Harvest index (%)	
	Kharif	*Rabi*	*Kharif*	*Rabi*			*Kharif*	*Rabi*	*Kharif*	*Rabi*
Rice-maize	5329	7372	-	6031	11361	31.13	5833	8477	47.74	46.51
Rice-sorghum	5291	3809	-	3532	8823	24.17	5929	4609	47.16	45.25
Rice-chickpea	5285	1975	-	5446	10731	29.40	5931	2390	47.12	45.25
Rice-sesame	5361	615	-	2981	8342	22.85	5944	1236	47.42	33.22
Maize-chickpea	7691	2075	6292	5723	12015	32.92	8971	2511	46.16	45.25
Cotton-sesame	4288	559	10405	2712	13117	35.94	7647	1124	34.83	33.22
Rice-rice	5395	5031	-	4421	9816	26.89	5929	5986	47.64	45.66
S.Em.±	114	81	-	-	216	0.60	199	96	0.79	0.18
CD (p=0.05)	352	250	-	-	668	1.80	606	294	2.45	0.55

TABLE 3: LAND USE EFFICIENCY, PRODUCTION EFFICIENCY, APPARENT NUTRIENT USE PRODUCTIVITY AND ECONOMICS OF DIFFERENT SEQUENCE CROPPING SYSTEMS

Sequence cropping system	Land use efficiency (%)	Production efficiency (kg REY ha^{-1}day^{-1})	Apparent nutrient use productivity (kg REY kg^{-1} nutrient applied)	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C Ratio
Rice-maize	69.32	44.90	20.20	62219	194608	132389	3.13
Rice-sorghum	69.32	34.88	17.13	54165	150855	96690	2.79
Rice-chickpea	66.03	44.53	28.62	53246	181222	127976	3.40
Rice-sesame	65.21	35.05	20.85	51400	141226	89826	2.75
Maize-chickpea	58.08	56.67	35.60	55185	203988	148803	3.70
Cotton-sesame	71.23	50.45	32.79	54485	220813	166328	4.05
Rice-rice	78.36	34.32	16.36	63980	167925	103945	2.62
S.Em.±	-	0.87	0.51	-	3343	3343	0.14
CD (p=0.05)	-	2.69	1.57	-	10301	10301	0.44

TABLE 4: CROP PROFITABILITY, SYSTEM PROFITABILITY, EMPLOYMENT GENERATION (MAN DAY'S), EMPLOYMENT GENERATION EFFICIENCY AND RELATIVE ECONOMIC EFFICIENCY AS INFLUENCED BY DIFFERENT SEQUENCE CROPPING SYSTEMS

Sequence cropping systems	Crop profitability (₹ ha^{-1}day^{-1})		System profitability (₹ ha^{-1}day^{-1})	Employment generation (man day's)			Employment generation efficiency (%)	Relative economic efficiency (%)
	Kharif	*Rabi*		*Kharif*	*Rabi*	Total		
Rice-maize	405.82	688.83	362.71	122	110	232	64	27
Rice-sorghum	404.59	350.58	264.90	124	100	224	61	-7
Rice-chickpea	407.24	728.01	350.62	132	80	212	58	23
Rice-sesame	414.45	316.52	246.10	140	72	208	57	-14
Maize-chickpea	686.43	719.22	407.68	128	84	212	58	43
Cotton-sesame	827.80	284.47	455.69	184	76	260	71	60
Rice-rice	416.89	306.13	284.78	120	124	244	67	-
S.Em.±	11.42	29.12	9.15	3	3	5	3	-
CD (p=0.05)	35.30	90.28	28.22	9	8	17	9	-

Employment generation

Significantly higher employment generation (man day's) and employment generation efficiency was recorded with cotton-sesame cropping system (260 days and 71 %, respectively) and it was followed by rice-rice (244 days and 67 %). These findings are in conformity with the results of [15]. Employment generation depends on duration of the cropping system and number of crops per year.

Relative economic efficiency

Relative economic efficiency of alternate cropping systems tested against the rice-rice cropping system indicated that cotton-sesame recorded highest relative economic efficiency (60 %) compared to rest of the cropping systems. Lowest relative economic efficiency was recorded with rice-sesame cropping system (-14). This might be due to lowest net returns recorded with rice-sesame. Similar results were also reported by [2].

CONCLUSION

Based on findings of this experiment it can be concluded that under conditions of Tunga Bhadra Project area, cotton-sesame, maize-chickpea and rice-maize cropping systems proved to better in terms of production. The cotton-sesame and maize-chickpea crop sequences are more productive, profitable and remunerative as they fetched more net returns per unit area for time invested, and can be a better cropping systems in place of rice-rice for the farmers of the Tunga Bhadra Project area of Karnataka for higher profitability.

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