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Alternate system to rice (*Oryza sativa*) under Cauvery Command area of Karnataka

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ABSTRACT

A field experiment was conducted at the research farm of College of Agriculture, V.C. Farm, Mandya, Karnataka from 2017–18 to 2019–20 to study the efficient cropping system alternate to Rice (*Oryza sativa* L.) under Cauvery Command area of Karnataka for higher productivity and profitability. The experiment was laid out in Randomized Complete Block Design (RCBD) consisting of 12 crop sequences with 3 replications. Initial and final soil samples were collected and analyzed for soil *p*H (7.4), EC (0.15 dS/m), organic carbon (0.56%), N (130 kg/ha), P_2O_5 (17.2 kg/ha) and K_2O (306.6 kg/ha). The EC and Organic carbon recorded after harvest Bhendi [*Abelmoschus esculentus* (L.) Moench]-Ragi [*Eleusine coracana* (L.) Gaertn.] and marigold (*Tagetes* spp.)-Blackgram [*Vigna mungo* (L.) Hepper] sequence was on par with Rice (*Oryza sativa* L.)-Rice system. However the highest organic carbon (%) was recorded in Cowpea [*Vigna unguiculata* (L.) Walp.]-Ragi + Cowpea. The highest available soil nitrogen (363.78 kg/ha) and available soil P_2O_5 (63.66 kg/ha) was recorded in Blackgram-Groundnut (*Arachis hypogaea* L.) followed by Cowpea-Ragi + Cowpea and Marigold-Blackgram. Significantly higher available K_2O (173.88 kg/ha) was recorded in Maize (*Zea mays* L.)-Greengram [*Vigna radiata* (L.) R. Wilczek] system. Among all the cropping sequences, Bhendi grown in rainy (*kharif)* season and Ragi in summer recorded appreciable Rice equivalent yield with higher B:C ratio. The highest water productivity (20.05 kg/ha-mm) was recorded in Marigold followed by Bhendi (16.75 kg/ha-mm), Ragi (11.44 kg/ha-mm) and Maize (8.11 kg/ha-mm). However, the sequence Cowpea in *kharif* followed by Ragi + Cowpea in summer also resulted better under rice production system.

Keywords: Cropping sequence, Cropping system, Nutrient status, Productivity, Profitability

In India, the rice based cropping system is a major food production system and approximately for 70% of world's population rice is the second most important food crop next to wheat and maize. It is being cultivated in more than 100 countries in 163 million ha with production of 740.9 million tonnes. Rice is cultivated two or three times in a year in diverse environmental conditions and in various cropping systems starting with sole cropping systems under rainfed and irrigated conditions (temperate and tropical regions) to predominant monocropping in irrigated regions of tropics (Laborte *et al.* 2017). Among the rice growing countries, India ranks second in production (157.2 million tons) next to China with a productivity of 2578 kg/ha (Indiastat 2018). The best option for horizontal expansion is diversification of rice-based cropping systems with inclusion of pulses/ legumes and oilseeds in summer fallow because as they are known to improve soil organic matter content through biological nitrogen fixation, leaf shedding, root exudates and higher below ground biomass. An intensification of cropping sequence is essential in the existing farming situation. Inclusion of non- rice crop like oilseeds, pulses and vegetables are receiving more attention owing to higher price due to increased demand and changes the economics of the cropping sequences (Samant 2015 and Kalita *et al.* 2018).

Southern dry zone of Karnataka comprising 18 taluks of 5 districts, viz. Mandya, Mysore, Chamarajanagar, Hassan and Tumkur is characterized by a typical bimodal rainfall with an average rainfall of 785 mm distributed with two peaks in the months of May and October. The zone also comprises an irrigated area of 4.0 lakh ha under canal and borewell irrigations mainly with paddy to the extent of 3.0 lakh ha. There is a scope to increase the area under different potential crops in rice cropping systems. Moreover there is also single cropped paddy area to the extent of 2.65 lakh ha which can be utilized to grow different crops in early-*kharif*, late-*kharif* and early summer seasons which can intensify the cropping system with adequate agronomical interventions.

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MATERIALS AND METHODS

The experiment was planned on targeted crops to study the alternate system for rice (*Oryza sativa* L.) under Cauvery Command area of Karnataka during rainy (*kharif)* season 2018, summer 2019 and *kharif* 2019 at College of Agriculture, V.C. Farm, Mandya. The field experiment consists of 12 crop sequences laid out in RCBD design with 3 replications. The 12 cropping sequences during *kharif*-summer were Rice-Rice (T_1), Blackgram-Groundnut (T_2), Cowpea-Ragi+Cowpea (T_3), Maize-Greengram (T_4), Ragi-Cowpea (T_5), Navane-Marigold (T_6), Baragu-Sorghum (T_7), Quinoa-Maize (T_8), Amaranthus-Ragi (T_9), Bhendi-Ragi (T_{10}), Marigold-Blackgram (T_{11}) and Soybean-Green chilli (T_{12}). Soil samples were collected before and after conducting the experiment and analyzed for soil *p*H, EC, organic carbon (%) and major nutrients, viz. NPK. The initial soil has shown 130 kg/ha N, 17.2 kg/ha P_2O_5 and 306.6 kg/ha K_2O. The *kharif* crops were sown during the month of August 2018, 2019 and summer crops were sown during January 2019. The recommended dose of fertilizers was applied to the respective crops. FYM was incorporated to the soil two weeks before sowing as per the package of practice. The crops were sown as per the treatments, observations were recorded on growth parameters and yield periodically and the data was subjected to statistical analysis as suggested by Gomez and Gomez (1984).

Rice equivalent yield (REY) was calculated to compare the system performance by converting the yield of non-rice crops into equivalent rice yield on price basis. The yield obtained from *kharif* and summer crops were converted into Rice equivalent yield (REY) as:

$$REY = Yx\ (Px/Pr)$$

where Yx, yield of non-rice crops (kg/ha); Px, price of non-rice crops (₹).

Water productivity (kg/ha mm) was worked out for different crops considering grain yield of respective crops and total amount of water supplied.

Water productivity = grain yield / total amount of water supplied

Economics were worked out for different crops in terms of gross returns, net returns and B:C ratio based on prevailing market price as:

Net returns (₹/ha) = Gross returns (₹/ha) - Cost of cultivation (₹/ha)

B:C ratio = Gross returns (₹/ha) / Cost of cultivation (₹/ha)

RESULTS AND DISCUSSION

Plant height and dry weight: Different crops were tested to identify the alternate viable crops to rice during *kharif* and summer (Table 1). Among various cropping system tested, the pooled data of experiments conducted during *kharif* 2018–19 and 2019–20 showed that the higher plant height was obtained in the treatment Maize (T_4) (183.17 cm) followed by Amaranthus (T_9) (120.32 cm). Similarly, higher dry weight was obtained in (T_1) Rice (18.50 g/plant) followed by maize (16.47 g/plant).

Rice equivalent yield and water productivity: Different crops were tested to identify the viable alternate system to rice during *kharif* and summer in Cauvery Command area of Karnataka. The results of the experiment showed significant differences among the treatments with respect to Rice equivalent yield and water productivity (Table 1). The experiment results showed that significantly higher Rice equivalent yield was recorded in Bhendi (T_{10}) and Marigold (T_{11}), followed by Maize (T_4) under Rice production system compared to other crops during *kharif* 2018–19 and 2019–20. The pooled data (Fig 1) of experiments conducted during *kharif* 2018–19 and 2019–20 showed significantly higher rice equivalent yield in Bhendi (T_{10}) of 10052 kg/ha and Marigold (T_{11}) of 10028 kg/ha respectively when

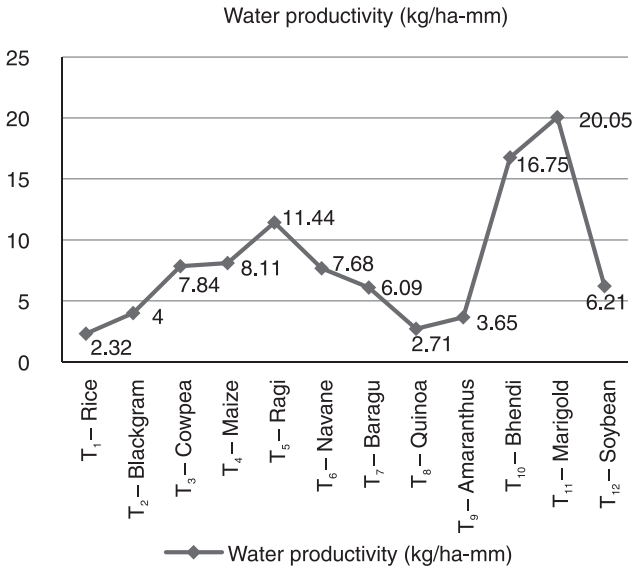

Fig 1 Water productivity (kg/ha-mm) of alternate crops under rice production system.

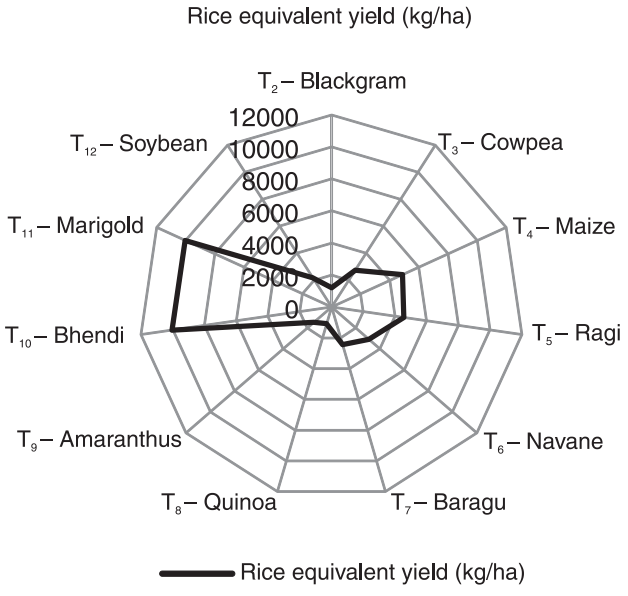

Fig 2 Rice equivalent yield (kg/ha) of alternate crops under rice production system.

Table 1 Growth, yield and water productivity (kg/ha-mm) of alternate crops under rice production system during *kharif* 2018–19 and 2019–20

Treatment	Plant height (cm)			Dry weight (g/plant)			Grain yield (kg/ha)			Rice equivalent yield (kg/ha)			Water productivity (kg/ha-mm)		
	2018–19	2019–20	Pooled mean	2018–19	2019–20	Pooled mean	2018–19	2019–20	Pooled Mean	2018–19	2019–20	Pooled mean	2018–19	2019–20	Pooled mean
T_1	77.93	134.67	106.30	17.17	19.83	18.50	4931	5278	5104	-	-	-	2.24	2.4	2.32
T_2	45.53	52.00	48.77	5.39	8.13	6.76	516	653	585	1161	1241	1201	3.87	4.14	4.00
T_3	58.13	58.17	58.15	4.98	10.37	7.68	1046	1150	1098	2616	2875	2745	7.47	8.21	7.84
T_4	166.33	200.00	183.17	13.03	19.90	16.47	4269	5465	4867	4269	5465	4867	7.11	9.11	8.11
T_5	74.47	166.67	120.57	5.39	12.95	9.17	4026	4288	4157	4429	4717	4573	11.07	11.8	11.44
T_6	82.37	108.57	95.47	5.87	10.40	8.14	1207	1249	1228	3018	3122	3070	7.55	7.8	7.68
T_7	68.73	79.80	74.27	5.53	6.93	6.23	887	1063	975	2217	2658	2438	5.54	6.64	6.09
T_8	99.70	116.53	108.12	6.25	11.85	9.05	750	693	722	1125	1040	1083	2.82	2.6	2.71
T_9	101.60	139.03	120.32	8.31	10.30	9.31	987	956	972	1480	1435	1457	3.7	3.59	3.65
T_{10}	85.67	103.20	94.44	8.93	10.52	9.73	10733	9370	10052	10733	9370	10052	17.88	15.62	16.75
T_{11}	71.47	93.03	82.25	10.77	11.70	11.24	11093	8962	10028	11093	8962	10028	22.18	17.92	20.05
T_{12}	57.00	64.37	60.69	5.70	8.67	7.19	1097	942	1020	2469	1883	2176	7.05	5.38	6.21
SEM±	8.24	6.06	NA	0.66	1.21	NA	516	214.39	324.38	506.57	221.51	315.44	NA	NA	NA
CD (P=0.05)	24.17	17.77	-	1.93	3.54	-	1514.89	628.77	951.38	1485.71	649.66	925.17			
CV %	17.32	9.57	-	14.06	17.74	-	25.4	11.12	16.52	23.60	10.77	15.01			

NA, Not analyzed statistically. Treatment details are given under Materials and Methods.

compared to all the crops. The differential productivity of cropping systems was due to the differences in yield potential of component crops (Rathore *et al.* 2022). Banjara *et al.* (2021) stated that REY was found to be significant which might be due to variation in weather and improvement in soil fertility because of legume crops inclusion in cropping sequence.

Among the different crops evaluated under rice production system, the pooled data (Fig 2) on water productivity was found highest in Marigold (20.05 kg/ha-mm) followed by Bhendi (16.75 kg/ha-mm), Ragi (11.44 kg/ha-mm) and Maize (8.11 kg/ha-mm). The less water productivity was observed in the treatment Rice (2.32 kg/ha-mm), Quinoa (2.71 kg/ha-mm) and Amaranthus (3.65 kg/ha-mm) crops in the system (Table 1). The inclusion of legume crops in sequences might have improved soil fertility which enhances the yield of rice (Banjara *et al.* 2021). There are several benefits associated with crop sequences other than the rice-rice cropping system. The cultivation of pulses or oilseed crops instead of rice resulted in the improvement of soil health, reduced the water requirement and increased water productivity (Arora *et al.* 2020).

The results of summer experiment (Table 2) conducted during 2019–20 showed significantly higher Rice equivalent yield of 7240 kg/ha in Marigold (T_6) followed by Chilli (T_{12}) 6351 kg/ha and lowest Rice equivalent yield was observed in Blackgram (T_{11}) (1029 kg/ha) and Greengram (T_4) (1107 kg/ha). The highest water productivity (18.15 kg/ha-mm) was recorded in Chilli (T_{12}) followed by Marigold (18.1 kg/ha-mm) and Ragi (11.05 kg/ha-mm) when compared to Rice (2.2 kg/ha-mm). This result might be due to higher accumulation of dry matter with less water consumption.

Economic analysis: The pooled data on economic analysis (Table 2) of the experiments conducted during *kharif* 2018–19 and 2019–20 to study the viable alternate crops under Rice production system recorded highest B:C ratio in Bhendi (T_{10}) 4.5 with 44626 ₹/ha cost of cultivation and net return of 156404 ₹/ha followed by Marigold (T_{11}) 3.56 with a cost of cultivation of 56362 ₹/ha and the net return 144188 ₹/ha over the rice crop which recorded 2.84 B:C ratio, cost of cultivation 35982 ₹/ha and net return 66108 ₹/ha, respectively. Among other crops tested, B:C ratio of 3.56 and 3.36 were recorded in Ragi and Maize respectively.

The experimental results of summer 2019–20 on economic analysis (Table 3) revealed that highest B:C ratio of 3.99 in Ragi inter cropping (T_3) with Cowpea (4:2), with a cost of cultivation of 23229 ₹/ha and the net return 69573 ₹/ha. The crops like Chilli (3.87), Ragi (3.11), Marigold (3.14) and Sorghum (3.1) recorded the B:C ratio more than Rice (2.63). Banjara *et al.* (2021) reported that legumes benefit by atmospheric N fixing, which contributes to better development of plant growth and biomass production and higher productivity of all sequences as compared to rice-wheat-fallow owing to the replacement of wheat with high yielding or high priced crops in the system along with the addition of summer crops in sequences. Intensification

Table 2 Economic analysis of alternate crops under rice production system during *kharif* 2018–19 and 2019–20

Treatment	2018–19			2019–20			Pooled data		
	Cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C	Cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C	Cost of cultivation (₹/ha)	Net return (₹/ha)	B:C
T_1	35982	62638	2.74	35982	69578	2.93	35982	66108	2.84
T_2	17930	5290	1.3	17930	6884	1.38	17930	6087	1.34
T_3	17930	34370	2.92	17930	39570	3.21	17930	36970	3.06
T_4	28943	56437	2.95	28943	80357	3.78	28943	68397	3.36
T_5	25658	62914	3.45	25658	68678	3.68	25658	65796	3.56
T_6	16809	43541	3.59	16809	45641	3.72	16809	44591	3.65
T_7	15453	28897	2.87	15453	37697	3.44	15453	33297	3.15
T_8	19227	3273	1.17	19227	1563	1.08	19227	2418	1.13
T_9	20237	9373	1.46	20237	8443	1.42	20237	8908	1.44
T_{10}	44626	170034	4.81	44626	142774	4.2	44626	156404	4.50
T_{11}	56362	165498	3.94	56362	122878	3.18	56362	144188	3.56
T_{12}	19930	29435	2.48	19930	17750	1.89	19930	6092	1.31
SEM±	NA	NA	NA	NA	NA	NA	NA	NA	NA
CD (P=0.05)	-	-	-	-	-	-	-	-	-
CV %	-	-	-	-	-	-	-	-	-

NA, Not analyzed statistically. Treatment details are given under Materials and Methods.

Table 3 Grain yield, Rice equivalent yield, water productivity (kg/ha-mm) and economic analysis of alternate crops under rice production system during summer 2019–20

Treatment	Grain yield (kg/ha)	REY (kg/ha)	Water productivity (kg/ha-mm)	Cost of cultivation (₹/ha)	Net return (₹/ha)	B:C
T_1	4835	-	2.2	36828	59872	2.63
T_2	1139	1423	4.74	17102	11373	1.67
T_3	2650	3352	9.58	23229	69573	3.99
T_4	553	1107	1.85	17929	4191	1.23
T_5	704	1759	4.4	17929	17271	1.96
T_6	7240	7240	18.1	46162	98638	3.14
T_7	2421	1816	4.54	19456	40859	3.1
T_8	3743	2808	7.02	31265	24880	1.8
T_9	4019	4421	11.05	28434	59984	3.11
T_{10}	4599	5059	8.43	28434	70984	3.49
T_{11}	556	1029	3.24	17929	2643	1.15
T_{12}	6351	6351	18.15	32828	94192	3.87
SEM±	168.92	123.91	NA	NA	NA	NA
CD (P=0.05)	495.41	363.42				
CV %	9.71	7.08				

NA, Not analyzed statistically. Treatment details are given under Materials and Methods.

of crop sequences with legumes increased yield and profitability.

Soil analysis before sowing and after harvest of crops: Soil samples were collected before the start of the experiment and after the completion of the experiment (cropping sequence). The data on initial soil analysis showed 7.4 *p*H, 0.15 EC (dS/m), 0.56% organic carbon, 130 kg/ha N, 17.2 kg/ha P_2O_5 and 306.6 kg/ha K_2O (Supplementary Table 1). The results of the final soil status after the completion of cropping sequence revealed non-significant difference in *p*H of the soil. The EC and organic carbon recorded in cropping sequence Bhendi-Ragi (T_{10}) and Marigold-Blackgram (T_{11}) is on par with Rice-Rice system. However, the highest organic carbon (%) was recorded in Cowpea-Ragi + Cowpea (T_3) sequence.

The available nitrogen and phosphorus was higher in all the treatments when compared to the initial soil status. The highest available nitrogen (363.78 kg/ha) and available P_2O_5 (63.66 kg/ha) was recorded in Blackgram-Groundnut (T_2) followed by Cowpea-Ragi + Cowpea (T_3), Marigold-Blackgram (T_{11}). Significantly higher available K_2O (173.88 kg/ha) was recorded in Maize-Greengram system (Supplementary Table 1). The conventional system of rice cultivation includes puddling to reduce percolation losses for easy seedling transplantation, to suppress weeds, etc. But the continuous adoption of this system has resulted in several negative effects on soil health (Nandan *et al.* 2021). Repeated puddling in coarse and medium textured soils has resulted in subsurface compaction and affects the cultivation of successive upland crops like wheat, by restricting the root growth and causing aeration problems. Repeated cultivation of submerged rice exposes the hidden organic matter to air and results in oxidation, thus leading to structural degradation of the soil. These results are in conformity with Hossain *et al.* (2021) and Saurabh *et al.* (2021).

Different crops listed above were tested to identify the viable crops for summer under rice cropping system. The results (Table 3) showed significantly higher Rice equivalent yield of 7240 kg/ha in Marigold (T_6) followed by Chilli (T_{12}) 6351 kg/ha. Among the different crops tested under Rice production system, the highest water productivity (18.15 kg/ha-mm) was recorded in chilli (T_{12}) followed by Marigold (18.1 kg/ha-mm) and Ragi (11.05 kg/ha-mm) when compared to Rice (2.2 kg/ha-mm). The data on economic analysis revealed highest B:C ratio of 3.99 in T_3 in inter cropping of Ragi and Cowpea (4:2) with a cost of cultivation of 23229 ₹/ha and the net return of 69573 ₹/ha. The crops Chilli (3.87), Ragi (3.11), Marigold (3.14) and Sorghum (3.1) recorded the B:C ratio more than Rice (2.63). Intensification of crop sequences with legumes increased yield and profitability. Similar results were also reported by Banjara *et al.* (2021).

Among all the cropping sequences studied, Bhendi grown in *kharif* and Ragi in summer has recorded appreciable Rice equivalent yield with higher B:C ratio. However, the sequence growing Cowpea in *kharif* followed by Ragi + Cowpea intercropping system in summer is also found to be better under rice production system with lower cost of cultivation and higher profitability. Hence, these crops can be grown alternate to rice in Cauvery Command area when there is abnormal rain fall or scarcity of water. Alternative viable cropping system can effectively be diversified with inclusion of other crops like Cowpea,

Bhendi, Marigold during *kharif* and Ragi + Cowpea, Ragi, Maize and Blackgram during summer and are alternative viable crops for Rice in enhancing productivity and economical point of view.

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