Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 6 Special issue [3] 2017: 252-257

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.533
Universal Impact Factor 0.9804
NAAS Rating 4.95

FULL LENGTH ARTICLE **OPEN ACCESS**

Studies on Soil Nutrient Balance in Alternate Cropping Systems to Rice-Rice (*Oryza sativa* L.) in Tunga Bhadra Project Area

Shridhara B. Nagoli., Basavanneppa. M. A., Sawargaonkar, G.L., Biradar. D. P., Biradar. S.A. And Tevari, P.
University of Agricultural sciences, Raichur-584102, Karnataka
University of Agricultural sciences, Dharwad-580005, Karnataka
International Crop Research Institute for Semi-arid Tropics, Hyderabad
Email: snagoli4858@gmail.com and bma_68@gmail.com

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 "Studies on the economic feasibility of alternate sequential copping systems to rice-rice (Oryza sativa L.) system in Tunga Bhadra Project 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 treatments were laid out in completely randomized block design with three replications. Data on yield of each crop was recorded and statistically analyzed. During the experiment there were significant variations among the sequential cropping systems. Significantly higher rice equivalent yield (REY) was recorded in cotton-sesame cropping system (13117 kg ha^{-1}) compared to rest of the cropping systems. Significantly higher system productivity was recorded with maize-chickpea (35.94 REY kg ha^{-1} day^{-1}) cropping system and it was significantly superior over existing rice-rice (26.89 REY kg $ha^{-1}day^{-1}$) cropping systems. Net gain of nitrogen was highest after the harvest of chickpea (54.01 kg ha^{-1}) in maize-chickpea cropping system and highest net loss of nitrogen after harvest of rice-rice cropping system (-43.9 kg ha^{-1}). Net gain of phosphorus was higher after the harvest of rice-sesame (10.25 kg ha^{-1}) cropping system. Whereas, highest net loss of phosphorus was noticed after the harvest of sorghum (-43.06 kg ha^{-1}) in rice-sorghum cropping system. Potassium loss was not observed under different cropping systems. Highest net gain of potassium was recorded after harvest of maize-chickpea (78.23 kg ha^{-1}) cropping system. The rice-chickpea and maize-chickpea crop sequences are more productive and sustainable as they improve fertility status of soil when compared to other cropping sequences and can be a better option for the farmers of the Tunga Bhadra Project area, Karnataka.

Key words: *Alternate sequential cropping system, Nutrient uptake, Rice equivalent yield, Soil fertility, System productivity.*

Received 11.08.2017 Revised 19.08.2017 Accepted 29.08. 2017

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, card board and as a litter in poultry keeping. Besides, rice straw is also used to feed cattle. Rice has been cultivated in four major ecosystems in India *viz*., irrigated, rainfed lowland, rainfed upland and flood prone system. More than half of rice growing area (55%) is under rainfed ecosystem. 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 [2].

The system of rice cultivation is most water consuming and utilizes about 60 per cent of total available irrigation water [1]. Traditional low land rice grown with continuous flooding in Asia has relatively required high water input. Since, the rice is cultivated under continuously flooded ecosystem and it is associated with sequestration of N in resistant lignin compounds formed from the large amounts of retained crop residues. If this is the case, then perhaps there is an important role for rice rotations that include low land and upland crops, such as cereals and grain legumes, to break this sequestration of N [10]. Constraints like high water requirement during summer season, and delay in rice planting due to long duration of summer grain legumes, however, restrict the integration of legumes in cereal–cereal systems on a large-scale. Diversification and intensification of rice-based or alternate cropping system for paddy-paddy to increase productivity per unit resource is very pertinent. Crop diversification shows lot of promises in alleviating these problems 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 [3]. In this context, efforts are being made to promote diversification of rice based cropping sequence or development of an alternate cropping systems to paddy-paddy in our country as well as TBP 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.

MATERIAL AND METHODS

A field experiment was conducted at farmer's field near Agriculture Research Station, Siruguppa ($76^0.54''$ E Longitude, $15^0.38''$ N Latitude), Karnataka to Studies on Economic Feasibility of Alternate Sequential Cropping Systems to Rice-rice (*Oryza sativa* L.) in Tunga Bhadra Project area. During *kharif-rabi* 2014-15. The soil of the experimental site was medium black belong to the order vertisol. The soil has a pH of 8.01, EC 0.54 (dS m^{-1}) available N 240.80 kg ha^{-1}, available P_2O_5 22.90 kg ha^{-1} and available K_2O 347.49 kg ha^{-1}. Seven sequential cropping systems as treatments in three replication with randomized block design was carried out. Treatment details are five rice based cropping systems viz., rice-maize, rice-sorghum, rice-chickpea, rice-sesame and rice-rice. Two non rice based cropping systems viz., maize-chickpea and cotton-sesame. All the crops under the above seven rice-based cropping sequences were chosen on the basis of their prevalence in the region. The rice–rice system is the major cropping sequence while the other crops, viz., sorghum, maize, sesame, cotton and chickpea are also taken by the farmers after harvesting of rice. The fitness of these crops in rice-based cropping system in the region is situation specific and also on the basis of choice and need of the farmers. Thus, there were seven rice-based cropping sequences formulated in the present study. However, accordingly farmer were agreed upon to conduct participatory on-farm trials for assessing productivity, profitability, and sustainability of these seven crop sequences in the system. Recommended dose of N, P and K (150:75:75 kg N, P_2O_5 K_2O ha^{-1}) were applied to the soil in the form of urea, di ammonium phosphate and muriate of potash to all the crops at the time of sowing and subsequent N applications were done by following 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, chickpea whereas sesame at 2 to 3 cm deep by following the specified row and plant spacing. The details of date of sowing, date of harvest, crop variety, plot size of each treatment, spacing adopted, amount of N applied in different treatments and total quantity during *kharif* and *rabi* is tabulated in Table 1. All agronomical packages of practices were followed to raise the crops in different cropping sequences.

Yield and yield parameters of rice and other crops in the cropping system viz., grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), harvest index (%), rice equivalent yield (kg ha^{-1}), system productivity (kg REY $ha^{-1} day^{-1}$) were recorded. 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 [15].

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

Whereas, YCC= Yield of component crop (kg ha^{-1}), 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 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 total duration of crop in that rotation.

Available nitrogen was determined by modified alkaline potassium permanganate method as described by [14]. Available phosphorus was determined by Olsen's method [8] using Systronics UV visible Spectrophotometer (Model: 117). Available potassium was extracted with neutral ammonium acetate (pH 7.0) and the content of potassium in the solution was estimated by Systronics Flame Photometer (Model: 128) [6]. Nitrogen, phosphorus and potassium content in composite plant sample of rice at harvest was estimated by modified micro-kjeldhal method, vanadomolybdate yellow colour method and flame photometer method, respectively as outlined by [5]. Nutrient uptake was calculated by using the following formula.

Nutrient content (%)

Nutrient uptake ($N/P_2O_5/K_2O$ kg ha^{-1}) = $\frac{nutrient\ content\ (percent)}{100}$ ----------------------------x dry weight (kg ha^{-1})

100

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 [4].

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 (9816 REY kg ha^{-1}) cropping systems. Whereas, minimum rice equivalent yield was noticed with rice-sesame (8342 REY kg ha^{-1}) system. Significantly higher system productivity was recorded with maize-chickpea (35.94 REY kg $ha^{-1}day^{-1}$) cropping system and 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 [14], 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. Similarly, rice-maize and rice-chickpea cropping systems which 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 results are also reported by [15].

Nutrient balance

Nutrient balance is an important parameter in deciding the sustainability in soil fertility management. Net gain of nitrogen and phosphorus was not recorded during *kharif* under different cropping systems (Table 3). Maximum loss of nitrogen was observed after the harvest of rice in rice-chickpea (-35.91 kg ha^{-1}) and least loss of nitrogen was recorded in maize (-6.02 kg ha^{-1}) under maize-chickpea cropping system. Maximum net loss of phosphorus was observed after the harvest of rice in rice-sorghum (-52.89 kg ha^{-1}). Net loss of potassium was higher after the harvest of cotton (-5.69 kg ha^{-1}) in cotton-sesame cropping system. Net gain of potassium was maximum after the harvest of maize (67.96 kg ha^{-1}) in maize-chickpea cropping system.

Net gain of nitrogen was highest in *rabi* after the harvest of chickpea (54.01 kg ha^{-1}) in maize-chickpea cropping system (Table 4). These results were also in line with findings of [13] who reported that the crop sequences like rice-rice-cowpea and rice-rice-groundnut showed positive balance of nitrogen in soil. In the present study highest net loss of nitrogen after harvest of rice was recorded during *rabi* in rice-rice cropping system (-43.9 kg ha^{-1}) and minimum net loss of nitrogen was registered with rice-sesame (-2.86 kg ha^{-1}) cropping system. Net gain of phosphorus was higher after the harvest of sesame in (10.25 kg ha^{-1}) rice-sesame cropping system. Whereas, highest net loss of phosphorus was noticed after the harvest of sorghum (-43.06 kg ha^{-1}) in rice-sorghum cropping system. But, during *rabi* potassium loss was not observed under different cropping systems. Highest net gain of potassium was recorded after harvest of maize (78.23 kg ha^{-1}) in maize-chickpea cropping system and minimum gain of nitrogen was observed in rice-sesame cropping system (16.89 kg ha^{-1}). Similar results were also reported by [7].

CONCLUSION

Based on findings of this experiment it can be concluded that under conditions of Tunga Bhadra Project area, rice-chickpea and maize-chickpea cropping systems proved to better in terms of soil fertility (N, P2O5, K20 and Organic carbon) status of soil. Hence these cropping systems were found to be alternate cropping systems to existing rice-rice system.

ACKNOWLEDGEMENT

The authors wish to acknowledge the UAS, Raichur and ARS, Siruguppa for providing good facilities. We also appreciate greatly the financial support by the International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patencheru, for carrying out this study.

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TABLE 1: DETAILS OF CROP, SEASON, CULTIVAR SPACING, RECOMMENDED DOSE OF FERTILIZER, CROPPING DURATION AND HECTARE FACTOR USED OF THE EXPERIMENT

Sequence cropping system	Crop	Season	Cultivar	Spacing (cm)	Recommended dose of fertilizers (N, P_2O_5, K_2O kg ha^{-1})	Maturity duration (days)	Total cropping duration (Days)	Hectare 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	90		541.12
Cotton-sesame	Cotton	*Kharif*	Ajeet-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*	GNV-05-01	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 ($kg\ ha^{-1}$)		Total 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: NUTRIENT BUDGETING AFTER HARVEST OF *KHARIF* CROPS AS INFLUENCED BY DIFFERENT CROPPING SYSTEMS

Treatment	Applied NPK ($kg\ ha^{-1}$) (2)			Initial available NPK in soil + added NPK (1*+2)=3			NPK uptake by crop ($kg\ ha^{-1}$) (4)			Estimated balance ($kg\ ha^{-1}$) (3-4)=5			Actual balance / Available nutrient ($kg\ ha^{-1}$) (6)			Net gain (+) or loss (-) (6-5)		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
T_1	150	75	75	390.8	97.95	422.49	130.6	23.4	128.4	260.19	74.51	294.12	224.51	22.00	335.83	-35.68	-52.51	41.72
T_2	150	75	75	390.8	97.95	422.49	130.2	23.6	129.0	260.65	74.39	293.46	225.63	21.50	334.50	-35.02	-52.89	41.04
T_3	150	75	75	390.8	97.95	422.49	129.0	23.6	129.0	261.82	74.40	293.51	225.91	21.80	332.83	-35.91	-52.60	39.32
T_4	150	75	75	390.8	97.95	422.49	131.1	23.7	130.0	259.66	74.21	292.48	226.12	22.51	333.67	-33.54	-51.70	41.19
T_5	150	75	37.5	390.8	97.95	384.99	183.3	38.3	150.0	207.53	59.63	235.04	201.51	24.89	303.00	-6.02	-34.74	67.96
T_6	150	75	75	390.8	97.95	422.49	143.2	26.3	132.5	247.59	71.69	290.02	212.51	28.50	284.33	-35.08	-43.19	-5.69
T_7	150	75	75	390.8	97.95	422.49	132.5	23.8	130.2	258.31	74.17	292.26	223.50	22.20	336.50	-34.81	-51.97	44.24
S.Em.±							3.15	0.6	3.02				1.42	1.23	1.20			
CD (p=0.05)							9.75	1.8	9.3				4.61	3.80	3.80			

Note: * Initial NPK ($kg\ ha^{-1}$): 240.80 kg N, 22.95 kg P_2O_5, 347.49 kg K_2O **(1)**

TABLE 4: NUTRIENT BUDGETING AFTER HARVEST OF *RABI* CROPS AS INFLUENCED BY DIFFERENT CROPPING SYSTEMS

Treatment	Applied NPK ($kg\ ha^{-1}$) (2)			Initial available NPK in soil + added NPK ($kg\ ha^{-1}$) (1*+2)=3			NPK uptake by crop ($kg\ ha^{-1}$) (4)			Estimated balance ($kg\ ha^{-1}$) (3-4)=5			Actual balance / Available nutrient ($kg\ ha^{-1}$) (6)			Net gain (+) or loss (-) (6-5)		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
T_1	150	75	37.5	374.50	97.00	373.33	180.7	33.3	145.6	193.82	63.72	227.73	182.51	26.86	302.11	-11.31	-36.86	74.38
T_2	100	75	40	325.60	96.50	374.50	134.7	25.3	98.5	190.90	71.24	276.00	183.22	28.18	320.42	-7.68	-43.06	44.42
T_3	25	50	0	250.90	71.80	332.83	75.3	28.4	58.5	175.60	43.43	274.33	210.21	34.22	322.81	34.61	-9.21	48.48
T_4	50	25	25	276.10	47.51	358.67	58.3	25.5	47.7	217.81	22.01	310.93	204.52	32.26	327.82	-13.29	10.25	16.89

T_5	25	50	0	226.50	74.89	303.00	72.3	29.5	59.6	154.20	45.39	243.38	208.21	34.20	321.61	54.01	-11.18	78.23
T_6	50	25	25	262.50	53.50	309.33	55.6	25.6	44.6	206.94	27.90	264.71	204.52	32.35	328.33	-2.42	4.45	63.62
T_7	150	75	75	373.50	97.20	411.50	128.1	29.7	122.3	245.40	67.46	289.21	201.50	24.21	330.10	-43.90	-43.25	40.89
S.Em.±							3.38	0.8	2.5				0.60	0.60	0.90			
CD P=0.05)							10.42	2.5	7.8				1.90	1.90	3.00			

Note: *Kharif* season available soil nutrient status (6) is considered as *rabi* season initial soil nutrient (1) status Table 3.

CITATION OF THIS ARTICLE

Shridhara B. Nagoli., Basavanneppa. M. A., Sawargaonkar, G.L., Biradar. D. P., Biradar. S.A. And Tevari, P.Studies on Soil Nutrient Balance in Alternate Cropping Systems to Rice-Rice (*Oryza sativa* L.) in Tunga Bhadra Project Area. Bull. Env. Pharmacol. Life Sci., Vol 6 Special issue [3] 2017: 252-257

