International Journal of Agricultural Sciences
Volume **10** | Issue 1| January, 2014 | 124-129

RESEARCH PAPER

Intensification and diversification of rice (*Oryza sativa*) based cropping systems for productivity, profitability and water expense efficiency in Jharkhand

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Abstract : A field experiment was conducted at BAU, Kanke, Ranchi under irrigated medium land condition in 2008-09, 2009-10 and 2010-11 to evaluate the production potential, nutrient uptake, water expense efficiency and economics of seven rice based cropping systems. Seven cropping systems *viz*., rice-wheat, rice-mustard-green gram, rice-rajma-green gram, rice-potato-green gram, rice – wheat + mustard (5:1)-green gram, rice-wheat+ rajma (5:1)-green gram, and rice-potato + wheat (1:1)-green gram were evaluated in this study. Among the cropping systems, rice-potato + wheat (1:1)-green gram recorded highest rice equivalent yield (215.81 q/ha), system productivity (59.13 kg rice/ha/day), water expense efficiency (35.74 kg/ha/mm) and land use efficiency (95.89%) as compared to other cropping systems. Crop sequences with potato as *Rabi* crop resulted in significantly higher N, P and K uptake. The use of resources and their efficiencies were higher *i.e.* economic analysis revealed that the maximum net profit (Rs. 120602), benefit: cost ratio (1.26) and monetary efficiency (305.41 '/ha/day) were recorded in rice- potato + wheat (1:1)-green gram crop sequence closely followed by rice – potato –green gram which were significantly superior over other cropping system. Hence, rice- potato + wheat (1:1)-green gram and rice-potato-green gram were found to be the most productive, resource- use efficient and remunerative cropping system under irrigated conditions and can be followed in place of rice-wheat systems for higher profitability.

Key Words : Resource- use efficiency, Rice-equivalent yield, Cropping system, System productivity, Net returns

View Point Article : Mall, Uday Shanker, Manjhi, R.P. and Thakur, R. (2014). Intensification and diversification of rice (*Oryza sativa*) based cropping systems for productivity, profitability and water expense efficiency in Jharkhand. *Internat. J. agric. Sci.*, **10** (1): 124-129.

Article History : Received : 18.03.2013**; Revised :** 30.09.2013**; Accepted :** 25.10.2013

INTRODUCTION

Rice-fallow cropping systems are prevalent in the eastern India. The prevailing practice of mono cropping of rice and leaving the field fallow after harvest of the crop proves uneconomical. Utilization of fallow lands is likely to generate substantial income and employment opportunities for the millions of small landholders in the region. There is an increasing stress to augment agricultural production from these lands to meet the growing food demand. Since there is little scope to meet the additional as well as balance food requirement by horizontal expansion of land, the only way is to increase cropping intensity by adopting suitable sequential cropping. As rice is synonymous with life of the rural population of eastern India, 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. Hence, choice of the component crops needs to be suitably maneuvered to harvest the synergism among them towards efficient utilization of resource-base and to increase overall productivity (Anderson, 2005). Crop diversification in India is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops as it offers a wider choice in crop production in a given area to expand production related activities and also to lessen risk. However, in areas of shrinking resource base of land, water and energy, diversification of rice-based system to increase productivity

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per unit resource is very pertinent. As resource- use efficiency as an important aspect for considering the suitability of a cropping system (Yadav, 2002). So, diversification has been envisaged as a new strategy for enhancing and stabilizing productivity, making Indian agriculture competitive and increasing net farm income and economic security toward achieving the sustainable agricultural development. Keeping this in view, the present investigation was undertaken to select productive, resource use efficient and remunerative rice based cropping system for irrigated ecosystem of Jharkhand.

MATERIAL AND METHODS

Field experiments were undertaken at Agronomy Research farm of the Birsa Agricultural University (BAU) at Kanke, Ranchi under irrigated medium-land condition during 2008-09, 2009-10 and 2010-11. The soil (*Alfisol*) of the experimental site is poor in fertility with acidic in reaction (pH 6.0), sandy-clay-loam texture, low in organic carbon (0.38%), available nitrogen (225.0 kg/ha), available phosphorus (20.0 kg/ha), available potassium (115.0 kg/ha), available sulphur (13.5 kg/ha) and available zinc (0.650 ppm). The experiment was laid out in randomized block design with three replications on a fixed site. The seven rice-based cropping systems *viz.*, rice-wheat, rice-mustard-green gram, rice - rajma - green gram, rice – potato - green gram, rice - wheat+mustard (5:1) -green gram, rice - wheat + rajma (5:1)-green gram and rice - potato + wheat (1:1)-green gram were evaluated for their production potential, soil data, nutrient uptake, resource use efficiency and economics. All the crops were grown successfully with recommended practices under irrigated conditions (Table 1). In rainy season (*Kharif*) rice was sown in the last week of June and after harvest in the last week of October, the subsequent crops were sown in *Rabi* season at optimum sowing time recommended for the region except in case of intercropping of wheat in potato sowing was done late (at 25 DAS) at the time of earthing up. In summer season, green gram was plucked three times to harvest its yield potential and the remains were incorporated into the soil. The crops were irrigated optimally as and when required. The grain and straw samples of crops taken at harvest stage were dried, ground , digested and analyzed for total N, P and K uptake by crop. The data were subjected to statistical analysis as prescribed by Gomez and Gomez (1984) and significant highest order interaction effects are presented and discussed in this paper. To compare the crop sequences, the yield of all crops were converted to rice-equivalent grain yield (REGY) on prevailing market price of produce by using following formula :

$$\text{Rice equivalent yield (q/ha)} = \text{Yield of } \textit{Kharif} \text{ crop (q/ha)} + \frac{\text{Yield of } \textit{Rabi} \text{ crop (q/ha) x Price of that crop (Rs./q)}}{\text{Price of rice crop (Rs./P)}} + \frac{\text{Yield of summer crop (q/ha) x Price of that crop (Rs./q)}}{\text{Price of rice crop (Rs./P)}}$$

System productivity was calculated by adding the rice-equivalent grain yield of each component crops. Production efficiency values in terms of kg REGY/ha/day was worked out by dividing the total production of a sequence by total duration of crops in that sequence (Tomar and Tiwari, 1990). Land use efficiency (LUE) was obtained by taking the total duration of crops in individual cropping system divided by 365 days. Net returns were the difference between the gross return of a system and total cost of cultivation of the component crops. The monetary efficiency values in terms of '/ha/day were calculated by net returns of a sequence divided by total duration of the crop in that sequence. The benefit: cost ratios for different cropping sequences were calculated by dividing the net returns by the cost of cultivation in a system.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Productivity of *Kharif* crops:

Rice-potato-green gram system produced higher grain and straw yield of rice (Table 1) which may be attributed to difference in foraging area of nutrients by growing potato during *Rabi* and the beneficial effect of legumes grown in summer season (Quayyam and Maniruzzaman, 1996). Rice - wheat system produced lowest rice yield of 33.60 q/ha. As keeping the land fallow improves compaction, reduces pore space and aeration and increase the temperature of the soil profile. This might have deteriorated the biological activities of soil and ultimately reduced the yield of rice. Rajma, being a shy nodulating crop, might not have expressed the desired advantage of legumes in the systems.

Productivity of *Rabi* crops:

Growth and yield of the component crops varied with the systems. In general, lower yield of *Rabi* season crops were obtained in 2010-11 as compared to 2008-09 and 2009-10 in all the sequences (Table 1). Among the crop sequences potato grown as sole as well as intercropped with wheat in winter season out yielded all the other crops during both the years. Among grain crops, wheat yield was considerably higher than mustard and Rajma. Yield of Rajma and mustard was lower during three years. Impaired soil structure, poor aeration, excess moisture retention for extended periods in the plough layer due to puddling and continuous submergence of rice might have resulted in poor crop stand, restricted root growth and yield of *Rabi* pulse crop like rajma (Prasadini *et al*., 1993) and oilseed crop, mustard. Sole rajma performed better than its intercrop as wheat + rajma (5:1) because of more number of irrigation in wheat suppressed the performance (growth and yield) of

Table 1: Yield of *Kharif*, *Rabi* and summer crops of different rice based cropping system

Treatments	Yield (q/ha) *Kharif*				*Rabi*				Summer			
	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean
Rice - Wheat	37.06	37.21	26.53	33.60	36.87	40.30	30.51	35.89				
Rice - Mustard - Green Gram	36.24	36.67	30.00	34.30	10.30	12.02	9.40	10.57	7.13	7.30	6.42	6.95
Rice - Rajma - Green Gram	36.71	38.33	30.53	35.19	12.53	12.73	12.10	12.45	7.80	7.87	6.97	7.55
Rice - Potato - Green Gram	39.74	42.50	33.20	38.48	246.46	248.46	182.82	225.91	10.33	10.66	8.49	9.83
Rice - Wheat + Mustard (5:1) - Green Gram	36.47	36.50	30.53	34.50	23.93 (3.89)	32.6 (4.10)	22.93 (3.54)	26.49 (3.84)	6.43	7.07	6.21	6.57
Rice - Wheat + Rajma (5:1) - Green Gram	37.52	37.71	30.80	35.34	25.55 (4.39)	34.30 (4.50)	24.79 (4.10)	28.21 (4.33)	6.50	6.67	6.26	6.48
Rice - Potato + Wheat (1:1) - Green Gram	38.22	41.83	34.00	38.02	189.88 (18.79)	230.28 (19.60)	195.97 (17.07)	205.38 (18.49)	9.43	9.59	8.79	9.27
S.E.±	2.42	1.72	1.84	1.99	-	-	-	-	0.45	0.71	0.25	0.47
C.D. (P=0.05)	7.43	5.27	5.64	6.11	-	-	-	-	1.39	2.19	0.78	1.45
CV%	11.19	7.68	10.31	9.73	-	-	-	-	11.52	17.60	7.12	12.08

Rajma while it did better in sole cropping where less irrigation was applied. On the other hand, sole mustard produced lowest yield than wheat + mustard (5:1) intercropping. It might be due to the fact that nutrients supplied in wheat caused better harvest of wheat as well as the intercrop, mustard.

Productivity of summer crops:

Among the seven cropping sequences, green gram grown as summer crop performed better when grown after sole potato followed by rice-potato + wheat (1:1)-green gram cropping sequence (Table 1). This was mainly due to timely sowing of green gram after sole potato that provided favorable weather conditions for initial growth and development. The other crops like wheat, rajma and mustard vacated the field 20-25 days later resulting in poorer grain yield. This variation in the yield of crops might be attributed to the biological and environmental complexities and interaction in the cropping systems (Francis, 1989).

System productivity:

The results revealed that there is sufficient scope to replace rice-wheat cropping system with other cropping systems without any decline in economic yield rather it improved substantially. The system productivity in terms of rice-equivalent grain yield (REGY) of rice – potato + wheat (1:1) – green gram was highest (230.3 q/ha in 2008-09, 216.07 q/ha in 2009-10 and 201.04 q/ha in 2010-11) followed by that of rice – potato – green gram (245.31 q/ha in 2008-09, 204.68 in 2009-10 and 170.05 q/ha in 2010-11) as against 94.99, 88.12 and 64.66 q/ha/annum of rice equivalent yield in 2008-09, 2009-10 and 2010-11 in rice-wheat system (Table 2). The winter crops mostly governed the REGY of the systems, because rice was the base crop and contribution of summer crops was only marginal. The higher production potential of potato and better market price of potato were instrumental for attaining higher REGY, besides, the bonus yield of wheat in potato + wheat (1:1) enhanced REGY of the system. These results corroborate with that of Khaurb *et al.* (2003). Intensification of rice - wheat system by inclusion of green gram grown in summer also intensified the system to add yield and consequently resulted in significantly higher REGY than that of rice - wheat sequence. Soni and Kaur (1984) were also of the opinion that addition of third crop as legume in the sequence resulted in higher yield and profitability. These results are in close conformity with the results of earlier workers Padhi (1993); Singh *et al*. (1996) and Sharma *et al*. (2004). But, wheat substituted by mustard or wheat + mustard (5:1) resulted in very poor performance of the system. It was apparent that poor yield of the mustard was responsible for lower REGY than rice - wheat sequence during three years.

Table 2 : Rice Equivalent yield (q/ha) and System Productivity (kg rice/ha/day) of different rice based cropping systems

Treatments	Rice equivalent Yield (q/ha)				System productivity (kg rice/ha/day)			
	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean
Rice - Wheat	94.99	88.12	64.66	82.59	26.03	24.14	17.72	22.63
Rice - Mustard - Green Gram	86.06	84.76	70.28	80.37	23.58	23.22	19.25	22.02
Rice - Rajma - Green Gram	103.73	108.41	98.82	103.65	28.42	29.70	27.07	28.40
Rice - Potato - Green Gram	245.31	204.68	170.05	206.68	67.21	56.08	46.59	56.62
Rice - Wheat + Mustard (5:1) - Green Gram	103.58	107.58	86.50	99.22	28.38	29.47	23.70	27.18
Rice - Wheat + Rajma (5:1) - Green Gram	111.94	117.26	97.41	108.87	30.67	32.13	26.69	29.83
Rice - Potato + Wheat (1:1) - Green Gram	230.33	216.07	201.04	215.81	63.10	59.20	55.08	59.13
S.E.±	4.85	3.32	2.59	3.58	2.16	1.96	2.08	2.07
C.D. (P=0.05)	14.88	10.18	7.94	11.00	6.63	6.01	6.38	6.34
CV%	6.02	4.33	3.97	4.77	9.79	9.33	11.65	10.26

Table 3: Nutrient uptake of different rice based cropping system

Treatments	Nutrient uptake (kg/ha)															
	Nitrogen (N)				Phosphorus (P)				Potassium (K)				Total NPK			
	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean
Rice - Wheat	167.05	172.95	146.90	162.30	30.79	34.54	27.96	31.09	120.23	165.16	143.35	142.91	318.07	372.66	318.21	336.31
Rice - Mustard - Green Gram	150.03	184.66	150.20	161.63	20.50	36.05	21.74	26.10	76.53	152.95	114.12	114.53	247.05	373.65	286.06	302.26
Rice - Rajma - Green Gram	158.77	182.20	140.94	160.64	25.08	32.11	22.48	26.56	83.41	142.02	88.43	104.62	267.27	356.33	251.86	291.82
Rice - Potato - Green Gram	182.97	286.13	159.45	209.51	63.54	68.54	42.05	58.18	66.48	254.84	152.06	157.79	313.38	609.50	353.56	425.48
Rice - Wheat + Mustard (5:1) - Green Gram	175.12	214.29	181.67	190.36	27.68	40.26	28.61	32.18	104.94	190.51	146.04	147.16	307.74	445.07	356.32	369.71
Rice - Wheat + Rajma (5:1) - Green Gram	179.65	217.57	184.71	193.98	29.78	39.65	31.80	33.74	105.79	194.14	159.46	153.13	315.23	451.35	375.97	380.85
Rice - Potato + Wheat (1:1) - Green Gram	204.26	298.88	191.62	231.59	63.33	80.53	51.81	65.22	91.67	287.38	199.20	192.75	359.26	666.79	442.63	489.56
S.E.±	8.37	9.30	5.10	7.59	2.51	2.01	1.99	2.17	6.10	6.37	6.40	6.29	16.02	11.83	12.13	13.32
C.D. (P=0.05)	25.68	28.54	15.67	23.29	7.71	6.18	6.10	6.66	18.71	19.57	19.66	19.31	49.17	36.31	37.23	40.90
CV%	8.32	7.23	5.35	6.97	11.65	7.36	10.62	9.88	11.37	5.57	7.73	8.22	9.11	4.37	6.16	6.55

Nutrient uptake :

Among the different cropping sequences, rice – potato + wheat (1:1) - green gram registered the highest N, P, K uptake followed by rice – potato - green gram and it remained superior than rest of the sequences. Potato is heavy feeder of nutrients so, inclusion of potato as *Rabi* crop improved the uptake of N, P and K as compared to other crop sequences (Table 3). This result is in conformity with the findings of Sharma *et al.* (2004). The intercropping of mustard and rajma with wheat resulted in higher N, P and K uptake than sequences having sole crop of mustard and rajma and rice – wheat system due to higher removal of nutrients in intercropping system. Crop sequences *viz.*, rice – wheat, rice – rajma – green gram and rice - mustard – green gram showed comparatively similar N, P and K uptake due to lower production of oilseeds and pulses in cropping sequences resulting in lower nutrient uptake (Table 3).

Resource-use efficiency:

Land use efficiency (LUE) of all seven cropping sequences reveled that the highest land use efficiency was observed in rice - potato + wheat (1:1) - green gram (95.89%). Other crop sequences having 300 per cent cropping intensity showed LUE in the range of 77.63% to 89.04% (Table 4). As rice is the common *Kharif* crop in all the systems and summer crops also having similar duration, the LUE was governed mostly by duration of *Rabi* crops. Potato + wheat intercropping occupied the field for a maximum period of 325 days and hence, the LUE of the systems having potato + wheat was maximum. Intensification of rice based cropping sequence by growing summer green gram recorded markedly higher land use efficiency than crop sequences without summer crops *viz.*, rice-wheat sequence (70.78%).

System productivity refers to per day productivity of entire cropping system under a particular treatment. Thus, productions depend on the quantum of total production as well as duration of total crop period under a particular treatment. The rice – potato + wheat (1:1) – green gram had the highest production efficiency (59.13 kg rice/ha/day) followed by rice – potato – green gram (56.62 kg rice/ha/day) and these two sequences had significantly higher production efficiency than other sequences (Table 4). Potato is a short duration, labour intensive crop which when intercropped with wheat produced the highest rice equivalent grain yield of 215.81 q/ha amongst all the *Rabi* crops resulting in the highest production efficiency. In general, inclusion of green gram in summer season improved the production efficiency over crop sequence having 200% cropping intensity (rice-wheat).

Economics:

Among all the system, rice was the common *Kharif* crop and summer crop was also common so, economic parameters were mostly governed by the *Rabi* crops. The highest cost of cultivation (Rs. 89536/ha/annum) was incurred on rice-potato+wheat (1:1)-green gram closely followed by rice-potato-green gram (Rs. 87052/ha/annum) (Table 4). The inclusion of potato in the cropping system increased the total variable cost due to more seed rate, fertilization and human labour requirement. The gross returns were also higher in these systems because of higher value of produce. The rice-potato+ wheat (1:1)-green gram fetched a gross return of Rs. 201010/ ha/ annum followed by rice-potato-wheat cropping system with a gross return of Rs. 188376/ha/annum were at par to each other but significantly higher gross return when compared with that of other cropping systems. The net profitability was highest in rice – potato+ wheat (1:1) – green gram (Rs. 120602/ha), being at par with rice– potato- green gram (Rs. 110110/ha) but significantly higher over other cropping systems. The inclusion of potato in crop sequences can boost the profitability of the sequences. These results confirm the findings of Samui *et al.* (2004). In general, cropping sequences of 300% cropping intensity gave significantly higher net return than rice-wheat (Rs. 43660/ha) except rice

Table 4: Indices of resource - use efficiency and economics of different rice based cropping systems (pooled data of 3 years)

Treatments	Water expense efficiency (kg/ha/mm)	Land use efficiency (%)	Total variable cost (`/ha)	Gross return (`/ha)	Net return (`/ha)	B:C ratio	monetary efficiency (`/ha/day)
Rice - Wheat	24.14	70.78	45481	84948	43660	0.91	108.13
Rice - Mustard - Green Gram	20.27	85.84	50445	80271	34469	0.61	81.72
Rice - Rajma - Green Gram	27.36	88.58	56662	105404	54129	0.89	133.54
Rice - Potato - Green Gram	31.59	77.63	87052	188376	110110	1.22	277.60
Rice - Wheat + Mustard (5:1) - Green Gram	18.38	89.04	58904	99851	46405	0.72	112.18
Rice - Wheat + Rajma (5:1) - Green Gram	20.08	89.04	64042	120229	61770	0.91	153.94
Rice - Potato + Wheat (1:1) - Green Gram	35.74	95.89	89536	201010	120602	1.26	305.41
S.E.±	1.85	-	-	3180	4614	0.04	7.97
C.D. (P=0.05)	5.35	-	-	9209	13362	0.12	23.08
CV%	7.28	-	-	2.53	6.85	4.36	4.76

- mustard - green gram (Rs. 34469/ha) which gave net return lower than rice-wheat sequence due to poor performance of mustard in the cropping sequence. The benefit : cost ratio was highest in rice – potato+ wheat (1:1)– green gram (1.26) followed by rice – potato- green gram system (1.22). This was due to higher gross return of the above systems. The other cropping systems having 300 per cent cropping intensity gave comparatively lower benefit:cost ratio than rice-wheat cropping sequence. It was owing to higher cost of cultivation and poor yield of crops. Further, monetary efficiency in terms of '/ha/day was also maximum (305.41) in rice – potato + wheat (1:1) - green gram followed by rice – potato– green gram (277.60). The lowest monetary efficiency was noted with rice-mustard-green gram system (81.72) which may be due to lower net return of the system. Thus rice – potato + wheat (1:1) – green gram and rice – potato – green gram are biologically efficient, resource conservative, highly profitable crop sequences under irrigated medium lands of Chhotanagpur plateau region, which has the potential to serve as a viable and better alternative to the existing rice-fallow and rice-wheat system. However, the farmer still prefer rice-wheat sequence because of better stability and assured government procurement policy with greater remunerative profit margins than other less assured crop sequences. Similar results were also reported by Yadav *et al.* (2005) and Walia *et al.* (2011).

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