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Evaluation of diversified rice-based cropping system for higher productivity under irrigated ecosystem of Central Bihar

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ABSTRACT

A field experiment was conducted at Patna under irrigated condition to evaluate the production potential, water use efficiency and economics of eight rice- based cropping systems involving pulse/oilseed/vegetables as second or third crop. During all the year of experimentations, there were significant variations among cropping systems. Inclusion of pulse/oilseed/vegetables gave higher production and monetary gain over existing rice-wheat system. Maximum rice equivalent yield was recorded in rice-tomato-bottle gourd (39.64 t/ha) followed by rice-potato-onion (29.55 t/ha). Maximum water-use-efficiency was recorded in rice-tomato bottle gourd (155.2 kg/ha/cm) followed by rice-coriander ladys finger (113.7 kg/ha/cm) rice-potato-onion (112.3 kg/ha/cm) and minimum in rice-wheat cropping system (59.2 kg/ha/cm). Highest net return of Rs. 1, 38,905/ha was obtained with rice-tomato-bottle gourd followed by rice-potato-onion (Rs. 97,850/ha) and rice-coriander-lady's finger (Rs. 96,188/ha). Highest net profit on per rupee investment was also recorded with rice-tomato-bottle gourd (2.64) followed by rice-coriander-lady's finger (2.49).

Keywords: Rice-based cropping system, production efficiency, water-use-efficiency, rice equivalent grain yield, profitability

INTRODUCTION

Development of improved production technology with suitable crop sequences for different agro-climatic zones play an important role in enhancing the productivity and monetary return without impairing the soil health. Rice-wheat cropping system is the prevalent cropping system of Bihar. This system covers about 10.5 million hectare area and contributes about 38% to the national food basket, and is also considered as the back bone of the food security (Laik *et al.,* 2014). In future also rice-wheat system is likely to play an important role in sustaining the self sufficiency in food grains (Singh *et al.,* 2014). Further continuous cultivation of rice-wheat cropping system has resulted several problems along with deterioration of the fertility status of the soil resulting into low productivity, stagnation in system productivity and profitability of the cropping system. Due to multifold problems and stagnation in system productivity a need is being felt to diversify and intensify the existing rice-wheat cropping system. However, inclusion of pulse/oilseed/ vegetables in the system was found more beneficial than pure cropping of cereal after cereals (Prasad *et al.,* 2013). Gangwar and Ram (2005) also reported that inclusion of legumes and other crops using intensification and interruptive approaches as per resource availability with considerable improvement in productivity and profitability on one hand with improvement in soil fertility on other. Agricultural diversification towards high value crops can potentially increase productivity and thereby farm incomes, especially in a developing country like India, where demand for high value crops are increasing faster than staple crops. So, diversification has been envisaged as a new strategy for enhancing and stabilizing productivity, providing economic security and towards achieving the sustainable agricultural development. Hence to develop economically viable, technically feasible, sustainable and need based crop sequence for irrigated ecosystem of central Bihar; the present investigation was executed for four consecutive years by incorporating pulses, oilseeds and vegetables.

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MATERIAL AND METHODS

A field experiment was conducted at main farm of ICAR Research Complex for Eastern region, Patna in randomized block design replicated thrice during 2010-11 to 2013-14 to develop a suitable cropping system by introducing pulse/oilseed/vegetables as second or third crop in rice based cropping system. Eight rice- based cropping systems viz. rice-wheat(C_1), rice-wheat-green gram (C_2), rice- mustard- tomato (C_3), rice-potato- onion (C_4), rice-coriander- ladies finger (C_5), rice- tomato- bottle gourd (C_6), rice- pea- green chilli (C_7) and rice- lentil- sponge gourd (C_8) were undertaken. All the crops were grown with recommended package and practices. The soil of the experimental field was silt clay loam with initial pH 7.3, electrical conductivity 0.2 ds/m in 1:2 soils: water solution, organic carbon 0.54 %, available nitrogen 253.0 kg /ha, available phosphorus 24.4 kg /ha and available potash 394.0 kg and/ha respectively. Nutrient requirement of all the crops was met through urea (46%N), DAP (18 kg N &46 kg P_2O_5 and Muriate of Potash (60% K_2O). Full dose of phosphorous and potassium along with50% nitrogen were applied as basal to all the crops. Remaining nitrogen was given in two splits in rice, wheat, potato and other vegetables and in single split to mustard. All pulses received nitrogen as basal dose. During kharif irrigation was given as and when required depending

upon the intensity of rains to keep the soil in saturated condition throughout the crop growth period. The rabi and summer crops were irrigated optimally as and when required. All the crops under different cropping systems were sown and harvested as per their sequence.

For comparison between different cropping systems, the yield of all the cropping systems was converted into rice equivalent grain yield. Production efficiency in terms of kg/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). System productivity was calculated by adding the rice equivalent grain yield of each component crops. Net returns were the difference between the gross returns of the system and total cost of cultivation of the component crops. Profitability in terms of Rs/ha/day was obtained by dividing net returns of the sequence by total duration of the sequence (Rautaray, 2005). The economics and the rice equivalent grain yield (REGY) of different cropping systems were computed as per market price during that crop season.

RESULTS AND DISCUSSION

System productivity

Pooled analysis of four years data of different crops in various cropping systems in terms of rice equivalent grain yield revealed that during all the year of experimentations, there were significant variations among cropping systems. Rice grain yield of different cropping systems varied from 3.64 to 4.27 t/ha. Yield equivalence of different crops during rabi season varied from 3.6 t/ha to 27.2 t/ha where as during summer season the yield equivalence varied from 1.8 t/ha to 17.9 t/ha. Green gram grown as summer crop after potato performed better than that sown after wheat (Table 1). This was mainly due to timely sowing of greengram after potato that provided favourable weather condition for initial growth and development. Wheat vacated the field 25 days later resulting in delayed sowing of greengram and consequently poorer grain yield. Tomato grown during rabi season yielded higher than that of summer season.

The results revealed that there is sufficient scope of diversification of rice-wheat system with other cropping systems without any decline in the economic yield rather it improved substantially. The system productivity in terms of rice grain equivalent yield was highest in rice-tomato-bottle gourd (39.64 t/ha) cropping system. It was followed by rice-potato-onion (29.55 t/ha), rice-coriander-ladies finger (26.82 t/ha) and rice-mustard-tomato (24.47 t/ha), respectively (Table 1). All the diversified cropping systems produced higher system productivity in terms of rice grain equivalent yield than the traditional rice-wheat cropping system. Intensification and inclusion of vegetables crops during rabi and summer season may be attributed to higher system productivity. Kumar *et al.* (2012) and Singh *et al.* (2016) also reported suitability of vegetable crops for diversification of rice-wheat system.

Table 1: Rice equivalent grain yield (REGY), production efficiency and water use efficiency of different cropping systems (2010-11 to 2013-14)

Cropping systems	Rice equivalent grain yield (t/ha)			System productivity (t REGY/ha)	Production Efficiency (kg/ha/day)	Water Use Efficiency (kg/ha -cm)
	Kharif	Rabi	Summer			
Rice-Wheat	3.54	5.21	-	8.75	28.1	57.6
Rice-Wheat -Greengram	3.84	5.52	3.14	12.50	38.6	73.5
Rice-Mustard -Tomato	3.91	4.98	15.58	24.47	75.3	108.1
Rice-Potato -Onion	3.83	22.6	3.12	29.55	87.4	112.3
Rice-Coriander -Ladies Finger	4.07	3.60	19.15	26.82	76.32	113.7
Rice-Tomato -Bottle Gourd	3.90	25.89	9.85	39.64	108.6	155.2
Rice-Pea-Green Chilli	4.18	7.19	2.21	13.58	40.5	61.9
Rice-Lentil-Sponge Gourd	4.03	6.73	8.46	19.22	61.0	95.0
SE(m) ±	0.18	0.54	0.65	2.04	0.9	-
CD at 5%	0.52	1.61	1.93	6.06	2.6	-

Production efficiency

Production efficiency refers to per day productivity of entire cropping system under a particular treatment. Thus, production depends on the quantum of total production as well as duration of total crop period under a particular cropping system. Trend for production efficiency was the same as of system productivity (Table1). The rice- tomato-bottle gourd had the highest production efficiency (108.6 kg/ha/day) being significantly higher than the rest of the cropping systems. It was followed by rice - potato - onion (87.4 kg/ha/day). Traditional rice - wheat cropping system showed the lowest production efficiency (28.1 kg/ha/day) mainly because of the lowest rice equivalent grain yield. Higher production efficiency under the diversified cropping systems with vegetables, pulses and oilseeds may be owing to higher rice equivalent grain yield under these cropping systems.

Water-use-efficiency

Sequences having 300% cropping intensity consumed more number and quantity of irrigation water as compared to sequences having 200% cropping intensity. This is mainly due to inclusion of summer crop which utilized additional irrigations and contributed to higher water use than rice-wheat cropping system. Data presented in table 1 revealed that maximum water-use-efficiency was recorded in rice-tomato- bottle gourd (155.2 kg/ha/cm) followed by rice-coriander-ladies finger (113.7 kg/ha/cm), rice-potato-onion (112.3 kg/ha/cm) respectively. Whereas, minimum water use

efficiency was observed in rice- wheat (57.6 kg/ha/cm) and rice- pea- green chilli (61.9 kg/ha/cm). Similar results were reported by Walia *et. al.* (2011).

Economics

Economics of different cropping systems is shown in Table 2. Among all the cropping system, rice was the common kharif crop so economic parameters were mostly governed by rabi and summer crops. Traditional rice - wheat cropping system recorded the lowest cost of cultivation (Rs. 55,613). Maximum net profit was recorded in rice-tomato-bottle gourd (Rs. 1,38,905) followed by rice-potato-onion(Rs. 97,850) and rice-coriander-lady's finger (Rs. 96,188) respectively. But in case of benefit cost ratio, rice-tomato-bottle gourd was followed by rice-coriander-lady's finger and rice-potato-onion (Rs. 2.64, 2.49 and 2.12, respectively). Under diversified cropping system maximum profitability (Rs. 484.6/ha/day) was recorded in rice-tomato-bottle gourd followed by rice-mustard-tomato (Rs. 288.5/ha/day) and rice-coriander-ladies finger (Rs. 281.2/ha/day), while minimum in rice-pea-green chillies (Rs. 72.2/ha/day), respectively. The profitability obtained by rice-white cropping system was the lowest (Rs. 63.82/ha/day) Higher system productivity under the diversified cropping systems may be owing to better prices of vegetables, pulses and oilseeds. Prasad *et al.* (2013) and Singh and Kumar (2014) also reported better economic parameters under the diversified rice-wheat systems by adding vegetables and pulses.

Table 2: Economics of diversified cropping systems

Treatments	Gross income (Rs./ha)	Cost of cultivation (Rs./ha)	Net return (Rs./ha)	Profitability (Rs./ha/day)	B :C Ratio
Rice -Wheat	79540	55613	23927	63.82	1.43
Rice -Wheat -Greengram	96360	57445	38915	77.41	1.63
Rice -Mustard -Tomato	145640	58665	87975	288.46	2.48
Rice -Potato -Onion	184840	86990	97850	267.67	2.12
Rice -Coriander -Ladies Finger	160545	64357	96188	281.15	2.49
Rice -Tomato -Bottle Gourd	223441	84536	138905	484.56	2.64
Rice -Pea -Green Chilli	79375	54820	24555	72.22	1.45
Rice -Lentil -Sponge Gourd	116335	52605	63730	201.95	2.21
SE(m) ±		-	3062	-	0.05
CD at 5%		-	8971	-	0.16

Table 3: Chemical properties of soil after completion of crop cycles in diversified cropping systems

Treatments	Chemical properties									
	EC		Org. Carbon (%)		Av. Nitrogen (kg/ha)		Av. Phosphorus (kg/ha)		Av. Potash (kg/ha)	
	2010-11	2013-14	2010-11	2013-14	2010-11	2013-14	2010-11	2013-14	2010-11	2013-14
Rice-Wheat	0.10	0.09	0.49	0.49	253.0	225.3	24.4	21.3	194.0	167.5
Rice-Wheat-Greengram	0.10	0.10	0.69	0.70	261.3	238.5	22.6	20.7	215.6	177.8
Rice-Mustard-Tomato	0.11	0.12	0.56	0.66	219.5	208.7	20.7	16.1	204.4	160.8
Rice-Potato-Onion	0.13	0.09	0.54	0.70	218.7	201.0	23.3	17.9	260.4	177.8
Rice-Coriander-Ladies Finger	0.12	0.09	0.59	0.71	240.7	197.9	24.2	15.2	198.8	186.7
Rice-Tomato-Bottle Gourd	0.13	0.11	0.69	0.73	240.4	229.5	21.1	14.8	196.3	190.4
Rice-Pea-Green Chilli	0.13	0.11	0.70	0.76	230.2	218.7	24.1	17.5	201.5	178.3
Rice-Lentil-Sponge Gourd	0.16	0.11	0.73	0.81	250.9	229.1	20.6	18.4	205.3	195.3
SE(m) ±	0.02	0.01	0.08	0.13	27.03	14.1	1.71	1.23	17.42	9.0
C.D. at 5%	0.05	0.03	NS	0.37	80.33	41.9	5.08	3.65	51.75	26.8

Soil fertility status

Soil studies indicated that there was decreasing trend of average nutrient status such as EC, available nitrogen, available phosphorus and available potash after completion of fourth crop cycle and found significantly superior over each other (Table 3). This may be due to more uptakes of nutrients from the soil by vegetables crops. Most of the soil parameters are significantly superior over each other after completion of first and fourth crop cycles. It has been observed that there was buildup of organic carbon in most of the cropping systems after completion of fourth crop cycle because of litter falls and addition of organic matter through underground portion of rice and other crops in the systems. It has been observed that 10-15 percent of top portion of dry matter per square meter is added to the soil every season. Apart from this, we are adding recommended dose of nitrogen to all the crops but only 40- 50 % is made available to the crop and remaining nitrogen get fixed in the soil. This may be the reason for building up of organic carbon in the soil. Available phosphorus and potash have decreased from initial status of soil in almost all the cropping systems because of vegetable dominating cropping system; whose phosphorus and potash requirement is more than cereals and pulses dominated crops in the system (Kanaujia , 2016).

CONCLUSION

Thus rice equivalent grain yield, system productivity, production efficiency, net return, benefit: cost ratio and system profitability were higher under diversified cropping system over the traditional rice-wheat system. Out of these diversified cropping systems, rice-tomato-bottle gourd was superior to the other cropping systems for all yield and economic parameter. It was followed by rice-coriander-lady's finger and rice-potato-onion cropping system. It is interesting to note that vegetable dominated cropping systems were more remunerative than cereal and pulse dominated cropping systems. These cropping systems are biologically efficient and highly profitable which have the potential to serve as a viable and better alternative to the existing rice-wheat system for irrigated situations of central Bihar.

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