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Production potentiality and sustainability of rice-based cropping sequences in flood prone lowlands of North Bihar

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ABSTRACT

A field experiment was conducted to find out the most profitable rice based cropping sequence on sandy loam soil of North Bihar under rainfed lowand. Significantly higher rice grain equivalent yield was recorded in rice-lentil-green gram cropping sequence (10.39 t ha^{-1}).Production efficiency was also found highest with rice-lentil-green gram (33.52 kg ha^{-1} day^{-1}). The maximum total return ha^{-1} day^{-1} (102.76) and benefit:cost ratio (2.38) was recorded with rice-lentil-green gram sequence.. The maximum land use efficiency (89.0%) was associated with rice-linseed-green gram. However, rice-pea-green gram cropping sequence achieved the highest energy output (146.85 MJ x 10^3 ha^{-1}) with maximum energy use efficiency (4.12) which were significantly superior to rest of the cropping sequences.

Key words: *rice-based cropping sequences, system productivity, economics, production efficiency,*

Nearly 38 million hectares (i.e. 25% of the world's rice) of rice cultivation is under rainfed lowland ecosystem. Only 17% of the global rice supply is produced from rainfed lowland ecosystem. India has the largest area (i.e. 17.2 million hectares) under rainfed lowland amongst the South-east Asian countries (Khush and Baenziger,1998). Widawsky and O'Toole (1995) showed that out of 42 biotic and abiotic stresses which prevail in rainfed lowland rice areas of Eastern India, submergence stress is the third most important limitation for rice production (surpassed by drought and weeds). The importance of highly intensive crop sequence is well recognized to meet the growing demand of ever-increasing population. An intensive cropping which is not only highly productive and profitable but also stable over time and maintains soil fertility has a great importance in present conditions (Ghosh 1987). An intensification of cropping sequence is essential depending on the need of the area. Oilseeds and pulses including vegetables are receiving more attention owing to higher prices due to increased demand. Inclusion of these crops in a sequence changes the economics of the cropping sequences (Tomar and Tiwari 1990). Rice–based cropping sequences form an integral part of agriculture in rainfed lowland situation of North Bihar. In view of the limited scope for horizontal expansion to augment food production, the alternative is to move on with vertical growth by increasing the productivity of the available land area. Momentum is gaining to focus the attention on sequential cropping in mono-cropped areas and crop diversification for improved agricultural production. Increased productivity, profitability, employment-generation potential and increase in soil fertility also could be ensured by adopting modern scientific cropping sequence. The present investigation was carried out to evaluate the performance of rice based cropping sequences for higher production and profit in flood prone areas of North Bihar.

MATERIALS AND METHODS

Field experiment was carried out at Rice Research Sub-station, Jhanjharpur, Madhubani, Bihar. The soil of experimental field was sandy loam in texture with pH 8.0, electrical conductivity 0.49 dS/m, and low in organic carbon (0.41%), medium in available nitrogen (250 kg ha^{-1}), medium in available phosphorus (18 kg ha^{-1}) and medium in available potassium (140 kg ha^{-1}) content. The experiment replicated thrice in randomized block design, consisted of six crop sequences, *viz.* rice (Barh Avarodhi)-lentil (Aruna)-green gram(Pusa vishal), Rice-linseed (Subhra)-green gram, rice-wheat (HUW 234)-green gram, rice-Indian mustard (Varuna)-green gram, rice-coriander(Local)-green gram and rice-pea (Rachna)-green gram. Comparision among cropping sequences was done by converting the yield into rice equivalent yield, based on prevailing market price. The sustainable yield index (SYI suggested by Singh *et al.,* 1990) is defined as-

$$SYI = \frac{Y - sd}{Y_{max}}$$

Where SYI = sustainable yield index, Y is the average yield of rice and wheat over years and sd is the standard deviation and Y_{max} is the observed maximum yield in the experiment over the years of cultivation. Similarly sustainable yield index of the system was worked out using the Rice Equivalent Yield (REY) in place of Y and REY_{max} is the observed maximum REY in the experiment over the years of cultivation. Equivalent yield is calculated in terms of kharif crop (Rice) using the following formula -

$$REY = \frac{\sum Yi.Pi}{P(p)}$$

Where, REY denotes Rice equivalent yield; Yi= Yield of different crops; Pi = Price of respective crops and P(p)= Price of rice.

Land use efficiency and production efficiency were calculated by adopting standard techniques. The profitability in terms of Rs. ha^{-1} day^{-1} was computed by dividing the net realization of the sequence by 365 days in a year (Gangwar *et al.*, 2003).

To study energy inputs and outputs of individual cropping systems, a complete inventory of all crop inputs (fertilizers, seeds, plant protection chemicals, fuels, human labor and animal power) and outputs of both main and by-products was prepared. The energy value of each cropping system was determined based on energy inputs and energy production for the individual crops in the system. Inputs and outputs were converted from physical to energy unit measures through standard conversion coefficients. Average annual energy use efficiency (EUE = energy output/energy input) and energy productivity (EP = yield/energy input) were calculated for each cropping system. Specific energy was calculated by dividing energy input to the corresponding mean grain yield.

RESULTS AND DISCUSSION

The highest yield of rice (4.15 t ha^{-1}) was recorded in rice-lentil-green gram cropping sequence but it was at par with other cropping sequence (Table 1). Significantly higher seed yield of green gram was obtained in rice-lentil-green gram cropping sequence. This might be due to enhanced soil fertility due to incorporation of lentil in crop sequence. Introduction of green gram in crop sequences not only improved the grain yield of rice but also attributed to less exhaustion of soil fertility and also improved physical properties of the soil to some extent. The beneficial effects of legumes on succeeding crop had also been reported by many workers (Deka *et al.*, 1984; Sharma *et al.*, 1995;

Table 1. Yield, economics, system productivity and sustainability index of different rice based cropping sequences (Pooled data of 3 years).

Cropping sequences	Grain yield (q ha^{-1})			Rice-Grain Equivalent Yield (t ha^{-1})	Net return (Rs ha^{-1} $annum^{-1}$)	Benefit: Cost ratio	Profitability (Rs $ha^{-1}day^{-1}$)	System productivity ($kgha^{-1}day^{-1}$)	Sustain-ability yield	Index value
	Wet season	Dry season	Summer season							
Rice-Lentil-Green gram	41.5	6.5	7.0	10.39	37508	2.38	102.76	28.5	63.82	64.75
Rice-Linseed-Green gram	33.8	4.8	5.0	7.87	22667	2.10	62.10	21.6	24.25	40.52
Rice-Wheat-Green gram	40.5	34.5	4.0	9.58	31560	2.21	86.47	26.2	47.96	56.96
Rice-Indian mustard-Green gram	38.6	5.0	6.0	8.84	29807	2.15	81.66	24.2	43.29	49.87
Rice-Coriander-Green gram	34.5	2.3	5.5	8.77	26568	1.89	72.79	24.0	34.66	49.22
Rice-Pea-Green gram	37.5	5.8	4.5	8.73	25500	2.20	69.86	23.9	31.81	48.80
CD (P=0.05)	NS		1.8	0.89	228.56	-	-	-	-	-

Price of crops (Rs q^{-1}) : Rice, 500; Lentil, 2000; Wheat, 800; Linseed, 1800; Indian mustard, 1700; Coriander, 5000; Pea, 2000; Green gram 1600.
Price of straw (Rs q^{-1}) : Rice, 100; Lentil, 80; Wheat, 150; Linseed, 60; Indian mustard, 60; Coriander, 40; Pea, 60; Green gram, 60.

Sharma and Prasad, 1999; Quayyum and Maniruzzaman 1996).

The highest rice equivalent yield (10.39 t ha^{-1}) (Table 1) and production efficiency (33.52kg$day^{-1}ha^{-1}$) (Table 2) was also recorded with rice-lentil-green gram cropping system. Significantly higher production efficiency in terms of rupees (Rs 120.99 $day^{-1}ha^{-1}$) was recorded with the same treatment. Land use efficiency was highest (89%) in rice-linseed-green gram sequence and the lowest (82.7%) in rice-lentil-green gram sequence.

The highest system productivity (28.5 kg ha^{-1} day^{-1}) in terms of rice equivalent yield was recorded by rice-lentil-green gram sequence and the lowest system productivity (21.6 kg ha^{-1} day^{-1}) was recorded by rice-linseed-green gram sequence (Table-1). Shah *et al.* (1999) also recorded lower rice-equivalent yield in rice-oilseed crop sequence as compared to rice-legume. Similar results also been reported by Padhi (1993).

Net returns were directly related to the price that the producer received for the product and inversely related to the production cost. Both net return and BCR were highest for lentil containing cropping systems than for other crops and systems. Among all rice-based systems, economic performance of rice-lentil-green gram system was the best in terms of both net return (Rs. 37508 ha^{-1}) and BCR (2.38) (Table 1). Rao and Willey (1980) concluded that the multiple cropping systems with legume offer special advantage to farmers and reduce the probability of low income. It may be owing to higher production cost and less market price of the economic produce. The highest profitability (Rs.102.76$ha^{-1}day^{-1}$) (Table-1)and economic efficiency (102.8%) (Table-2) was recorded under rice-lentil-green gram cropping sequence.

The total annual energy input in individual cropping systems ranged from about 32.95 x 103 MJ ha^{-1} in rice-linseed-green gram to 40.99 x 103 MJ ha^{-1} in rice-wheat-green gram cropping system (Table 2). The lowest energy output occurred in rice-coriander-green gram cropping system, while the highest energy output was estimated rice-pea-green gram. All systems produced more energy than what was required for annual crop production, but the system-wise energy use efficiency varied from 1.79 to 4.12. The EUE was highest for rice-pea-green gram system because of the large energy output of this system (Table 2). It was relatively low in cropping system with coriander because of the large energy input associated with growing this crop. Energy productivity was highest for rice-lentil-green gram (302 g MJ^{-1}) followed by rice-Indian mustard-green gram (247 g MJ^{-1}), primarily due to the high grain yield in these cropping systems. Rice-wheat-green gram (234 g MJ^{-1}) and rice-coriander-green gram (235 g MJ^{-1}) recorded the lowest energy productivity, mainly because of the high energy input (Table-2). These results are in close agreement with those of Subbian *et al.* (1995) and Parihar *et al.* (1999).

Table 2. Efficiency and energy use of different rice based cropping sequences (Pooled data of 3 years).

Cropping sequences	Duration of crop sequence (days)	Production efficiency		Economic efficiency (%)	Land use efficiency (%)	Total input energy (MJ x10^3 ha^{-1})	Total output energy (MJ x10^3 ha^{-1})	Energy use efficiency (EUE)	Specific energy (MJ t^{-1})	energy productivity (gMJ^{-1})
		(kgday^{-1} ha^{-1})	(Rsday^{-1} ha^{-1})							
Rice-Lentil-Green gram	310	33.52	120.99	102.8	84.9	34.45	77.85	2.26	332	302
Rice-Linseed-Green gram	325	24.22	69.74	62.1	89.0	32.95	67.98	2.06	419	239
Rice-Wheat-Green gram	302	31.72	104.50	86.5	82.7	40.99	113.94	2.78	428	234
Rice-Indian mustard-Green gram	320	27.63	93.15	81.7	87.6	35.85	98.52	2.75	405	247
Rice-Coriander-Green gram	315	27.86	84.34	72.8	86.3	37.42	66.82	1.79	426	235
Rice-Pea-Green gram	323	27.03	78.95	69.9	88.4	35.63	146.85	4.12	408	245
CD (P=0.05)	-	2.56	6.25	-	-	-	7.5	0.23	-	-

Table 3. Effect of different rice- based cropping sequences on final soil fertility status.

Cropping sequences	Organic carbon (%)	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
Initial soil fertility status	0.413	250	18.0	140.0
Rice-Lentil-Green gram	0.448	287	20.5	148.7
Rice-Linseed-Green gram	0.421	252.5	19.9	143.5
Rice-Wheat-Green gram	0.425	258.8	18.8	146.5
Rice-Indian mustard–Green gram	0.416	251.5	18.3	141.5
Rice-Coriander-Green gram	0.428	256.4	18.8	144.7
Rice-Pea-Green gram	0.433	264.7	19.8	147.6
CD (P=0.05)	0.03	0.09	0.03	0.07

The Sustainable Index in terms of yield and value of products were highest for rice-lentil-green gram (63.82 and 64.75) (Table 1). Thus adoption of pulses and oilseeds as companion crop after rice followed by green gram proved to be best crop sequence for flood prone situation of North Bihar. These sequences will not only give higher monetary gain but also fulfill the demands of farm families and solve the crisis of cereals, pulses and oilseeds.In the present study, organic matter increased significantly in all the cropping systems (Table-3). This might be due to greater rhizodeposition and shedding of leaves by the leguminous crops, both contributing to an increase in organic carbon (Thakur and Sharma, 1988).Increases in organic matter in rice-based cropping system (Ghosh and Malik, 1999) have also been observed in West Bengal.

The initial available nitrogen status of the soil was 250 kg ha^{-1} (Table-3). Progressive increase in available N status was observed with the inclusion of leguminous crop in the rotation. Among the cropping systems tested rice-lentil-green gram cropping system significantly improved the soil available nitrogen status and maximum status of nitrogen was recorded under this cropping system. The fixation of atmospheric nitrogen by the leguminous crops might have contributed for the increased soil N status (Mongia *et al.*, 1989). Cultivation of legume crop is viewed more as a soil fertility improver than as independent crops grown for their grain output. This is because legume crops are self sufficient in N supply (Kanwarkamla, 2000).

Fertilizer was the dominant source of P and K input, with minor contributions from rain and irrigation water and from seed material. The maximum Phosphorus and Potassium status was recorded under rice-lentil-green gram cropping sequence (Table-3). Increase in available phosphorus and potassium content in cropping sequences involving vegetable, pea, green gram were reported by Gangwar and Ram (2005).There is potential for greater adoption of intensified rice-based cropping systems with increased productivity and energy efficiency as in flood prone lowlands of North Bihar. Diversified triple cropping systems like rice-lentil-green gram gives highest annual yield, net return, benefit: cost ratio, and energy productivity compared to other cropping systems. This system also maintained or improved soil organic matter and NPK status of soil. Considering all this, triple cropping systems involving legume appears to be most suitable for flood prone lowlands.

REFERENCES

Deka JC, Singh Y, Sharma KC, Gupta PC and Bhardwaj AK 1984. Studies on rice-based multiple crop sequence. I. Crop yields and economics. Indian J.Agron. 29(4):485-489.

Gangwar B and Ram B 2005. Effect of crop diversification on productivity and profitability of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) system. Indian J .Agric. Sci. 75(7): 435-438.

Gangwar B, Katiyal V and Anand KV 2003. Productivity, stability and efficiency of different cropping sequences in Maharashtra. Indian Journal of Agricultural Sciences. 73 (9) : 471-477.

Ghosh DC and Malik GC 1999. Fertility management in potato under potato-sesame-rice cropping system. Environ. Ecol. 17: 643-645.

Ghosh A B 1987. Some aspects of sustainability in soil fertility and crop production. Journal of Indian Society of Soil Science. 35(4): 552-565.

Kanwarkamla 2000). Legumes - the soil fertility improver. Indian Farming. 50(5): 9

Khush GS and Baenziger PS 1998. in Crop Productivity and Sustainability - Shaping the Future (eds Chopra, V. L., Singh, R. B. and Varma, A.), Oxford and IBH Publishers, New Delhi, pp. 113-125.

Mongia AD, Gangwar B, Shyam Singh V, Kumar BAK 1989. Long term effect of fertilizers on important crops in Andaman and Nicobar Islands, Fertil. News. 34(4): 81 - 85.

Padhi AK 1993. Productivity and economics of rice (Oryza sativa)-based cropping sequences. Indian Journal of Agronomy. 39(3): 351-356.

Parihar SS, Pandey D, Shukla RK, Verma VK, Chaure NK, Choudhary KK and Pandya KS 1999. Energetics, yield, water use and economics of rice based cropping system. Ind. J. Agron. 44: 205-209.

Quayyum MA and Manijuzzaman AFM 1996. Effect of preceding crops on yield of succeeding transplanted aman rice (Oryza sativa). Indian Journal of Agronomy. 41 (3): 349-353.

Rao MR and Willey RW 1980. Evaluation of yield stability in intercropping studies with sorghum/pigeonpea. Experimental Agriculture. 16: 605-616.

Shah MH, Khan GM, Bali AS, Singh KN and Kanth R 1999. Productivity potential of rice-based cropping sequences under temperate environment. Indian Journal of Agronomy. 44(1): 12-15.

Sharma SN and Prasad R 1999. Effect of Sesbania green-manuring and mungbean residue incorporation on productivity and nitrogen uptake of a rice-wheat cropping system. Bioresource Technology. 67:171-175.

Sharma SN, Prasad R and Singh S 1995. The role of mungbean residues and Sesbania aculeata green manure in nitrogen economy of rice-wheat cropping system. Pl. Soil. 172:123-120.

Singh RP, Das SK, Bhaskara Rao UM & Narayana Reddy M 1990. Sustainability index under different management. Annu. Rep. Central Res. Inst. for Dryland Agric., Hyderabad, India.

Subbian P, Gopalsundaran P and Palaniappan SP 1995. Energetics and water use efficiency of intensive cropping system. Ind. J. Agron. 40: 398-401.

Thakur HC, Sharma NN 1988. Effect of various cropping patterns including cereals, pulses and oilseeds on Chemical properties of the soil. Indian J. Agric. Sci. 58(9): 708 - 709.

Tomer SS and Tiwari AS 1990. Production potential and economics of crop sequences. Indian Journal of Agronomy. 35 (1, 2): 30-35.

Widawsky DA and O'Toole JC 1995. Prioritizing the Rice Biotechnology Research Agenda for Eastern India, The Rockefeller Foundation, New York.