Effect of crop diversification in rice-wheat cropping system on productivity, economics, land use and energy use efficiency under irrigated ecosystem of Varanasi

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ABSTRACT

The possibility of crop diversification in existing rice-wheat system was explored under irrigated eco-system of Varanasi. The treatments comprising ten crop sequences viz. rice-wheat, rice-chickpea, rice-wheat-green gram, rice-wheat-Sesbania (green manure), rice-mustard-green gram, rice-lentil-cowpea (fodder), rice-pea (grain), rice-lentil + mustard (3:1)-cowpea (fodder), rice-maize (green cob) + vegetable pea (1:1) - cowpea (fodder) and rice-potato-green gram were arranged in a randomized block design under four replications. Results show rice-potato-green gram sequence gave highest rice grain equivalent yield (21.66 t ha^{-1}), net return (Rs. 64,192 ha^{-1}), output input ratio (2.17), production efficiency (Rs 219 ha^{-1} day^{-1}) and employed maximum labourers (421 ha^{-1} $year^{-1}$) followed by rice-mustard green gram, and rice-maize + pea-green gram sequences. However, rice-chickpea sequence proved least remunerative. In general, land use efficiency, production efficiency as well as labour engagement were improved by inclusion of summer crops in sequence. Maximum amount of energy (173540 MJ ha^{-1}) was obtained from rice potato-green gram, followed by rice-maize (green cob) + vegetable pea (1:1)-cowpea (fodder) and rice-lentil + mustard (3:1)-cowpea (fodder) sequences. The net energy return and energy use efficiency were significantly higher in rice-potato-green gram sequence than in other sequences.

Key words: *Crop diversification, energy use efficiency, irrigated ecosystem, production efficiency, rice-wheat system*

Rice-wheat is the predominant cropping system in India, mostly practiced in entire Indo-Gangetic plains. Although, both rice and wheat registered a remarkable growth in terms of area, production and yield since mid 1960s, reports of yield plateauing or even declining in high productive zone of northern India has raised serious concern on sustainability of rice-wheat system. Among the various factors responsible for such declining trend in productivity, degradation in soil health and fertility as well as water supply and quality are considered important. Moreover, in recent years, the farmers are facing problems in selling their rice and wheat produce at remunerative price due to escalating input cost as compared to the marginal rise in selling price.

However, looking into the soil and climatic conditions, it is rather difficult to replace the rice by any other crop particularly under irrigated condition. So, for diversification of rice-wheat system in most parts of the region, the only option left is to replace wheat. Therefore, wheat may partially be substituted in rotation with some remunerative crops of diverse nature including grain legumes. The system may also be diversified through crop intensification and more profit can be earned along with the restoration of soil health by introducing short duration pulse /fodder or green manuring during summer. With these facts in view, the present study was undertaken.

MATERIALS AND METHODS

A long term field experiment on diversification in rice-wheat system was initiated during 2001-02 at the Agriculture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. Experimental data of 2002-03 and 2003-04 have been pooled. The experimental soil was sandy clay loam having pH 7.4 and 0.37% organic carbon, 150 kg available nitrogen (N ha^{-1}), 19.3 available phosphorus (P ha^{-1}) and 206 kg potassium (K ha^{-1}).

The treatment consisting of ten systems of cropping patterns: rice-wheat, rice-chickpea, rice-wheat-green gram, rice-wheat-*Sesbania* (green manure), rice-mustard-green gram, rice-lentil-cowpea (fodder), rice-pea (grain), rice-lentil + mustard (3:1)-cowpea (fodder), rice-maize (green cob) + vegetable pea (1:1)-cowpea (fodder) and rice-potato-green gram were arranged in randomized block design with four replications in the plot size of 7 m x 6 m with one meter plot border. Individual plots were thoroughly prepared in isolation to avoid the mixing of soil in different treatments. Cultivation practices were followed as per local recommendation for each crop. *Sesbania aculeata* as green manure and green gram after last picking were cut from the ground level and green biomass so obtained was incorporated *in situ*. The cowpea for green fodder was harvested from the ground level at 60 days stage. The other crops were harvested at maturity. However, harvesting of maize for green cobs and vegetable pea for green pods were done at proper stage. The weather conditions during the two years trial was congenial for the growth and development of crops.

For comparison of different crop sequences, the yield data for different seasons and years (2002-03 and 2003-04) were pooled and converted into rice grain equivalent yield (RGEY). Land use efficiency was worked out on the basis of field occupied by an individual cropping sequence during a year. Production efficiency of the sequence was obtained as per the method given by Tomer and Tiwari (1990). Whereas, the crop energy (MJ ha^{-1}) was calculated as per method described by Sriram *et al* (1991).

RESULTS AND DISCUSSION

Rice taken after summer green gram, cowpea and green manuring recorded significantly higher grain yield of rice than after wheat. However, maximum grain yield (4.22 t ha^{-1}) was obtained in rice-wheat-*Sesbania* (for green manuring) sequence. This can be attributed to the legume effect of green gram and cowpea as well as green manuring on succeeding rice (Singh and Singh, 1975, Purushothaman, 1979 and Yadav *et al*., 2005).

During dry season potato out yielded other crops and by maize + vegetable pea intercropping

Table 1. Effect of crop diversification in rice-wheat system on productivity, economics, land use efficiency and labour engagement.

Treatment	Grain/seed/tuber/fodder yield (t ha^{-1})									
	Wet season (Rice)	Dry season: Crops	Dry season: WGEY	Summer corps	RGEY (t ha^{-1})	Net return (Rs ha^{-1})	Output input ratio	Production efficiency (Rs ha^{-1} day^{-1})	Land use efficiency (%)	Total man days ha^{-1} $year^{-1}$
Rice-wheat	3.81	3.86	4.88	-	10.50	26245	1.83	122	59.2	248
Rice-chickpea	3.88	1.01	2.99	-	8.19	15941	1.55	75	58.4	267
Rice-wheat-green gram	4.15	4.07	5.10	0.68	14.41	35537	1.84	122	83.3	367
Rice-wheat-*Sesbania* (GM)	4.22	4.16	5.21	-	11.88	30506	1.95	154	59.2	258
Rice-mustard-green gram	4.10	1.70	4.81	0.98	15.90	43065	2.01	153	80.0	413
Rice-lentil-cowpea (F)	4.13	1.04	3.12	23.94	10.90	23300	1.65	82	79.7	345
Rice-pea (grain)	4.01	1.26	3.05	-	8.94	17336	1.60	93	60.0	267
Rice-Lentil + mustard (3:1) cowpea (F)	4.15	0.67 (0.86)	4.40	25.0	13.42	30541	1.80	122	79.7	353
Rice-maize (green cob) + vegetable pea (1:1)- cowpea(F)	4.18	8.75 (1.83)	6.22	24.3	14.27	38983	1.92	121	81.4	368
Rice-potato-green gram	4.21	20.78	10.39	1.28	21.66	64192	2.17	219	80.3	421
CD (P=0.05)	0.26	-	0.65	-	1.55	4939	0.14	32	-	-

(Table 1). Among the grain/seed crops, wheat yield was considerably higher than in pulses and mustard. These yield differences could be attributed to the diverse nature of the crops and the stage of their harvesting. When different dry season crops were compared on the basis of wheat grain equivalent yield (WGEY), it was clearly noticed that potato out yielded the other crops. The next was maize + vegetable pea (1:1) intercropping that also proved significantly superior to other crops. The three pulse crops taken in pure stand though remained at par, recorded significantly lower WGEY than other dry season crops and intercropping treatments. It was interesting to note that lentil + mustard (3:1) intercropping produced significantly higher WGEY than sole lentil in rice-lentil-cowpea sequence due to better yield of intercrop mustard.

Green gram taken after potato as well as mustard produced markedly higher grain yield than after wheat in rice-wheat-green gram sequence. This was mainly due to its delayed sowing (mid April) in rice-wheat-green gram sequence. Whereas in rice-potato green gram and rice-mustard-green gram sequences, timely sowing of green gram i.e. second fortnight of March was possible. Consequently, only two pickings of green gram were possible in rice-wheat-green gram sequence as against the three in other two sequences However, cowpea (fodder) yield did not differ much in different cropping sequences, suggesting that timely sowing and picking of green gram is more important than cowpea fodder.

The pooled data of two years revealed distinct superiority of rice-potato-green gram sequence over the other crop sequences (Table 1) followed by rice-mustard-green gram, rice-wheat-green gram and rice-maize (green cob)+vegetable pea (1:1)-cowpea(fodder) sequences. These sequences along with rice-lentil + mustard (3:1) – cowpea (fodder) produced significantly higher RGEY than rice-wheat sequence. The productivity of these sequences were better because of substitution of more productive/remunerative crops during winter season by replacing wheat as well as the intensification of the crop sequences by including summer green gram having good market value (Padhi,1993). Contrary to that rice-chickpea sequence was found the least productive. This was due to the wilt infestation in chickpea in both the years of experimentation. In chickpea, wilt is becoming a serious problem in Varanasi region and in spite of using resistant variety (Avarodhi), about 18 % mortality of plants was observed during the two years trial. So, among all the crop sequences, chickpea contributed least towards the RGEY.

With the exception of rice-lentil-cowpea sequence, crop sequences involving green gram and cowpea (fodder) during summer recorded markedly higher net return as compared to rice- wheat sequence (Table 1). Thus, intensification of rice based sequence by incorporating green gram/cowpea (fodder) during summer proved remunerative (Rao and Willey, 1980 and Yadav *et. al.*, 2005). Rice-potato-green gram sequence produced highest net return (Rs 64,192) as well as output-input ratio (2.17) mainly due to higher productivity of potato. This was followed by rice-mustard-green gram sequence that remained at par with rice-maize (green cob) + vegetable pea (1:1)-cowpea sequence produced significantly higher net return (Rs. 43,065) and output–input ratio (2.01) than in other sequences. Further, it was evident from wheat grain equivalent yield (WGEY) that mustard was not as remunerative as maize (green cob) + vegetable pea (1:1) intercropping even though rice-mustard-green gram sequence was more profitable than maize (green cob) + vegetable pea (1:1) – cowpea sequence. This could be ascribed to the better performance of green gram after mustard and its good market price. However, rice-chickpea sequence gave the lowest net return (Rs 15,941) and output-input ratio of 1.55 (Gupta and Rai, 1990 and Padhi, 1993).

Rice-potato-green gram sequence, due to its higher biological efficiency and net return, resulted in significantly higher production efficiency (Rs 219 ha^{-1} day^{-1}) than other crop sequences (Table 1). Rice-wheat-*Sesbania* (Rs 154 ha^{-1} day^{-1}) and rice-mustard-green gram (Rs 153 ha^{-1} day^{-1}) though remained comparable, both proved significantly superior to rice-wheat sequence (Rs 122 ha^{-1} day^{-1}). Nevertheless, rice-chickpea sequence was found most in efficient in terms of production efficiency (Rs 75 ha^{-1} day^{-1}).

In general, the land use efficiency (LUE) increased with intensification by inclusion of summer crops in the sequence. The highest LUE (83.3%) was observed in rice-wheat-green gram sequence as it occupied the land for maximum number of 304 days. It was closely followed by rice-maize (green cob) + vegetable pea (1:1) - cowpea (81.4%), rice-potato-green gram (80.3%) and rice-mustard-green gram (80%0) sequences. However, the lowest LUE of 58.4% was noticed in rice-chick pea sequence.

Intensification of crop sequences provided more opportunity for labour engagement. All the crop sequences, particularly those with 300% intensity engaged markedly higher labourers than in rice-wheat sequence (248 man days ha^{-1} $year^{-1}$). The maximum number of 421 labourers were engaged in rice-potato-green gram sequence followed closely by rice-mustard-green gram (413 man days ha^{-1} $year^{-1}$). This was apparently due to higher number of labourers engaged in potato cultivation as well as in the picking of green gram.

Amount of energy consumed and obtained in unit area of land has also been found useful in comparing cropping sequences. Rice-potato-green gram sequence in spite of higher energy consumption, recorded maximum (111039.2 MJ ha^{-1} $year^{-1}$) net energy return and it was 64.4% higher than in rice-wheat system (Table 2). Similarly, rice-maize + vegetable pea (1:1)-cowpea (fodder) and rice-lentil + mustard (3:1)-cowpea (fodder) sequences though remained comparable, recorded significantly higher system net energy return than other sequences. This indicated that crop sequences with high productive crops and higher intensity brought about greater system net energy return. Rice-potato-green gram sequence also recorded significantly higher energy use efficiency than other sequences. This could be attributed to the higher biological efficiency of rice-potato-green gram sequence, resulting into greater energy output than other sequences.

These results clearly indicated that diversification of rice-wheat system under irrigated eco-system of Varanasi by substituting wheat with potato, mustard and maize (green cob) + Vegetable pea (1:1) intercropping as well as intensification of rice based sequences could enhance the overall productivity, profitability, energy use efficiency and labour engagement. Thus, as compared to rice-wheat system, the crop sequences *viz*. rice-potato-green gram, rice-mustard-green gram and rice-maize (green cob) + Vegetable pea (1:1)-cowpea (fodder) were found to be highly remunerative. However, the complete diversification of the rice-wheat system is neither possible nor worth recommended; but it might be practiced on rotational basis in a farm to sustain the productivity of rice-wheat system.

Table 2. Effect of crop diversification in rice-wheat system on system energy input, energy output, energy return and energy use efficiency.

Treatment	System energy output (MJ ha^{-1})	System energy input (MJ ha^{-1})	System net energy return (MJ ha^{-1})	Energy use efficiency (MJ ha^{-1} day^{-1})
Rice-wheat	111881	44338	67543	518.0
Rice-chickpea	65521	29289	36233	307.6
Rice-wheat-green gram	126723	52529	74194	416.9
Rice-wheat-*Sesbania* (GM)	119243	45634	73609	552.0
Rice-mustard-green gram	109304	43693	65611	374.3
Rice-lentil-cowpea (F)	133604	37105	96499	459.1
Rice-pea (grain)	77709	29583	48126	354.8
Rice-Lentil + mustard (3:1)cowpea (F)	145796	41247	104549	501.0
Rice-maize (green cob) + vegetable pea (1:1)- cowpea (F)	153148	47022	106126	515.6
Rice-potato-green gram	173540	62501	111039	592.3
CD (P=0.05)	3748	-	3748	13.8

REFERENCES

Gupta SK. and Rai RN 1990. Cropping system for efficient crop land use in Sikkim. Indian J of Agron 35(1,2): 36-39

Padhi AK 1993. Productivity and economics of rice (*Oryza sativa*) based on cropping sequences. Indian J of Agron 38(3): 351-356

Purushothaman S 1979. Studies on rice-based multiple cropping system. Ph.D. Thesis, TNAU, Coimbatore.

Rao M and Willey RW 1980. Evaluation of yield stability in intercropping studies with sorghum and pigeon pea. Experimental Agriculture 16: 6052-616

Singh M and Singh RK 1975. Prospects of growing pulses under multiple and intercropping. Indian J of Genetic and Plant Breeding 35:216-220

Sriram C, Thyagraj CR, Mayande VM and Srinivas Rao P 1991. Indo-US project on research on mechanization of dryland agriculture (Operation Search). Central Research Institute for Dryland Agriculture, Hyderabad, India, Annexure-I.

Tomar SS and Tiwari AS 1990. Production potential and economics of different crop sequences. Indian J of Agron 35(1, 2): 30-35

Yadav MP, Rai J, Kushwaha SP and Singh GK 2005. Production potential economic analysis of various cropping systems for Central Plains Zone of Uttar Pradesh. India J of Agron 50 (2): 83-850