Mustard (*Brassica juncea*): agood option for diversification of rice-wheat system under irrigated ecosystem of north eastern plain zone of India

J. S. Bohra, R. K. Singh, Yogeshwar Singh

Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi - 221005, India.
Email: jsbohra2005@rediffmail.com

Abstract

Rice-wheat is the predominant cropping system in entire south- west Asia, more particularly the Indo Gangetic Alluvial belt. However, the prolonged cultivation of the same nature of crops has resulted in yield plateauing or even decline in high productive zone of northern India. Therefore, a long-term experiment was initiated under All India coordinated Research Project on Cropping Systems in 2001-02 to study the crop diversification options in rice-wheat system. The treatment consisting of ten cropping sequences: 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 by using power tiller. For comparison of different crop sequences, the yield data for different seasons and years (2001-02 and 2002-03) were pooled and converted into rice equivalent yield (REY). The results indicated that rice-potato-greengram sequence was most productive in terms of REY. It recorded significantly higher net return, output-input ratio and engaged maximum number of man-days. The next best sequence in terms of productivity, profitability and employment generation was rice-mustard green gram. However, the rice-chickpea sequence proved to be the most inefficient. Mustard and potato provided better option than wheat for intensification of the sequence by taking green gram during summer. System net energy return and energy use efficiency was significantly higher in rice-potato-green gram sequence than other sequences. Rice-maize (green cobs) + vegetable pea (1:1)-cowpea (fodder) also recorded significantly higher system net return than remaining sequences. Nevertheless, the lowest system net energy return as well as energy use efficiency were associated with rice-chickpea sequence. Among the two most remunerative sequences *viz*. rice-potato- green gram and rice-mustard-green gram, the latter has better scope to be followed by farmers in the area because of the perishable nature of the potato and limited cold storage facility in the area besides limited scope for its export.

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 decline 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 In Varanasi region of Ganges basin too, rice-wheat is the most commonly practiced cropping system and there is the need to diversify the system. However, looking into the soil and climatic conditions, it is rather difficult to replace rice by other crops particularly under irrigated condition. So, for diversification of rice-wheat system in most parts of the region, the possible options are the substitution of wheat and the intensification of system by including some leguminous crops. With these facts in view, the present study was undertaken.

Materials and methods

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

The treatment consisting of ten cropping squences: 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 (REY). 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) was calculated as per method described by Sriram *et al.* (1991).

Results and discussion

Productivity of component crops in different seasons

***Rainy*:** As the data presented in Table 1 are the average of 2nd and 3rd year i.e. 2002-03 and 2003-04, marked effect of preceding crops was observed on the grain yield of rice. In general, rice taken after summer green gram, cowpea and green manuring recorded significantly higher grain yield than grown after wheat. However, maximum grain yield (4.22 t ha^{-1}) was obtained in rice-wheat-*Sesbania* (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 and Purushothaman, 1979 and Yadav *et al*., 2005).

***Winter*:** During winter, potato out yielded other crops and it was followed by maize + vegetable pea intercropping (Table 1). Among the grain/seed crops, wheat yield was considerably higher than pulses and mustard. These yield differences could be attributed to the diverse nature of the crops and the stage of their harvesting. Nevertheless, when different winter crops were compared based on wheat equivalent yield (WEY), it was clearly noticed that potato was far more superior to other crops. The next best 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 WEY than other winter crops and intercropping treatments. It is interesting to note that lentil + mustard (3:1) intercropping produced significantly higher WEY than sole lentil in rice-lentil-cowpea sequence due to better yield of intercrop mustard.

***Summer*:** 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.

System productivity

***Rice equivalent yield (REY)*:** The pooled data of two years revealed distinct superiority of rice-potato-green gram sequence over the other crop sequences (Table 1) and this was 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 REY 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). However, 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. Therefore, among winter crops in different sequences, chickpea contributed least towards the REY.

Table 1. Production potential of different crop sequence (pooled data of 2002-03 and 2003-04)

Treatment	Grain/seed/tuber/fodder yield (t/ha)				Rice equivalent yield (t/ha)
	Season				
	Rainy	Winter		Summer	
		Crop	WEY		
Rice-wheat	3.81	3.86	4.88	-	10.79
Rice-chickpea	3.88	1.01	2.99	-	7.68
Rice-wheat-greengram	4.15	4.07	5.10	0.68	15.09
Rice-wheat-*Sesbania* (G M)	4.22	4.16	5.21	-	11.51
Rice-mustard-greengram	4.10	1.7	4.81	0.98	15.46
Rice-lentil-cowpea (F)	4.13	1.04	3.12	23.94	12.10
Rice-pea (grain)	4.01	1.26	3.05	-	9.24
Rice-lentil + mustard (3:1)-cowpea (F)	4.15	0.67 (0.86)*	4.40	24.99	13.18
Rice-maize (green cob) + vegetable pea-cowpea (F)	4.18	8.75 (1.83)	6.22	24.35	14.01
Rice-potato-greengram	4.21	20.78	10.39	1.28	21.28
CD (P=0.05)	0.26	-	0.65	-	0.80

*Figure in parentheses show the yield of intercrop

Net return, output-input ratio and production efficiency

With the exception of rice-lentil-cowpea, crop sequences involving green gram and cowpea (fodder) during summer recorded markedly higher net return as compared to rice-wheat sequence (Table 2). 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 (U.S. $ 1306) as well as output-input ratio (2.21) 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 and produced significantly higher net return (U.S. $ 878.1) and output –input ratio (2.01) than other sequences. Further, it is evident from wheat equivalent yield (WEY) 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 (US $ 277.7) 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 (US $ 4.46/ha/day) than other crop sequences (Table 2). Rice-wheat-*Sesbania* (US $ 3.04/ha/day) and rice-mustard-green gram (US $ 3.01/ha/day) though remained comparable, both proved significantly superior to rice-wheat sequence (US $ 2.64/ha/day). Nevertheless, rice-chickpea sequence proved most inefficient in terms of production efficiency.

Table 2. Effect of different crop sequences on economics (pooled data of 2002-03 and 2003-04)

Treatment	Net return (US $/ha /year)	Output-input ratio	Land use efficiency (%)	Production efficiency (US $./ha /day)	Total man-days/ha/year
Rice-wheat	566.9	1.90	59.2	2.64	248
Rice-chickpea	277.7	1.48	58.33	1.31	267
Rice-wheat-greengram	845.6	2.00	83.30	2.78	367
Rice-wheat-*Sesbania* (G M)	657.6	1.96	59.20	3.04	258
Rice-mustard-greengram	878.1	2.01	80.28	3.01	413
Rice-lentil-cowpea (F)	694.7	2.07	79.99	2.40	345
Rice-pea (grain)	470.7	1.85	59.86	2.15	267
Rice-lentil + mustard (3:1)-cowpea (F)	702.5	2.06	79.84	2.42	353
Rice-maize (green cob) + vegetable pea-cowpea (F)	774.6	1.95	81.35	2.61	368
Rice-potato-greengram	1306	2.21	80.15	4.46	421

Land use efficiency and labour engagement

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 rice-wheat sequence (248 man days ha^{-1} $year^{-1}$). The maximum number of 421 labourers was 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.

Table 3. Effect of different crop sequences on energy indices (pooled data of)

Treatment	System energy output (MJ/ha)	System energy input (MJ/ha)	System net energy return (MJ/ha)	Energy use efficiency (MJ/ ha/ day)
Rice-wheat	111881.38	44338.40	67542.98	517.97
Rice-chickpea	65521.56	29288.89	36232.67	307.61
Rice-wheat-greengram	126723.18	52528.49	74194.69	416.85
Rice-wheat-*Sesbania* (G M)	119242.72	45634.17	73608.55	552.05
Rice-mustard-greengram	109303.90	43693.47	65610.43	373.05
Rice-lentil-cowpea (F)	133603.75	37104.76	96498.99	457.55
Rice-pea (grain)	77708.99	29582.89	48126.10	354.83
Rice-lentil + mustard (3:1)-cowpea (F)	145795.80	41246.51	104549.29	501.02
Rice-maize (green cob) + vegetable pea-cowpea (F)	153147.58	47021.53	106126.05	515.65
Rice-potato-greengram	173539.88	62500.72	111039.16	592.29

Energy efficiency

Amount of energy consumed and obtained in unit area of land is used in comparing cropping sequences. Rice-potato-green gram sequence in spite of higher energy consumption, recorded maximum (111039.2 MJ/ha/year) system

net energy return and it was 64.4% higher than rice-wheat system (Table 3). 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.

Therefore, 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 can enhance 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 highly remunerative. However, the complete diversification of the rice-wheat system is neither possible nor recommended; it may be practiced on rotational basis in a farm to sustain the productivity of rice-wheat system. to b Among the two most remunerative sequences *viz*. rice-potato- green gram and rice-mustard-green gram, the latter has better scope to be followed by farmers in the area because of the perishable nature of the potato and limited cold storage facility in the area besides little scope for its export.

References

1. Sriram, C.; Thyagraj, C.R.:Mayande, V.M. 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*.
2. Gupta, S.K. and Rai, R.N. 1990. Cropping system for efficient crop land use in Sikkim. *Indian Journal of Agronomy* **35**(1,2): 36-39.
3. Padhi, A.K. 1993. Productivity and economics of rice (*Oryza sativa*)- based cropping sequences. *Indian Journal of Agronomy* **38**(3): 351-356.
4. Rao, M. and Willey, R.W. 1980. Evaluation of yield stability in intercropping studies with sorghum and pigeon pea. *Experimental Agriculture* **16**: 6052-616.
5. Tomar, S.S. and Tiwari, A.S. 1990. Production potential and economics of different crop sequences. *India Journal of Agronomy* **35**(1, 2): 30-35.
6. Purushothaman, S. 1979. Studies on rice-based multiple cropping system. Ph.D. thesis, TNAU, Coimbatore.
7. Singh, M. and Singh, R. K. 1975. Prospects of growing pulses under multiple and intercropping. *Indian Journal of Genetic and Plant Breeding* **35**:216-220.
8.Yadav, M. P.; Rai, J.; Kushwaha, S. P. and Singh, G. K. 2005. Production potential economic analysis of various cropping system for Central Plains Zone of Uttar Pradesh. *India Journal of Agronomy* **50** (2): 83-850 hjjiuybvgfr