EFFICIENCY OF DIVERSIFIED RICE-WHEAT CROPPING SYSTEMS INCLUDING POTATO, VEGETABLE PEAS AND GROUNDNUT CROPS IN TRANS-GANGETIC PLAINS

J.P. Singh¹, A. Salaria², K. Singh³ and B. Gangwar⁴

ABSTRACT: Field experiment was conducted during 2000-2003 on diversified rice-wheat cropping systems involving potato, vegetable peas and groundnut, and water management treatments in rice to increase the production, economics and water use efficiency. Inclusion of potato, vegetable peas and groundnut in rice-wheat cropping system increased the production, economics and land use efficiency on an average by 95, 75 and 11 percent, respectively. Rice equivalent yield (REY) was maximum in rice/groundnut/rice (R/G/R)-potato-wheat (24.60 t/ha/yr), which was at par with rice-potato-wheat (24.27 t/ha/yr) followed by rice-vegetable peas-wheat (19.02 t/ha/yr) as against traditional rice-wheat (11.63 t/ha/yr) system. Net returns was the highest in rice-vegetable peas-wheat (Rs.67540/ha/yr) system, which was at par with R/G/R-potato-wheat (Rs.67424/ha/yr) and rice-potato-wheat (Rs.64906/ha/yr) as against rice-wheat (Rs.38159/ha/yr) system. Irrigation to rice crop at hairline cracks (HC) in soil saved about 20 percent of total water use on an average in different cropping systems compared to traditional system of irrigating rice at disappearance of ponded water (DP). Decline in available soil K ranging from 4.0 to 12.0 percent and build up of available soil P from 41.7 to 62.5 percent was recorded from initial soil test values after 3 years in different cropping systems. The apparent soil nutrient balance (gain/loss) was negative for K (243-440 kg/ha) and positive for P (57.6-151.1 kg/ha) with varying degrees in different cropping systems.

INTRODUCTION

The rice-wheat is the dominant cropping system in the Trans-Gangetic plains comprising the states of Punjab, Haryana, Union territories of Chandigarh and Delhi, and Sri Ganganagar district of Rajasthan. The total area under the rice-wheat system in this region is about 2.11 m ha and is entirely grown under irrigated conditions. The system productivity (rice + wheat yield) is 6 t/ha (17). However, a stagnating or declining trend in productivity and profitability of rice-wheat system has been reported in the region due to several soil and water related constraints (2,7,16,17). Further, the rapid decline in ground water table has been attributed to the heavy and frequent irrigation to rice in this semi-arid region (9). Water conservation techniques in rice and diversification of the rice-wheat system may help sustain the productivity, improve soil fertility, conserve valuable water resources and increase the profitability of the system (7,13). Growing short duration potato, vegetable or legumes in rice-wheat system may ameliorate soil fertility and break the cycle of weed and disease complex as against continuous rice-wheat system over extended period of time (9,10). Therefore, a field experiment was conducted on diversified rice-wheat cropping system involving potato, vegetable peas and groundnut, and water management treatments in rice to increase the production, economics and water use efficiency.

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MATERIAL AND METHODS

Field experiment was conducted at the Central Potato Research Station, Jalandhar during 2000-2003. Treatments were combinations of four cropping systems and two methods of irrigation to rice. Three annual cropping systems were rice-wheat, rice-potato-wheat and rice-vegetable pea-wheat, and there was a three-year interventional cropping system of rice/groundnut/rice (R/G/R)-potato-wheat. The two methods of irrigation to rice were traditional method of irrigation in which after initial period of submergence for two weeks after transplanting, irrigations (5 cm each) were repeated after 24-48 h of disappearance of ponded water (DP), and a new method of irrigation in which after initial period of submergence for two weeks after transplanting, irrigations (5 cm each) were given for alternate wetting and drying at appearance of hair line cracks (HC) in soil (15). Eight treatment combinations were laid out in a randomized complete block design with 3 replications. The plot size was 5 x 6 m². Treatment details about varieties of different crops, water management, fertilizers applied, and dates of planting/harvesting are given in Table 1. The plant stand per unit area and other cultural practices were followed as per the recommendations for the zone. After harvesting of the crops, the grain/tuber and straw/haulm yields were recorded. Dry samples of grain, tuber, straw and haulms were analyzed for total N, P and K (6). Soil samples (0-15 cm deep) were taken before and after the experiment, and analyzed for organic carbon, available N (alkaline permanganate extractable), available P (0.5 M sodium bicarbonate extractable) and available K (ammonium acetate extractable) as per standard procedures (6). The experimental soil contained 0.35 percent organic carbon, and 210, 24 and 224 kg/ha of available N, P and K, respectively. Water use economy and weed population were also recorded. Climatological data of mean weekly maximum and minimum temperature and total rainfall from standard week 21st in a calendar year to 20th standard week of the next year comprising a single crop calendar year for 2000-01 to 2002-03 of the experiment are given in Fig. 1. Recommended plant protection measures were taken in all the crops against pests and diseases.

Productivity and production efficiency, land use efficiency, profitability and economic efficiency and soil nutrient balance were calculated by the following procedures.

Fig. 1. Climatological data pertaining to the three crop calendar years of the experiment.
<table>
<thead>
<tr>
<th>Cropping systems*, cultivars and irrigation treatments</th>
<th>Fertilizers applied (N-P-K kg/ha)</th>
<th>Sowing/ transplant dates</th>
<th>Harvesting date</th>
<th>Land used (days/yr.)</th>
<th>Irrigation frequency and total water used (mm/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kharif</td>
<td>Rabi</td>
<td>Kharif</td>
<td>Rabi</td>
<td>Kharif</td>
</tr>
<tr>
<td>Rice (DP)-Wheat; (PR115)-(PBW 343)</td>
<td>120-60-60</td>
<td>120-60-60</td>
<td>25/6</td>
<td>12/11</td>
<td>5/10</td>
</tr>
<tr>
<td>Rice (DP)-Potato- Wheat; (PR115)- (K. Jyoti)-(PBW373)</td>
<td>120-60-60</td>
<td>180-80-150</td>
<td>80-60-60**</td>
<td>25/6</td>
<td>11/10</td>
</tr>
<tr>
<td>R/G/R(DP)- Potato-Wheat; (PR115)- (K. Jyoti)-(PBW373)/(M335)</td>
<td>120-60-60</td>
<td>180-80-150</td>
<td>15-20-25</td>
<td>25/6</td>
<td>11/10</td>
</tr>
<tr>
<td>Rice (DP)- Veg. peas- Wheat; (PR115)- (Arkel)-(PBW373)</td>
<td>120-60-60</td>
<td>25-70-70</td>
<td>80-60-60**</td>
<td>25/6</td>
<td>10/10</td>
</tr>
<tr>
<td>Rice (HC)- Wheat; (PR115)- (PBW 343)</td>
<td>120-60-60</td>
<td>120-60-60</td>
<td>25/6</td>
<td>12/11</td>
<td>5/10</td>
</tr>
<tr>
<td>Rice (HC)- Potato- Wheat; (PR115)- (K. Jyoti)-(PBW373)</td>
<td>120-60-60</td>
<td>180-80-150</td>
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<td>11/10</td>
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<td>120-60-60</td>
<td>180-80-150</td>
<td>15-20-25</td>
<td>25/6</td>
<td>11/10</td>
</tr>
<tr>
<td>Rice (HC)- Veg. peas- Late wheat; (PR115)- (Arkel)- (PBW373)</td>
<td>120-60-60</td>
<td>25-70-70</td>
<td>80-60-60**</td>
<td>25/6</td>
<td>10/10</td>
</tr>
</tbody>
</table>

* Water management aspect dealt with irrigation at disappearance of ponded water (DP) and at hairline cracks in soil (HC) to rice as indicated. **Wheat after potato is recommended only 2/3 of the recommended nitrogen to main crop of rabi wheat.

¹Three year interruptive cropping system having rice/groundnut/rice crops in kharif season. Groundnut was raised in second year.
Productivity and production efficiency: The yields of all the crops were converted into rice equivalent yield (REY) (4). Sale price of crop commodities for calculating equivalent yield were: rice grains = Rs. 5400/t; groundnut kernel = Rs. 10600/t; potato tuber = Rs. 3000/t; wheat grain = Rs.6000/t; vegetable peas = Rs. 8000/t; rice straw =Rs. 470/t; and wheat straw =Rs. 600/t. The data on REY of individual years was subjected to pooled analysis after applying the ‘Bartlett test’ for homogeneity of variances (5). Production efficiency (PE) was computed by the following formula:

\[
\text{PE (\%)} = \left( \frac{(\text{REY}_{IS} - \text{REY}_{TS})}{\text{REY}_{TS}} \right) \times 100
\]

where \(\text{REY}_{IS}\) is REY in intervention system and management, \(\text{REY}_{TS}\) is REY in traditional rice-wheat system, and water management as in DP method of irrigation to rice.

Land use efficiency: The land use efficiency was calculated by dividing the total duration of the crops by 365 days expressed as percentage (14).

Profitability and economic efficiency: Economic efficiency (EE) was calculated by the following formula:

\[
\text{EE (\%)} = \left( \frac{(\text{NR}_{IS} - \text{NR}_{TS})}{\text{NR}_{TS}} \right) \times 100
\]

where \(\text{NR}_{IS}\) is NR in intervention system and management, \(\text{NR}_{TS}\) is NR in traditional rice-wheat system and water management as in DP method of irrigation to rice.

Soil nutrient balance: The apparent soil nutrient balance (gain or loss) was calculated by the following formula.

Nutrient balance = (Status at the end of experiment – Available nutrient at start) + (Total nutrients applied – Total uptake by the crops).

RESULTS AND DISCUSSION

The cropping system productivity, efficiencies and economics reported here were calculated from the pooled data over the two irrigation systems tried.

System productivity and production efficiency: The mean total REY was maximum in rice/groundnut/rice (R/G/R)-potato-wheat (24.60 t) system, which was at par with rice-potato-wheat (24.27 t) followed by rice-vegetable peas-wheat (19.02 t), and rice-wheat (11.63 t) system (Table 2). In the pooled analysis of REY, year x treatment interaction was not significant. This may be attributed to irrigated nature of all the component crops in various systems and similar climatological conditions during the period of experimentation (Fig. 1).

Inclusion of potato and vegetable peas increased the mean PE over the rice-wheat system by 109 and 63 percent, respectively (Table 2), while inclusion of groundnut once in three years in R/G/R-potato-wheat increased the PE by 111 percent. Productivity and PE was not affected by irrigation treatments to rice. Results indicated the utility of potato, vegetable peas and groundnut for diversification of rice-wheat system. Value of potato in diversification of rice-wheat system has been reported earlier (8,11). Irrigating at hairline cracks (HC) in soil or at saturation soil moisture has been reported to give grain yields at par with continuous submerged conditions in rice (13,15).

Land use efficiency: The land use efficiency ranged from 74.0 to 87.0 percent in different cropping systems. The highest land use efficiency (87.0%) was recorded in rice/groundnut/rice (R/G/R)-potato-wheat followed by rice-vegetable peas-wheat (84.9%), rice-potato-wheat (84.7%) and the lowest in rice-wheat (74.0%) system (Table 2).

Profitability and economic efficiency: The rice-vegetable peas-wheat system (Rs.67540 /
Table 2. Effect of cropping systems and water management treatments to rice on mean productivity, production efficiency, land use efficiency, profitability and economic efficiency

<table>
<thead>
<tr>
<th>Treatments (cropping systems)*</th>
<th>Mean** grain/tuber yield (t/ha)</th>
<th>Rice equivalent yield (t/ha/yr)</th>
<th>Production efficiency (%)</th>
<th>Land use efficiency (%)</th>
<th>Cost of cultivation (Rs/ha/yr)</th>
<th>Net returns (Rs/ha/yr)</th>
<th>B:C ratio</th>
<th>Economic efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kharif</td>
<td>Rabi</td>
<td>Late Rabi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice (DP)-Wheat</td>
<td>4.85</td>
<td>4.87</td>
<td>-</td>
<td>11.75</td>
<td>-</td>
<td>74.0</td>
<td>24463</td>
<td>38819</td>
</tr>
</tbody>
</table>
| Rice (DP)-Potato-Wheat        | 4.54   | 26.91| 3.02      | 24.14                | 105.47                      | 84.7                    | 66134                 | 64246                 | 1.97                   | 65.50
| R/G/R² (DP)-Potato-Wheat      | 2.35   | 26.97| 3.11      | 24.61                | 109.43                      | 87.0                    | 65255                 | 67493                 | 2.03                   | 73.87
| Rice (DP)-Veg. peas-Wheat     | 4.80   | 6.43 | 3.13      | 19.02                | 61.87                       | 84.9                    | 35150                 | 67570                 | 2.92                   | 74.06
| Rice (HC)-Wheat               | 4.40   | 5.05 | -         | 11.51                | -2.08                       | 74.0                    | 24643                 | 37499                 | 2.52                   | -3.46
| Rice (HC)-Potato-Wheat        | 4.66   | 26.81| 3.17      | 24.39                | 107.35                      | 84.7                    | 66134                 | 65566                 | 1.99                   | 68.90
| R/G/R² (HC)-Potato-Wheat      | 2.42   | 27.82| 3.10      | 24.59                | 109.25                      | 87.0                    | 65255                 | 67355                 | 2.03                   | 73.51
| Rice (HC)-Veg. peas-Wheat     | 4.65   | 6.50 | 3.14      | 19.01                | 61.78                       | 84.9                    | 35150                 | 67510                 | 2.92                   | 73.91
| CD (P ≤ 0.05)                 | 1.24   |      |           |                      |                             |                         | 4593                  |                       |                        |

* Water management aspect dealt with irrigation at disappearance of ponded water (DP) and irrigation at hairline cracks in soil (HC) to rice as indicated.
** Mean of three years.
1 Three-year interruptive cropping system having rice/groundnut/rice crops in kharif. Groundnut was raised in second year.
2 Includes groundnut kernel yield of 2.14 and 2.19 t/ha in treatments.
J.P. Singh et al.

ha/yr) maximized the mean net returns followed by R/G/R-potato-wheat (Rs.67424/ha/yr) and rice-potato-wheat (Rs. 64906/ha/yr), which were at par as against the traditional rice-wheat (Rs.38159/ha/yr) system (Table 2). Higher sale price of vegetable peas coupled with lower cost of cultivation may be attributed for higher net returns in rice-vegetable peas-wheat system. However, for diversification of rice-wheat, potato was equally efficient giving similar net return. The irrigation treatments to rice did not influence the profitability (Table 2).

The mean benefit:cost ratio (B:C) was maximized by rice–vegetable peas-wheat (2.92) followed by rice-wheat (2.55), R/G/R-potato-wheat (2.03) and rice-potato-wheat (1.98) system (Table 2). Irrigation treatment to rice did not influence the B:C ratio in different cropping systems. The mean economic efficiency in rice-vegetable peas-wheat, R/G/R-potato-wheat and rice-potato-wheat was 77.0, 76.7 and 70.0 percent more than the traditional rice-wheat system, respectively (Table 2).

Water use economy: The HC (irrigation at hairline cracks in soil) method of irrigation to rice saved 20.5 percent water on an average over the cropping systems as compared to irrigation at disappearance of ponded water (DP). The mean total water use in HC method was 1262 mm as against 1587 mm/ha in the DP method (Table 1).

Weed infestation: Weed infestation in various diversified rice-wheat cropping systems was less than that in rice-wheat system, which recorded a mean weed dry matter of only 5.1 g/m² at 30 days of sowing of wheat. However, the differences were not significant (data not presented). The low weed infestation may be attributed to the history of the experimental field, which was under seed potato cultivation for several years before the start of the experiment. Cultural practices of potato inhibits the common and problematic weeds of rice-wheat system particularly Phalaris minor (10,17).

Soil fertility and nutrient balance: The soil (0-15 cm deep) analysis after three years showed decline in available K and buildup of available P (Table 3). Mean decline in available K content in surface soil (0-15 cm deep) ranged from 4.0 to 12.0 percent in different cropping systems (Fig. 2). The decline was least in rice-vegetable peas-wheat system and maximum in rice-wheat system (Fig. 2). All the cropping systems showed a build up of available P in soil ranging from 41.7 to 62.5 percent (Fig. 2). Organic carbon in soil decreased from the initial values in surface soil without affecting available N (Table 3). However, the differences were not significant. Similar results have been reported earlier (1, 2).

![Available soil K](image1)

![Available soil P](image2)

Fig. 2. Status of available P and K in different cropping systems compared to initial soil test values. CS1: rice-wheat, CS2: rice-potato-wheat, CS3: rice/groundnut/rice-potato-wheat and CS4: rice-vegetable peas-wheat.
Nutrient balance of K in soil was negative in all the cropping systems ranging from 242.8 to 440.0 kg/ha, the maximum being in rice-wheat with irrigation to rice at hairline cracks in soil (Table 3). Similarly, the nutrient balance of P in soil was positive in all the cropping systems ranging from 57.6 to 151.1 kg/ha, the maximum being in rice-vegetable peas-wheat system with HC method of irrigation to rice (Table 3). In long term studies, severely negative balance of K has been reported in rice-wheat cropping system (2, 12).

The negative balance of K and positive balance of P in soils explained the decline and build up of available K and P in the soil, respectively. Results indicate the need to augment the fertilization of potash to different crops in diversified rice-wheat cropping system to sustain the productivity in the long run. At the same time, there is some scope of reducing the costly phosphorus fertilization in these cropping systems to increase the system productivity and profitability in the long run. High P in soil is not desirable as it decreases the availability of Zn, Mn, Fe and Cu in soil by forming insoluble phosphates with these elements resulting in reduced yield of many crops (3).

It may be concluded that diversified cropping systems including potato, vegetable peas and groundnut crops enhanced the mean productivity (rice equivalent yield) and profitability (net returns) over the traditional rice-wheat system by 95 and 75 percent, respectively. The rice-vegetable peas-wheat and rice-potato-wheat were the most productive and profitable annual diversified cropping systems. Growing groundnut as an interruptive crop once in three years in place of rice in rice-potato-wheat further improved the productivity and profitability. Water use in rice could be reduced to the extent of 20.5 percent by irrigating the crop at appearance of hair line crack (HC) in the soil.

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LITERATURE CITED


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