Hindawi Publishing Corporation
International Journal of Agronomy
Volume 2014, Article ID 740656, 5 pages
http://dx.doi.org/10.1155/2014/740656

Research Article

Evaluation of Agronomic Management Practices on Farmers' Fields under Rice-Wheat Cropping System in Northern India

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Received 26 June 2013; Accepted 12 November 2013; Published 30 January 2014

Academic Editor: Othmane Merah

Rice (*Oryza sativa L.*)-wheat (*Triticum aestivum L. emend. Fiori and Paol.*) is the most important two crops a year intensive rice based cropping system of Asia. Agronomic management is the most important input for getting potential yield and high net returns in any crop or crop sequence. Most of the farmers used to grow old varieties of rice and wheat without any row arrangement. Fertilization is mainly limited to nitrogenous fertilizer only. Therefore, the present study was undertaken to find out the effect of different agronomic management practices on productivity and economics of rice-wheat system at farmers' fields. Inclusion of improved variety in rice and wheat incurred additional cost of \$52/ha and provided additional return of \$101/ha, whereas sowing/transplanting of rice and wheat in lines incurred additional cost of \$30/ha and resulted in additional returns of \$146/ha. Balanced fertilization incurred additional cost of \$38 over the imbalanced fertilization and provided additional returns of \$180/ha. Recommended package of practices (improved variety, line sowing/transplanting and balanced fertilization) incurred additional cost of cultivation of \$120/ha over the farmers' practice and achieved additional net returns of \$426/ha.

1. Introduction

Rice (*Oryza sativa L.*)-wheat (*Triticum aestivum L. emend. Firori and Paol.*) is the most important two crops a year intensive rice based cropping system of Asia; a third of the irrigated rice and half of the irrigated wheat in South Asia come from this cropping system [1, 2]. Available estimates show that 12 million hectares (m ha) of this cropping system exist in four countries of South Asia: 9.4 m ha in India, 1.5 m ha in Pakistan, 0.6 m ha in Bangladesh, and 0.5 m ha in Nepal [3]. There are about 9 m ha in China [4] of this cropping system. In this cropping system, rice is grown during rainy season (June to November) and wheat during the winter season (November to April). This is an intensive cropping system and its productivity varies from 5 to 10 metric tons of grains per hectare per year.

Agronomic management is the most important input for getting potential yield and high net returns in any crop or crop sequence. Rice-wheat is the most predominant cropping system of the northern plains of India. Most of the farmers used to grow old varieties of rice and wheat without any row arrangement. Fertilization is mainly limited to nitrogenous fertilizer only. Due to heavy depletion of plant nutrients, soils and the system show signs of fatigue, and there is a general decline in yield of rice and wheat [5] and a decrease in partial factor productivity of the fertilizer applied [6]. All of these together contribute to low productivity of crops. During 2008-2009, productivity of rice and wheat in Uttarakhand was 19.66 q/ha and 20.02 q/ha, respectively, while it was 22.02 q/ha and 28.02 q/ha for the country as a whole during 2007-2008. Ratio of NPK use in the state has been 8.9 : 2.4 : 1 during 2008-2009 instead of the recommended 4 : 2 : 1 [7].

Therefore, the present study was undertaken to find out the effect of different agronomic management practices (improved varieties, proper plant spacing, and balanced fertilization) on productivity and economics of rice-wheat system on the farmers' fields.

2. Materials and Methods

The experiment was conducted on farmers' fields, for four consecutive years from 2006-2007 to 2009-2010. Total of

Table 1

Treatment	Details of the treatment
T_1	Farmers' practices (in general, no line sowing/transplanting, old varieties, and imbalanced fertilizer use, i.e., very low or no application of phosphorus and potassium)
T_2	Farmers' practices except improved varieties
T_3	Farmers' practices except improved varieties and proper plant spacing by line sowing/transplanting
T_4	Recommended practices, that is, improved varieties, proper plant spacing by line sowing/transplanting, and balanced fertilization

eighteen farmers were selected taking a single farmer as a replication from the six different blocks of district Dehradun and Pauri (Uttarakhand, India) for the study. Four treatments were evaluated in randomized block design; details of treatment are shown in Table 1.

Under the treatment T_3 and T_4 transplanting of rice was done at the spacing of 20 × 10 cm while the wheat crop was sown at 23 cm row spacing. In treatment T_4 the rice and wheat crops were fertilized as per the recommendations for the respective varieties. During the rainy season (*kharif*), rice was grown and during the succeeding winter season (*rabi*), wheat was grown under the rice-wheat cropping system continuously for four years of experimentation. During the rainy season, after taking the soil samples, the land was diced twice, flooded, and puddled several times; the land was then leveled and flooded before transplanting of rice seedlings. After rice harvest, the field was given a presowing irrigation where it was needed and when the soil came to condition, it was diced twice and leveled before sowing of wheat crop.

During 2006-2007, Pant Dhan 12 and PBW 343 were taken as improved varieties in rice and wheat, respectively, while during the next year, rice variety PR 113 and wheat variety UP 2572 were taken as improved ones. During 2008-2009, Pusa Sugandh 5 and PBW 502 were taken as improved varieties in rice and wheat, respectively, while during the next year, rice variety Pusa Sugandha 4 in district Dehradun and Pant Sankar Dhan 3 in district Pauri and wheat variety PBW 550 were taken as improved ones.

A uniform application of zinc sulphate @ 25 kg per hectare was done irrespective of treatments before transplanting of rice crop. The data was recorded on grain and straw yield. Cost of cultivation and gross returns were calculated as per the prevailing market prices of inputs and the produce. The rice equivalent yield was calculated on the basis of the average price of rice and wheat grain at eighteen locations during the year 2009-2010 in districts Pauri and Dehradun. The average price calculated for rice was \$21/q and for wheat it was \$22.1/ha.

Soils of the experimental sites were analysed during all the years of experimentation before sowing of *kharif* crop. In general, the soils were medium in organic carbon, low in available nitrogen, and medium in available phosphorus and potassium.

The data was analysed statistically as per the procedure given by K. A. Gomez and A. A. Gomez [8]. The sustainability index was calculated using the formula as adopted by Gangwar et al. [9].

3. Results

The data of four years (2006 to 2010) was pooled together for the analysis and depicted in Tables 2, 3, and 4.

3.1. Rice. Inclusion of improved variety in farmers' practice (treatment T_2) increased the grain yield (4197 kg/ha) significantly over the farmers' practice (treatment T_1) (3941 kg/ha). When farmers' practice was practiced with improved variety along with transplanting in lines (treatment T_3), it resulted in a significant increase in grain yield of rice (594 kg/ha) over the farmers' practice (treatment T_1).

Highest grain yield of rice (5108 kg/ha) was recorded with the treatment T_4 having all recommended management practices, that is, improved variety, transplanting in lines, and balanced fertilization, and it was significantly higher over the remaining management practices.

Again the highest straw yield (6703 kg/ha) was recorded with the treatment T_4 and it was superior to the rest of the treatments for the straw yield. Straw yield did not increase significantly over the farmers' practice by inclusion of improved variety alone, but it increased with the inclusion of improved variety along with (5911 kg/ha) transplanting of rice in lines. However, when all recommended management practices were followed (T_4), the increase in straw yield was found to be significant over the rest of the treatments.

Cost of cultivation increased significantly by inclusion of improved variety in farmers' practice (T_2); however, cost of cultivation did not increase further when transplanting was done in lines along with the improved variety (T_3). Highest cost of cultivation (\$410 per hectare) was observed with the treatment T_4 having all recommended management practices, that is, improved variety, transplanting in lines, and balanced fertilization, and it was higher than the rest of the treatments.

Net and gross returns in rice crop increased significantly by the replacement of old varieties with the improved ones by \$39 and \$47 per hectare, respectively. When transplanting was done in lines using improved variety, it resulted in a significant increase of \$57 and \$70 per hectare of net and gross returns, respectively, over the treatment having improved variety but transplanting without row arrangement. Highest net and gross returns were recorded with the treatment T_4 having all recommended management practices (\$572/ha and \$981/ha, resp.). The net and gross returns under this treatment were found to be significantly higher than the remaining treatments.

Use of improved rice variety incurred additional cost of cultivation of \$9 and provided additional net returns of \$39. When the rice crop was transplanted in lines, it incurred additional cost of cultivation by \$13 and provided additional net returns of \$57/ha. Balanced fertilization resulted in additional cost of cultivation by \$22/ha and provided

Table 2: Grain and straw yield and economics of different agronomic management practices in rice crop (pooled data of four years).

Agronomic management practices	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation ($*/ha)	Net returns ($/ha)	Gross returns ($/ha)	Incremental net returns ($/ha)	B : C ratio
T_1	3941	5207	366	398	765	—	1.08
T_2	4197	5478	375	437	812	39	1.16
T_3	4535	5911	388	494	882	96	1.27
T_4	5108	6703	410	572	981	173	1.39
SEm	68	97	2	10	11	—	—
cd at 5%	192	276	6	28	32	—	—

$*: US dollar and 1 US $equals 53 Indian rupees.

Table 3: Grain and straw yield and economics of different agronomic management practices in wheat crop (pooled data of four years).

Agronomic management practices	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation ($/ha)	Net returns ($/ha)	Gross returns ($/ha)	Incremental net returns ($/ha)	B : C ratio
T_1	3203	4107	333	577	911	—	1.73
T_2	3464	4387	347	639	986	62	1.84
T_3	3802	4777	364	728	1092	151	1.99
T_4	4254	5392	380	830	1210	252	2.18
SEm	49	74	2	13	15	—	—
cd at 5%	139	209	5	38	41	—	—

additional net returns of $78. Recommended package of practices, that is, improved variety, transplanting in lines, and balanced fertilization (treatment T_4), incurred additional cost of cultivation of $44/ha and provided additional net returns of $78/ha over the farmers' practices.

Several other workers also reported that improved variety, transplanting in lines, and balanced fertilization resulted in higher grain and straw yield which in turn increased net and gross returns in rice crop [10, 11].

Highest B : C ratio (1.39) was recorded with the treatment T_4 and it was followed by the treatments T_3 (1.27), T_2 (1.16), and T_1 (1.08).

3.2. Wheat. Grain as well as straw yield of wheat increased significantly when the improved variety of wheat was taken (treatment T_2) in place of old varieties under farmers' practice (treatment T_1). Grain as well as straw yields further increased significantly when the improved variety was sown in lines (treatment T_3) over the broadcast sown improved variety (treatment T_2). Highest grain and straw yields of wheat (4254 and 5392 kg/ha, resp.) were recorded when all recommended management practices were followed, that is, improved variety, line sowing, and balanced fertilization under the treatment T_4 (Table 3).

Cost of cultivation of wheat crop increased significantly by use of improved variety in place of old variety by $14, but it also provided significantly higher net returns by $62 per hectare. Line sowing of wheat crop significantly increased the cost of cultivation by $17 per hectare and it also resulted in significantly higher net returns by $151 per hectare. Balanced use of fertilizers significantly increased the cost of cultivation by $16 per hectare and provided significantly higher and additional net returns by $102 per hectare.

Additional net returns of $47 per hectare over the farmers' practice were recorded when all recommended management practices were followed, while the use of improved variety along with line sowing provided additional net returns of $31 per hectare over the farmers' practice. Use of improved variety provided additional returns of $14/ha over the farmers' practices.

Similar findings have also been reported that recommended package of practices resulted in higher mean grain yield and net returns compared to farmers' practice [12]. Increased net and gross returns by use of improved variety, line sowing, and balanced fertilization have also been reported by other workers [11, 13].

Highest B : C ratio (2.18) was recorded with the treatment T_4 and it was followed by treatment T_3 (1.99), treatment T_2 (1.84), and treatment T_1 (1.73).

3.3. Rice-Wheat System. Lowest rice equivalent yield (REY) of rice-wheat system (7311 kg/ha) was recorded with the farmers' practices. REY increased by 530 kg/ha by inclusion of improved varieties in rice and wheat. Sowing/transplanting of rice and wheat in lines provided additional REY by 694 kg/ha. Balanced fertilization in rice-wheat system provided additional REY of 1048 kg/ha. Highest system productivity (26.3 kg/ha) was recorded with the treatment having all recommended package of practices and the lowest with the farmers practice (20.0 kg/ha/year). Inclusion of improved varieties in rice and wheat increased the system productivity up to the level of 21.5 kg/ha/year. Use of improved varieties

Table 4: Economics of rice-wheat system under different agronomic management practices (pooled data of four years).

Agronomic management practices	Rice equivalent yield of the system (kg/ha)	System productivity (kg/ha/day)	Cost of cultivation ($/ha)	Net returns ($/ha)	Gross returns ($/ha)	Incremental net returns ($/ha)	B : C ratio	Sustainability index
T_1	7311	20.0	670	976	1675	—	1.39	0.82
T_2	7841	21.5	722	1076	1798	101	1.49	0.86
T_3	8535	23.4	752	1222	1974	246	1.62	0.88
T_4	9583	26.3	790	1402	2192	426	1.77	0.81
SEm	—	—	3	22	24	—	—	—
cd at 5%	—	—	10	62	69	—	—	—

along with sowing/transplanting in lines further increased the system productivity to 23.4 kg/ha/year.

Cost of cultivation increased significantly by $52 per hectare by the incorporation of improved varieties in farmers' practice, and it also resulted in significantly higher net and gross returns by $100/ha and $123/ha, respectively. Inclusion of line sowing/transplanting in rice-wheat system resulted in significantly increased cost of cultivation by $30/ha only and it also resulted in significantly increased net and gross returns by $146/ha and $176/ha, respectively. The treatment having all the recommended management practices (T_4) had significantly higher cost of cultivation ($790/ha) and net returns ($1402/ha) over the rest of the treatments.

Inclusion of improved variety in rice and wheat incurred additional cost of $52/ha and provided additional return of $101/ha, whereas sowing/transplanting of rice and wheat in lines incurred additional cost of $30/ha and resulted in additional returns of $146/ha. Balanced fertilization costed more by $38/ha over the imbalanced fertilization and provided additional returns of $180/ha. Recommended package of practices (treatment T_4) incurred additional cost of cultivation of $120/ha over the farmers' practice and achieved additional net returns of $426/ha. Incremental net returns of $246/ha were recorded in treatment T_3 having improved variety and line sowing/transplanting over the farmers' practice (treatment T_1), whereas incremental net returns of $101/ha were recorded in treatment T_2 having the improved variety over the farmers' practice.

Highest B : C ratio of 1.77 was recorded with the treatment having all the recommended management practices and it was followed by treatment T_3 (1.62) having improved variety and line sowing/transplanting with farmers' practice, treatment T_2 (1.49) having improved varieties with farmers' practice, and treatment T_1 (1.39) having farmers' practice.

Highest relative economic efficiency (47.7%) of the rice-wheat system was recorded with the treatment having all the recommended management practices, and it was followed by treatment T_3 (25.3%) having improved varieties as well as line sowing/transplanting and treatment T_2 (10.3%) having improved varieties.

Treatment T_4 having the improved variety, line sowing/transplanting, and balanced fertilization had a relative production efficiency 31.0%. Treatments T_2 and T_1 also had positive figures of relative production efficiency of 16.7% and 7.2%, respectively.

Sustainability index varied from 0.81 (treatment T_4) to 0.88 (treatment T_3). Treatment T_1 and treatment T_2 have sustainability index of 0.82 and 0.86, respectively. So, not much variation between treatments for sustainability suggests less variation in sustainability between treatments.

4. Conclusion

The findings of the present study envisage that for feeding the ever growing population and to earn higher returns, farmers should adopt the recommended management practices for rice-wheat cropping system.

The management practices increased productivity and ultimately the returns from each incremental change, with the recommendation that adoption of some of the practices would result in increased yields and returns.

However, the resource poor and marginal farmers who cannot afford to adopt the full package of recommended management practices should go for as much as affordable management practices (improved varieties, proper spacing, and recommended fertilization).

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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