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Productivity, Profitability and Energy Efficiency Analysis of Rice-Wheat Cropping System in Mid Hills of Himachal Pradesh

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***Abstract*:** A field experiment was conducted to evaluate the productivity, profitability and energy efficiency analysis of rice-wheat cropping system on a silty clay loam soil of Himachal Pradesh. Tillage options had no significant effect on the grain yield of wheat while significantly higher grain yield of rice was recorded in conventional tillage as compared to zero tillage. Zero tillage resulted in higher net returns per rupee invested as compared to conventional tillage whereas among nutrient management practices, N-rich plot recorded maximum net returns per rupee invested as compared to other treatments in rice-wheat cropping system. Maximum energy input and output was obtained in conventional tillage followed by zero tillage. However, energy use efficiency and energy productivity was highest in zero tillage as compared to conventional tillage. In case of nutrient management practices, energy use efficiency and energy productivity was maximum in SSNM + Green Seeker with top dressing of nitrogen before irrigation followed by other treatments.

***Keywords*:** Rice, Wheat, Conventional tillage, Zero tillage and nutrient management

The rice–wheat is the predominant cropping system of Indo-Gangetic plains of India, covering about 10.5 million ha area and contributing about 38% to the national food basket (Gangwar 2009). The system is considered as the backbone for food grain security. Farmers realize much of their food security from this cropping system. This is also an important cropping system in Himachal Pradesh. The productivity of both rice and wheat is low in this country which may be due to poor soil fertility and inadequate, imbalanced and inefficient use of fertilizers (Yadav et al 2000). The tillage practices play an important role in influencing crop growth, yield and crop's micro-environment. It is an integral part of cropping system aimed at optimizing crop production by solving specific soil related ecological constraints. Soil tillage systems such as zero and conventional tillage are considered important soil management practices. These practices alter the soil physical environment and affect the plant and root growth, thereby, water and nutrient uptake and crop yields. Energy is one of the most valuable inputs in agriculture for crop production. Agriculture itself is an energy consumer and energy supplier in the form of bio-energy (Alam et al 2005). Sufficient availability of the right energy and its effective and efficient use are prerequisites for improved agricultural production. Agricultural intensification requires more energy and energy input pattern for crop production depends on economic, technological and social constraints. Commercial and noncommercial energy are available in agricultural operations. Commercial energy inputs arrive on farm in many different forms, e.g. fuel, irrigation water, chemical fertilizer, machinery and pesticides (Khan and Hussain 2007). Energy analysis, therefore, is necessary for efficient management of scarce resources for improved agricultural production. Hence, the present study was carried out with the objective to analyze the profitability, input, output and net return energy of different tillage methods with nutrient management treatments.

MATERIAL AND METHODS

The field experiment was conducted for two years from *Rabi* (wheat) season of 2015-16 through *Kharif* (rice) at CSK Himachal Pradesh Krishi Vishvavidyalaya at Rice and Wheat Research Centre, Malan situated at 32°07' N latitude, 76°23'E longitude and at an altitude of 950 m above mean sea level. The area receives a high rainfall that ranges between 1500-2500 mm per annum, of which 80 per cent is received during monsoon months from June to September. The soil of the experimental site was silty clay loam in texture, acidic in reaction, high in organic carbon, medium in available nitrogen, high in available phosphorus and medium in available potassium. The experiment was laid out in strip plot design with tillage in horizontal plot and nutrient management in vertical plot with three replications. The experiment consisted of 10 treatments combinations comprising five nutrient management practices in wheat *i.e.* recommended fertilizer dose (120:60:30 kg ha^{-1} NPK) with top dressing of nitrogen after irrigation; recommended fertilizer dose with top dressing of nitrogen before irrigation; fertilizer dose as recommended by software Nutrient Expert – Wheat (125:45:78 kg ha^{-1} NPK) with top dressing of nitrogen before irrigation; Nutrient Expert – Wheat guided fertilizer dose (70% nitrogen recommended by software and rest with green seeker technology) with top dressing of nitrogen before irrigation and N-rich plot which received 150% of recommended nitrogen with top dressing of nitrogen before irrigation with two tillage options *i.e.* conventional tillage and zero tillage. In rice only tillage practices were studied as trial was laid out in fixed plots. Rice was uniformly fertilized. Wheat crop variety HPW 349 was sown at a spacing of 20 cm using a seed rate of 100 kg ha^{-1}. HPR 2795 (Him Palam Lal Dhan 1) variety of rice was used for sowing. Nutrient management in wheat was as per the details given in Table 1. Rice was fertilized with uniform application of 60 kg N, 30 kg P_2O_5 and 30 kg K_2O per hectare in the form of urea (46%), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively. Wheat received five irrigations, first irrigation was given at CRI stage (21 days after sowing) and subsequent irrigations were applied at tillering stage (40–45 days after sowing), late jointing stage (70–75 days after sowing), flowering stage (90–95 days after sowing) and dough stage (110–115 days after sowing) and in each irrigation 5±0.5 cm water was applied. Rice was irrigated as and when needed. In zero tillage, glyphosate 3 l ha^{-1} was applied prior to wheat and rice to tackle weed menace. Net returns per rupee invested were worked out by dividing net returns (Rs ha^{-1}) with cost of cultivation (Rs ha^{-1}).To study the energy input and output of crop, a complete inventory of all crop inputs (fertilizers, seeds, plant protection chemicals, fuels, human labour and machinery power) and outputs of both main and by-products was taken into account which are given in Table 5 (Singh and Mittal 1992). Inputs and outputs were converted from physical to energy unit measures through published conversion coefficients (Devasenapathy et al 2009 and Tuti et al 2013). The energy use efficiency and net energy was worked out as per Dazhong and Pimental (1984). Since data followed the homogeneity test, pooling was done over the seasons.

$$\text{Energy use efficiency} = \frac{\text{Total energy return (Output)}}{\text{Total input involved in term of energy (Input)}}$$

$$\text{Net energy} = \text{Energy Output (MJ ha}^{-1}\text{)} - \text{Energy Input (MJ ha}^{-1}\text{)}$$

$$\text{Energy productivity} = \frac{\text{Wheat equivalent yield (kg ha}^{-1}\text{)}}{\text{Energy input (MJ ha}^{-1}\text{)}}$$

RESULTS AND DISCUSSION

Yield of wheat and rice: Tillage options failed to produce significant variation on grain yield and straw yield of wheat. This showed that wheat sown either in conventional or zero tillage gave similar wheat yield. Similar results were reported across the country in different wheat producing zones (Anonymous 2016). Among nutrient management practices, N-rich plot while remaining at par with the application of recommended NPK where nitrogen was top dressed both after and before irrigation gave significantly higher grain yield and straw yield than the treatments which received fertilizer doses as recommended by Nutrient Expert – Wheat. The higher grain yield and straw yield recorded in nitrogen rich plot as well as with recommended dose may be due to the higher nitrogen application in these treatments (180 and 120 kg ha^{-1}) as compared to the nitrogen added on the basis of Nutrient Expert – Wheat and SSNM + Green Seeker which resulted in higher photosynthesis, which ultimately resulted in better growth and higher yield. Increase in grain yield of wheat with increasing nitrogen application has also been reported by Jat et al (2013).

Conventional tillage significantly increased the grain yield and straw yield of rice over zero tillage. The yield was higher with conventional tillage might be due to profuse root system and higher yield attributes under better soil condition as compared to zero tillage. In zero tillage higher immobilization of the nitrogen applied to wheat and high C: N ratio may be the reason of lower yield. Similar result was also reported by Singh et al (2006). Nutrient management practices adopted in wheat had no significant influence on grain yield of succeeding rice.

Economics of wheat and rice: In wheat, cost of cultivation

Table 1. Nutrient management in wheat for 2015-16 and 2016-17

Nutrient management	Tillage (2015-16)		Tillage (2016-17)	
	Conventional	Zero	Conventional	Zero
RFD – AI	120:60:30	120:60:30	120:60:30	120:60:30
RFD – BI	120:60:30	120:60:30	120:60:30	120:60:30
SSNM Nutrient Expert – BI	125:45:78	125:45:78	125:45:78	125:45:78
SSNM + Green Seeker – BI	101.4:45:78	100.3:45:78	94.1:45:78	95.9:45:78
N-rich plot – BI	180:60:30	180:60:30	180:60:30	180:60:30

*RFD: Recommended fertilizers dose; AI: Top dressing of nitrogen after irrigation; BI: Top dressing of nitrogen before irrigation

Table 2. Effect of treatments on yield of wheat and rice

Treatment	Wheat		Rice	
	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Tillage				
Conventional	4062	6450	4366	6354
Zero	3926	6255	4050	5928
CD (p=0.05)	NS	NS	200	271
Nutrient Management				
RFD – AI	4111	6517	4156	6011
RFD – BI	3966	6300	4153	6034
SSNM Nutrient Expert – BI	3893	6213	4240	6213
SSNM + Green Seeker – BI	3858	6142	4189	6106
150% RFD – BI	4145	6590	4301	6342
CD (p=0.05)	212	323	NS	NS

Table 3. Effect of treatments on economics of wheat and rice

Treatments	Wheat				Rice			
	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	Net returns per rupee invested	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	Net returns per rupee invested
Tillage								
Conventional	35553	109173	73621	2.07	32957	82677	49720	1.51
Zero	31399	105643	74245	2.37	28802	76777	47975	1.67
CD (p=0.05)		NS	NS	0.13		3298	NS	0.12
Nutrient management								
RFD – AI	33088	110420	77332	2.34	30880	78607	47727	1.55
RFD – BI	33088	106608	73520	2.23	30880	78626	47746	1.55
SSNM Nutrient Expert – BI	33670	104810	71141	2.11	30880	80397	49517	1.60
SSNM + Green Seeker – BI	33689	103777	70088	2.08	30880	79348	48468	1.57
150% RFD – BI	33844	111456	77613	2.29	30880	81659	50779	1.64
CD (p=0.05)		5083	5083	0.16		NS	NS	NS

Table 4. Effect of treatments on economics of rice-wheat cropping system

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	Net returns per rupee invested
Tillage				
Conventional	68509	191850	123340	1.80
Zero	60200	182419	122219	2.03
Nutrient management				
RFD – AI	63968	189026	125058	1.95
RFD – BI	63968	185233	121265	1.89
SSNM Nutrient Expert – BI	64550	185207	120657	1.87
SSNM + Green Seeker – BI	64569	183124	118555	1.84
150% RFD – BI	64724	193115	128391	1.98

and gross returns was highest in conventional tillage than zero tillage while net returns and net returns per rupee invested was incurred maximum under zero tillage as compared to conventional tillage, respectively which may be due to the lower cost of cultivation than conventional tillage. The higher cost of production under conventional tillage was due to more number of tillage operations, which diminished the net returns per rupee invested. Lower cost of cultivation in zero tillage resulted in higher net returns though the differences were not significant. Among nutrient management, significantly highest gross returns and net returns were observed in N-rich plot. However, statistically at par with application of recommended NPK where split dose of nitrogen was applied both after and before irrigation. The higher gross returns in these treatments were due to the higher grain yield and straw yield recorded in these treatments. Recommended NPK where split dose of nitrogen applied after irrigation recorded highest net returns per rupee invested and was statistically at par with recommended NPK where split dose of nitrogen applied before irrigation and N-rich plot. These results obtained in the present investigation are in accordance with those reported by Suryawanshi et al (2013) and Pandey et al (2018). Lowest gross returns and net returns per rupee invested were recorded under SSNM + Green Seeker with top dressing of nitrogen before irrigation. This was due to the lowest yield recorded in this treatment. In rice, maximum cost of cultivation, gross returns and net returns was recorded with conventional tillage (Rs. 32957 ha^{-1}, Rs 82677 ha^{-1}and Rs 49720 ha^{-1}) over zero tillage. However, zero tillage significantly increased the net returns per rupee invested (1.67) as compared to zero tillage (1.51). More number of tillage operations contributed greatly to cost of cultivation in any crop production system resulting to lower net returns per rupee invested. Among nutrient management, cost of cultivation is similar in all nutrient management practices as only tillage practices were studied in rice whereas N-rich plot recorded maximum gross returns, net returns and net returns per rupee invested.

Table 5. Equivalents for various sources of energy

Particulars	Units	Equivalent energy (MJ)
Inputs		
Human labour	Man-hour	1.96
Diesel	litre	56.31
Chemical fertilizers		
Nitrogen	kg	60.60
Phosphorus	kg	11.10
Potassium	kg	6.70
Chemicals (I) Superior chemicals (chemicals requiring dilution at the time of application)	kg	120
(ii) Inferior chemicals (chemicals not requiring dilution at the time of application)	kg	10
Output		
Grain yield (rice/wheat)	kg	14.7
Straw yield (rice/wheat)	kg	12.5

Source: Singh and Mittal (1992)

System economics: The conventional tillage resulted into higher cost of cultivation, gross returns and net returns (Table 4). Higher net returns per rupee invested were recorded with zero tillage than with conventional tillage. Among nutrient management, N-rich plot recorded maximum cost of cultivation but also resulted in higher gross returns, net returns and net returns per rupee invested followed by other treatments. Lowest values were recorded under SSNM + Green Seeker with top dressing of nitrogen before irrigation.

Energy indices of rice-wheat cropping system: The energy input for different tillage and nutrient management practices in rice-wheat system has been computed on the basis of two years (Table 6). Highest total input energy requirement was with conventional tillage (27.1 x 10^{3} MJ ha^{-1}) followed by zero tillage (24.3 x 10^{3} MJ ha^{-1}). Higher energy

Table 6. Effect of treatments on energy indices of rice-wheat system

Treatments	Total energy input (X 10^{3}MJ ha^{-1})	Total energy output (X 10^{3}MJ ha^{-1})	Net energy return (X 10^{3}MJ ha^{-1})	Energy use efficiency	Energy productivity (kg MJ^{-1})
Tillage					
Conventional	27.1	283.9	256.8	10.5	0.29
Zero	24.3	269.5	245.2	11.1	0.31
Nutrient management					
RFD – AI	25.0	277.7	252.7	11.1	0.31
RFD – BI	25.0	273.8	248.7	10.9	0.30
SSNM Nutrient Expert – BI	25.5	273.6	248.0	10.7	0.30
SSNM + Green Seeker – BI	23.8	272.9	249.1	11.5	0.32
150% RFD – BI	29.0	285.4	256.4	9.8	0.27

input requirement might be due to higher requirement of labour and field preparation. Among nutrient management, total energy input was in range from 23.8 to 29.0 x10^3 MJ ha^{-1}. Energy input was observed maximum in N-rich plot with top dressing of nitrogen before irrigation followed by SSNM Nutrient Expert with top dressing of nitrogen before irrigation, recommended NPK where top dressing of nitrogen was given both after and before irrigation. The lowest energy input was recorded in SSNM + Green Seeker with top dressing of nitrogen before irrigation. Total energy output was computed from main product and by-product of crop. Conventional tillage resulted in highest energy output (283.9 x 10^3 MJ ha^{-1}) as compared to zero tillage (269.5 x 10^3 MJ ha^{-1}). Among nutrient management, N-rich plot recorded maximum energy output followed by other treatments. The maximum energy productivity was observed with zero tillage (0.31 kg MJ^{-1}) followed by conventional tillage (0.29 kg MJ^{-1}). Among nutrient management practices, highest energy productivity was recorded in SSNM + Green Seeker with top dressing of nitrogen before irrigation followed by other treatments.

CONCLUSION

Wheat yield recorded with the application of fertilizer dose recommended by software Nutrient Expert – Wheat for a target of 5.5 Mg ha^{-1} was considerably lower than the targeted yield. Therefore, for higher productivity and profitability from rice-wheat system in mid hill region of Himachal Pradesh there is needed to improve the software.

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