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Chhatrapal Singh Puhup
Department of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Komal Gupta
Department of Agronomy, Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya, Gwalior, Madhya Pradesh, India

Sakh Ram Shori
Department of Agro meteorology, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Bhupendra Kumar
Department of Vegetable Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Corresponding Author:
Chhatrapal Singh Puhup
Department of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Energy assessment of different tillage with nutrient management practices in rice-linseed cropping system

Chhatrapal Singh Puhup, Komal Gupta, Sakh Ram Shori and Bhupendra Kumar

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Abstract
In rice-linseed cropping system, intensive tillage operations, which consume a huge amount of energy in the form of fuel and labor, are carried out harvesting of rice crop. Modification in tillage practices may not only reduce energy consumption but also could make the system more dynamic and efficient. Results reveled that the tillage with nutrient management practices, treatment T_2: CT-TPR 100% RDF + 2 t FYM gave significantly highest input energy, output energy and net energy, energy output-input ratio, energy productivity and profitability of rice and T_7: ZT-DSR 100% RDF recorded significantly higher specific energy of rice and energy intensity in physical term and T_8: CT-DSR 100% RDF + 2 t FYM in case of energy intensity in economics term, which was at par to T_5: CT-DSR 100% RDF + 2 t FYM in case of output energy and net energy. As compared to treatment of T_7: ZT-DRS + 100% RDF in case of energy output-input ratio**,** energy productivity and profitability. Moreover, was at par to treatment of T_3: CT-TPR 100% RDF (75% inorg + 25% FYM), T_1: CT-TPR 100% RDF, T_6: CT-DSR 100% RDF (75% inorg + 25% FYM), T_5: CT-DSR 100% RDF + 2 t FYM and T_4: CT-DSR 100% RDF in case of energy output-input ratio and energy profitability and during 2018 in case of energy productivity. T_8: ZT-DSR 100% RDF + 2 t FYM, T_9: ZT- DSR 100% RDF (75% inorg + 25% FYM), T_5: CT-DSR 100% RDF + 2 t FYM and T_4: CT-DSR 100% RDF in case of specific energy of rice and energy intensity in physical term. T_5: ZT-DSR 100% RDF + 2 t FYM in case of energy intensity in economics term during 2019 and on mean basis. While the lowest value was noted under T_9: ZT-DSR 100% RDF (75% inorg + 25% FYM) in case of input energy, output energy and net energy.

Keywords: Energy, rice, zero tillage, nutrient management and energy productivity

Introduction

Rice based cropping system is most dominant in the Chhattisgarh region of India and the system is considered as the backbone for food grain security. The productivity of rice 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) [14]. 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) [1]. 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) [4]. 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. Conventional agriculture system is an energy intensive farming system which invariably appeared to be excessive and inappropriate due to burning /removal of crop residue and poor nutrient replenishment through inadequate fertilizer use and depletion of organic matter, soil moisture and other nutrients which results to soil 2 degradation and productivity losses (Sharma *et al.*, 2012) [8]. However, technologies are needed to reduce energy, labour and water application and environmental pollution and improvement in soil physical, chemical and biological properties. Potential solution includes a shift from conventional agriculture system to conservation agriculture (CA) system.

Materials and Methods

A field experiment was undertaken at Research cum-Instructional Farm, Indira Gandhi Krishi Viswavidyalaya, Raipur, Chhattisgarh, during *Kharif* season of 2018-2019 and 2019- 2020 in random block design with three replications. Geographically, Raipur is situated in the center of Chhattisgarh state and lies between 21.160 N latitude and 81.360 E longitudes with an altitude of 298 m above the mean sea level. The crops varieties used for the experiment was Rajeshgwari (rice). The sowing of different tillage and nutrient management practices in treatments *viz* T_1: CT-TPR 100% RDF, T_2: CT-TPR 100% RDF + 2 t FYM, T_3: CT-TPR 100% RDF (75% inorg + 25% FYM), T_4: CT-DSR 100% RDF, T_5: CT-DSR 100% RDF + 2 t FYM, T_6: CT-DSR 100% RDF (75% inorg + 25% FYM), T_7: ZT-DSR 100% RDF, T_8: ZT-DSR 100% RDF + 2 t FYM and T_9: ZT-DSR 100% RDF (75% inorg + 25% FYM). All recommended package of practices of crop were adopted during study period. The maximum and minimum temperatures of study area during crop-growing period varied between from 33.66 °C to 25.31 °C during *kharif* 2018 and 36.80 °C to 28.00 °C during *kharif* 2019, whereas, minimum temperature varies from 25.31° to 25.73°C during kharif 2018 and 24.21 °C to 27.47 °C during *kharif* 2019, respectively with 224.61 mm and 152.25 mm rainfall during *kharif* season of 2018 and 2019, respectively. The energy inputs were calculated in MJ ha^{-1} with reference to the standard values prescribed by Mittal *et al.* 1985 [7]. The other energy studies were done with the help of established equations mentioned as follows:

Net energy (MJ) = Energy output (MJ ha^{-1})-Energy input (MJ ha^{-1})

$$\text{Energy output-input ratio} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}$$

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

$$\text{Energy intensity in economic term (MJ ₹}^{-1}) = \frac{\text{Total energy output (MJ ha}^{-1})}{\text{Total cost incurred (₹ ha}^{-1})}$$

$$\text{Specific Energy (MJ kg}^{-1}) = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Yield of crop (kg ha}^{-1})}$$

$$\text{Energy intensity in physical term (MJ kg}^{-1}) = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Total production (kg ha}^{-1})}$$

Results and Discussion

Input energy, output energy and net energy

The data are presented in Table 1. Tillage with nutrient management practices of T_2: CT-TPR 100% RDF + 2 t FYM recorded the highest input energy of rice and the lowest input energy of rice was recorded under T_9: ZT-DSR 100% RDF (75% inorg + 25% FYM). Similar findings have been reported by Lal *et al.* (2019) [5] and Singh & Benbi (2021), who observed that conventional tillage combined with organic amendments significantly raises energy inputs compared to reduced-tillage or zero-tillage systems. Treatment T_2: CT-TPR 100% RDF + 2 t FYM gave significantly highest output energy and net energy of rice which was at par to T_5: CT-DSR 100% RDF + 2 t FYM, while the lowest value was noted under T_9: ZT-DSR 100% RDF (75% inorg + 25% FYM). The results were similar to the findings of Jha *et al.* (2011) [3]. Sorokhaibam *et al.* (2017) [12] showed that the higher input energy was consumed by conventional tillage (16.82×10^3 MJ ha^{-1}) than no-tillage practices and gross energy output of conventional tillage was at par with no-tillage, but net energy output was higher under no-tillage.

Energy output-input ratio, energy productivity and energy profitability

The data on energy output-input ratio, energy productivity and profitability of rice as influenced by tillage with nutrient management practices in rice are presented in Table 2. Among tillage with nutrient management practices in rice, significantly higher energy output-input ratio of rice was obtained under treatment T_2: CT-TPR 100% RDF + 2 t FYM as compared to treatment of T_7: ZT-DRS + 100% RDF. Morever, it was at par to treatment of T_3: CT-TPR 100% RDF (75% inorg + 25% FYM), T_1: CT-TPR 100% RDF, T_6: CT-DSR 100% RDF (75% inorg + 25% FYM), T_5: CT-DSR 100% RDF + 2 t FYM and T_4: CT-DSR 100% RDF. Studies indicate consistently higher yields and energy output in TPR systems compared with DSR under similar nutrient regimes (Singh *et al.*, 2018; Tripathi *et al.*, 2019) [10, 13].
The significantly higher energy productivity and profitability of rice, treatment of T_2: CT-TPR 100% RDF + 2 t FYM as compared to T_7: ZT-DRS 100% RDF), but it was at par to treatment of T_3: CT-TPR 100% RDF (75% inorg + 25% FYM), T_1: CT-TPR 100% RDF, T_6: CT-DSR 100% RDF (75% inorg + 25% FYM), T_5: CT-DSR 100% RDF + 2 t FYM and T_4: CT-DSR 100% RDF during 2018 in case of energy productivity and for energy profitability. Similar findings have been reported by Singh *et al.* (2017) [11] and Choudhary *et al.* (2019) [2], who observed that incorporation of organic manures along with inorganic fertilizers increased energy productivity and net energy returns in rice due to higher yield stability and improved nutrient use efficiency.

Specific energy, energy intensity in physical term and energy intensity in economic term

The data related to the tillage with nutrient management practices in rice, are presented in Table 3. The treatment of T_7: ZT-DSR 100% RDF recorded significantly higher specific energy of rice and energy intensity in physical term as compared to others, however, but it was at par to T_8: ZT-DSR 100% RDF + 2 t FYM, T_9: ZT- DSR 100% RDF (75% inorg + 25% FYM), T_5: CT-DSR 100% RDF + 2 t FYM and T_4: CT-DSR 100% RDF, respectively. Significantly higher energy intensity in economics term of rice was obtained under treatment T_8: CT-DSR 100% RDF + 2 t FYM as compared to others, but it was at par to treatment T_5: ZT-DSR 100% RDF + 2 t FYM during 2019 and on mean basis reported by Mandal *et al*. (2002) [6].

Table 1: Input energy, output energy and net energy of rice as influenced by tillage with nutrient management practices in rice-linseed cropping system

Treatment		Input energy (x 10^3 MJ ha^{-1})			Energy output (x 10^3 MJ ha^{-1})			Net energy (x 10^3 MJ)		
		2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
T_1:	CT-TPR 100% RDF	14.57	14.57	14.57	172.95	174.81	173.88	158.38	160.24	159.31
T_2:	CT-TPR 100% RDF + 2 t FYM	15.18	15.18	15.18	186.48	187.23	186.85	171.30	172.05	171.67
T_3:	CT-TPR 100% RDF (75% inorg + 25% FYM)	13.74	13.74	13.74	164.12	170.87	167.50	150.38	157.14	153.76
T_4:	CT-DSR 100% RDF	14.80	14.80	14.80	170.63	172.88	171.76	155.83	158.09	156.96
T_5:	CT-DSR 100% RDF + 2 t FYM	15.40	15.40	15.40	179.83	180.43	180.13	164.42	165.02	164.72
T_6:	CT-DSR 100% RDF (75% inorg + 25% FYM)	13.96	13.96	13.96	160.81	166.83	163.82	146.85	152.87	149.86
T_7:	ZT-DSR 100% RDF	13.81	13.81	13.81	145.78	153.19	149.48	131.97	139.38	135.67
T_8:	ZT-DSR 100% RDF + 2 t FYM	14.42	14.42	14.42	151.74	164.67	158.20	137.32	150.25	143.79
T_9:	ZT-DSR 100% RDF (75% inorg + 25% FYM)	12.98	12.98	12.98	138.29	148.73	143.51	125.31	135.75	130.53
SEm±		-	-	-	5.27	3.41	3.77	5.27	3.41	3.77
CD (P=0.05)		-	-	-	15.66	10.14	11.20	15.66	10.14	11.20

Table 2: Energy output-input ratio, energy productivity and energy profitability of rice as influenced by tillage with nutrient management practices in rice-linseed cropping system

Treatment		Energy output-input ratio			Energy productivity (kg MJ ha^{-1})			Energy profitability		
		2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
T_1:	CT-TPR 100% RDF	11.87	12.00	11.93	0.402	0.409	0.405	10.87	11.00	10.93
T_2:	CT-TPR 100% RDF + 2 t FYM	12.28	12.33	12.31	0.414	0.417	0.416	11.28	11.33	11.31
T_3:	CT-TPR 100% RDF (75% inorg + 25% FYM)	11.95	12.44	12.19	0.405	0.429	0.417	10.95	11.44	11.19
T_4:	CT-DSR 100% RDF	11.53	11.68	11.61	0.393	0.399	0.396	10.53	10.68	10.61
T_5:	CT-DSR 100% RDF + 2 t FYM	11.67	11.71	11.69	0.396	0.398	0.397	10.67	10.71	10.69
T_6:	CT-DSR 100% RDF (75% inorg + 25% FYM)	11.52	11.95	11.73	0.393	0.412	0.403	10.52	10.95	10.73
T_7:	ZT-DSR 100% RDF	10.56	11.09	10.82	0.363	0.387	0.375	9.56	10.09	9.82
T_8:	ZT-DSR 100% RDF + 2 t FYM	10.52	11.42	10.97	0.360	0.401	0.381	9.52	10.42	9.97
T_9:	ZT-DSR 100% RDF (75% inorg + 25% FYM)	10.66	11.46	11.06	0.368	0.411	0.390	9.66	10.46	10.06
SEm±		0.37	0.23	0.26	0.012	0.012	0.009	0.37	0.23	0.26
CD (P=0.05)		1.10	0.69	0.78	0.036	0.037	0.027	1.10	0.69	0.78

Table 3: Specific energy, energy intensity in physical term and energy intensity in economic term of rice as influenced by tillage with nutrient management practices in rice-linseed cropping system

Treatment		Specific energy (MJ kg ha^{-1})			Energy intensity in physical term (MJ kg^{-1})			Energy intensity in economic term (MJ ₹$^{-1}$)		
		2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
T_1:	CT-TPR 100% RDF	2.49	2.45	2.47	1.14	1.13	1.13	4.59	4.52	4.56
T_2:	CT-TPR 100% RDF + 2 t FYM	2.42	2.40	2.41	1.10	1.10	1.10	4.92	4.81	4.87
T_3:	CT-TPR 100% RDF (75% inorg + 25% FYM)	2.47	2.33	2.40	1.13	1.09	1.11	4.44	4.50	4.47
T_4:	CT-DSR 100% RDF	2.55	2.51	2.53	1.18	1.16	1.17	4.99	4.93	4.96
T_5:	CT-DSR 100% RDF + 2 t FYM	2.53	2.52	2.53	1.16	1.15	1.16	5.22	5.11	5.16
T_6:	CT-DSR 100% RDF (75% inorg + 25% FYM)	2.55	2.43	2.49	1.18	1.13	1.15	4.80	4.85	4.82
T_7:	ZT-DSR 100% RDF	2.77	2.59	2.68	1.29	1.22	1.25	4.86	5.04	4.95
T_8:	ZT-DSR 100% RDF + 2 t FYM	2.78	2.50	2.64	1.29	1.19	1.24	5.02	5.37	5.20
T_9:	ZT-DSR 100% RDF (75% inorg + 25% FYM)	2.73	2.44	2.59	1.28	1.18	1.23	4.72	5.00	4.86
SEm±		0.08	0.08	0.06	0.04	0.02	0.03	0.16	0.09	0.11
CD (P=0.05)		0.25	0.23	0.17	0.12	0.06	0.08	0.48	0.28	0.33

Conclusion

Treatment T_2: (CT-TPR + 100% RDF + 2 t FYM) recorded the highest energy output, net energy, energy productivity, and profitability of rice, while T_7: (ZT-DSR + 100% RDF) showed higher specific energy and energy intensity. Other treatments were comparable for certain energy parameters, indicating that combining conventional tillage with integrated nutrient management optimizes both energy use and economic returns. Lowest energy performance was observed under T_9: (ZT-DSR + 75% inorganic + 25% FYM).

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