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Energetics of winter crops under rice based cropping sequences in irrigated condition of eastern Uttar Pradesh

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Abstract

The field experiment was conducted at the Agricultural Research Farm, Banaras Hindu University, Varanasi (U. P.) in two consecutive years of 2016-17 and 2017-18 to study the energetic of winter crops under rice based cropping sequences in irrigated condition of eastern Uttar Pradesh. Results revealed that energy output, net energy and energy intensity was found significantly higher with wheat grown in rice-wheat-cowpea fodder sequence (S_4) but it was remained comparable with wheat grown in rice-wheat-green gram sequence (S_2) and rice-wheat sequence (S_1) during first year, however during second year it was found at par only with rice-wheat-green gram sequence (S_2). The lowest energy output, net energy and energy intensity recorded in cabbage grown in rice-cabbage-cowpea fodder sequence (S_{10}) were mainly because of its having lowest energy equivalent in economic produce. Energy output: input ratio was significantly highest in mustard grown in rice-mustard-sudan grass fodder sequence (S_8) but it was found at par with mustard grown in rice-mustard-cowpea fodder sequence (S_9) during first year and vice-versa during second year. The energy productivity was highest in rice-cabbage-cowpea fodder sequence (S_{10}), proved distinct superiority over rest of the winter crop grown in different sequences. Nevertheless, highest specific energy was noted in berseem in rice-berseem-maize fodder sequence (S_6) remained at par with berseem grown in rice-berseem-cowpea fodder sequence (S_7) during both the years of investigation.

Keywords: rice based cropping sequence, energy intensity, energy productivity, energy output

Introduction

Rice based cropping system occupying largest areas of the country. Rice based systems are directly connected with development of water resources. In the era of shrinking resource base of land, energy and water, resource-use efficiency is an important aspect for considering the suitability of a cropping system (Yadav, 2002) [9]. Diversification and intensification of rice-based systems to increase productivity per unit resource is very important. The diverse agro ecological conditions in the country are favorable for growing of several oilseeds, pulses, vegetables, fodder and medicinal crops. Increasing demand of pulses, oilseeds and fodder crops can be successfully met by inclusion of these crops in cropping sequence. Moreover, inclusion of food legumes in rice production system not only brings additional area under the crops but also improves the physical, chemical and biological properties of soils. The selection of crops needs to be planned to utilize the synergism among crops towards the efficient utilization of resources and to increase overall productivity (Anderson, 2005) [1]. Growing of crops such as vegetables, pulses, oilseeds, and fodder during the post-rainy season is an alternative approach for realizing overall higher productivity and profitability (Newaj and Yadav, 1992) [5]. In present scenario due to over exploitation of natural resources (soil and water, energy) and offset the production cost and environmental footprints, the conservation agriculture (CA) based crop production technologies are gaining attention in this region to explore maximum yield potential of these winter crops (Saharawat *et al.*, 2012) [6]. The energy use in crop production has not been given adequate importance in earlier years, but the time has come, where more emphasis given on renewable and noncommercial source of energy, which is actively, involved in crop production processes using intensive energies directly or indirectly. Crop production is a way an energy conversion industry. Through photosynthesis plant transform solar and chemical energy derived from the soil into storable chemical energy as carbohydrates, fats, proteins and all cellulose. Excessive use of energy results in high unit cost of production, loss of profitability and market competitiveness. (Kachroo *et al.*, 2012) [4]. Inclusion of some crops in diversification would reduce the energy production as they are poor converters of it, therefore suitable cropping systems needs to be designed so that apart from higher productivity and profitability it must be efficient converter of energy. Hence, in the present investigation different rice based cropping systems involving five winter crops were evaluated to study the energetic of winter crop under irrigated conditions.

Materials and Methods

A field experiment was carried out at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi in two consecutive years of 2016-17 and 2017-2018, as a part of ongoing experiment under Varanasi center of AICRP on Integrated Farming System initiated during 2016-17. The experiment was laid out in randomized block design with three replications on fixed plots. Treatment involved ten rice-based cropping system *viz.*, S_1- rice-wheat, S_2- rice-wheat-green gram, S_3- rice-potato-green gram, S_4- rice-wheat-cowpea (fodder), S_5- rice-potato-cowpea (fodder), S_6- rice-berseem-maize (fodder), S_7- rice-berseem-cowpea (fodder), S_8- rice-mustard-sudan grass (fodder), S_9- rice-mustard-cowpea (fodder), S_{10}- rice-cabbage-cowpea (fodder). Individual plots were thoroughly prepared in isolation to avoid the mixing of soil in different treatments. All the crops in different seasons were grown with recommended package of practices under irrigated condition for eastern Uttar Pradesh. The full recommended dose of nutrients was applied to each crop. Whole quantity of P_2O_5 and K_2O along with half of the nitrogen was applied as basal application through urea, DAP and MOP. The remaining half quantity of nitrogen was top dressed in the form of urea in one or two equal splits at recommended stages of crops. The crops were irrigated optimally as and when required and need based plant protection measures were adopted. Similarly, all other recommended package of practices was followed. Energy values of various input and outputs used in the experimentation are presented in Table 1. The energy input for a particular cropping system was calculated as the summation of energy requirement for a human, diesel, electricity, water, seed, herbicide, FYM, chemical fertilizers used in that system. The other energy studies were done with the help of established equations and there are being mentioned as under:

$$\text{Energy output } (10^{-3} \times \text{MJ ha-}^{1}) = \text{Total biological yield (Seed + straw)} \times \text{Equivalent energy (MJ kg}^{-1})$$

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

$$\text{Energy intensity (MJ Rs}^{-1}) = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Cost of cultivation}}$$

$$\text{Energy productivity / energy use efficiency (kg MJ}^{-1}) = \frac{\text{Output grain + by product (Kg ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}$$

$$\text{Specific energy} = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Crop yield (Kg ha}^{-1})}$$

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

Table 1: Energy values of various inputs and outputs used in winter crop

S. No.	Particulars		Units	Energy coefficient MJ
Input				
1	Labour	(Adult man)	Man hr^{-1}	1.96
		(Adult women)	Women hr^{-1}	1.57
2	Diesel		$Litre^{-1}$	56.31
3	Electricity		KWH	11.93
4	Water		m^{-3}	0.63
5	Chemical fertilizer	Nitrogen	kg^{-1}	60.00
		P_2O_5	kg^{-1}	11.10
		K_2O	kg^{-1}	6.70
		Sulphur	kg^{-1}	1.12
6	Pesticide	Herbicide	kg^{-1}	238
		Fungicide	kg^{-1}	92
		Insecticide	kg^{-1}	199
7	Seed	Wheat	kg^{-1}	14.70
		Mustard	kg^{-1}	25
		Potato (tuber)	kg^{-1}	5.6
		Cabbage	kg^{-1}	25
		Berseem	kg^{-1}	14.7
Output				
Economic produce		Wheat	kg^{-1}	14.70
		Mustard	kg^{-1}	25
		Potato	kg^{-1}	5.6
		Cabbage	kg^{-1}	1.2
		*Berseem fodder	kg^{-1}	12
Straw/ Stover			kg^{-1}	12.50

*Dry fodder Source: Devasenapathy *et al.* (2009).

The data were analyzed by the method of analysis of variance as described by Gomez and Gomez (1984) [3].

Results and Discussion

Among the different sources, highest energy consumed by fertilizers except potato crop followed by machinery in most the winter crops, in case of potato highest energy required in seed (tuber) (Table 2 and Fig.1). The maximum energy input was recorded in potato grown in sequences rice-potato-green gram sequence (S_3) and rice-potato-cowpea fodder sequence (S_5) followed by wheat grown in different sequences thereafter cabbage grown in rice-cabbage-cowpea fodder sequence (S_{10}) and mustard grown in rice-mustard-sudan grass fodder sequence (S_8) and rice-mustard-cowpea fodder sequence (S_9) (Table 3). The lowest energy incurred in berseem crop grown in rice-berseem-maize fodder sequence (S_6) and in rice-berseem-cowpea fodder sequence (S_7).

Energetic of winter crops were significantly influenced by different cropping sequences (Table 3 and 4). Energy output, net energy and energy intensity was found significantly higher with wheat grown in rice-wheat-cowpea fodder sequence (S_4) but it was remained comparable with wheat in rice-wheat-green gram sequence (S_2) and rice-wheat sequence (S_1) during first year of study. However, during second year rice-wheat-cowpea fodder sequence (S_4) remained at par only with rice-wheat-green gram sequence (S_2). This was attributed to higher energy equivalent of wheat accompanied with its good productivity. Similarly, mustard grown in rice-mustard-sudan grass sequence (S_8) and rice-mustard-cowpea fodder sequence (S_9) remained comparable but recorded significantly higher energy output, net energy and energy intensity than potato, berseem and cabbage grown in different sequences during both the years of study. This was ascribed to highest equivalent energy of mustard seed as compared to other winter crops. However, potato grown in different sequences also gave significantly higher energy output, net energy and energy intensity than berseem and cabbage crops during both the years of experimentation. This was attributed to better equivalent energy of potato tuber as compared to berseem resulted higher energy output, net energy and energy intensity. Likewise, berseem grown in rice-berseem-maize fodder sequence (S_6) and rice-berseem-cowpea fodder sequence (S_7) also proved distinct superiority over cabbage sequence (S_{10}) during both the years of experimentation. Among the winter crops, the lowest value of energy output, net energy and energy intensity in cabbage were mainly because of its having lowest energy equivalent in economic produce. Singh (2008) [8] also obtained similar results in diversified rice-wheat cropping sequences. Sharma *et al.* (2009) [7] found that potato gave significantly higher energy outputs than wheat, which in turn, resulted in significantly higher energy outputs than rapeseed in all the three years of study.

Energy output: input ratio was significantly highest in mustard grown in rice-mustard-sudan grass fodder (S_8) but it was found at par with mustard in rice-mustard-cowpea fodder sequence (S_9) during first year and vice-versa during second year of study. This was might be due to lower input energy of mustard as proportionality of energy output in comparison to rest of the winter crops.

The energy productivity was highest in cabbage grown in rice-cabbage-cowpea fodder (S_{10}), proved distinct superiority over rest of the crop grown in different sequences. Potato grown in rice-potato-green gram sequence (S_3) and rice-potato-cowpea fodder sequence (S_5) ranked second and third though remained comparable but proved significantly superior over berseem, wheat and mustard grown in different sequences during both the years of study. This was followed by mustard grown in rice-mustard-sudan grass fodder sequence (S_8) and rice-mustard-cowpea fodder (S_9), and wheat grown in rice-wheat-cowpea fodder sequence (S_4), rice-wheat-green gram sequence (S_2), and rice-wheat sequence (S_1) also registered significantly higher energy productivity over berseem during both the years of experimentation. However, highest specific energy was noted in berseem grown in rice-berseem-maize fodder sequence (S_6) followed by berseem in rice-berseem-cowpea fodder sequence (S_7) during both the years of investigation. This was ascribed to higher energy input in proportion to its crop yield as compared to rest of the winter crops. Further analysis of data showed that wheat grown in rice-wheat-cowpea fodder (S_4), rice-wheat-green gram (S_2) and rice-wheat (S_1) were statistically comparable to each other registered significantly higher over cabbage (rice-cabbage-cowpea fodder) during both the years of study. Nevertheless, cabbage grown in rice-cabbage-cowpea fodder (S_{10}) noted lowest specific energy during both the years of experimentation. In rice based cropping sequences under irrigated condition cabbage was most energy efficient crop during winter season in eastern Uttar Pradesh.

Table 2: Source wise energy use in different winter crops (MJ ha^{-1})

Crops	Seed	Fertilizer	Pesticides	Pump (electric)	Water	Machinery (diesel)	Human	Total
Wheat	1470	8910	785	1002	1890	2647	1084	16589
Mustard	125	8948	1028	334	630	1805	1180	14892
Berseem (F)	441	3210	0	1169	2205	1267	1194	9486
Cabbage	7	10410	413	1336	1263	867	1523	15819
Potato	13600	9258	1264	501	945	845	1413	27826

Table 3: Energy input, output and net energy of winter crops under rice based cropping sequences

Treatments	Energy Input (MJ $ha^{-1} \times 10^3$)		Energy output (MJ $ha^{-1} \times 10^3$)		Net Energy (MJ $ha^{-1} \times 10^3$)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
S_1- Rice-Wheat	17.78	17.78	137.65	138.73	119.86	120.94
S_2- Rice-Wheat-Green gram	17.78	17.78	142.48	143.12	124.69	125.33
S_3- Rice-Potato-Green gram	27.83	27.83	131.67	133.51	103.84	105.67
S_4- Rice-Wheat-Cowpea (F)	17.78	17.78	142.88	146.00	125.09	128.21
S_5- Rice-Potato- Cowpea (F)	27.83	27.83	130.69	131.80	102.87	103.97
S_6- Rice-Berseem-Maize (F)	9.48	9.48	44.61	44.67	35.126	35.18
S_7- Rice-Berseem- Cowpea (F)	9.48	9.48	44.79	45.08	35.31	35.60
S_8- Rice-Mustard-Sudan grass (F)	13.01	13.01	126.27	124.46	113.26	111.46
S_9- Rice-Mustard- Cowpea (F)	13.01	13.01	122.77	127.01	109.77	114.00
S_{10}- Rice-Cabbage- Cowpea (F)	15.82	15.82	38.67	38.98	22.85	23.16
SEm±	-	-	2.15	2.76	2.15	2.76
CD (P = 0.05)	-	-	6.37	8.21	6.38	8.21

Table 4: Energy output: input ratio, energy intensity, energy productivity and specific energy of winter crops

Treatments	Energy output: input ratio		Energy intensity (MJ `-1)		Energy productivity/EUE (kg MJ^{-1})		Specific energy	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
S_1- Rice-Wheat	7.74	7.80	3.48	3.51	0.577	0.582	1.736	1.720
S_2- Rice-Wheat-Green gram	8.01	8.05	3.60	3.62	0.598	0.600	1.676	1.667
S_3- Rice-Potato-Green gram	4.73	4.80	1.64	1.66	0.845	0.857	1.184	1.167
S_4- Rice-Wheat-Cowpea (F)	8.03	8.21	3.61	3.69	0.599	0.613	1.669	1.633
S_5- Rice-Potato- Cowpea (F)	4.70	4.74	1.62	1.64	0.839	0.846	1.193	1.184
S_6- Rice-Berseem-Maize (F)	4.70	4.71	1.18	1.18	0.392	0.390	2.574	2.548
S_7- Rice-Berseem- Cowpea (F)	4.72	4.75	1.18	1.19	0.394	0.396	2.541	2.525
S_8- Rice-Mustard-Sudan grass (F)	9.71	9.57	3.39	3.34	0.618	0.609	1.619	1.641
S_9- Rice-Mustard- Cowpea (F)	9.44	9.76	3.29	3.41	0.601	0.621	1.666	1.610
S_{10}- Rice-Cabbage- Cowpea (F)	2.44	2.46	0.77	0.78	2.037	2.054	0.493	0.487
SEm±	0.15	0.17	0.05	0.06	0.034	0.020	0.057	0.041
CD (P = 0.05)	0.45	0.51	0.16	0.18	0.100	0.059	0.169	0.125

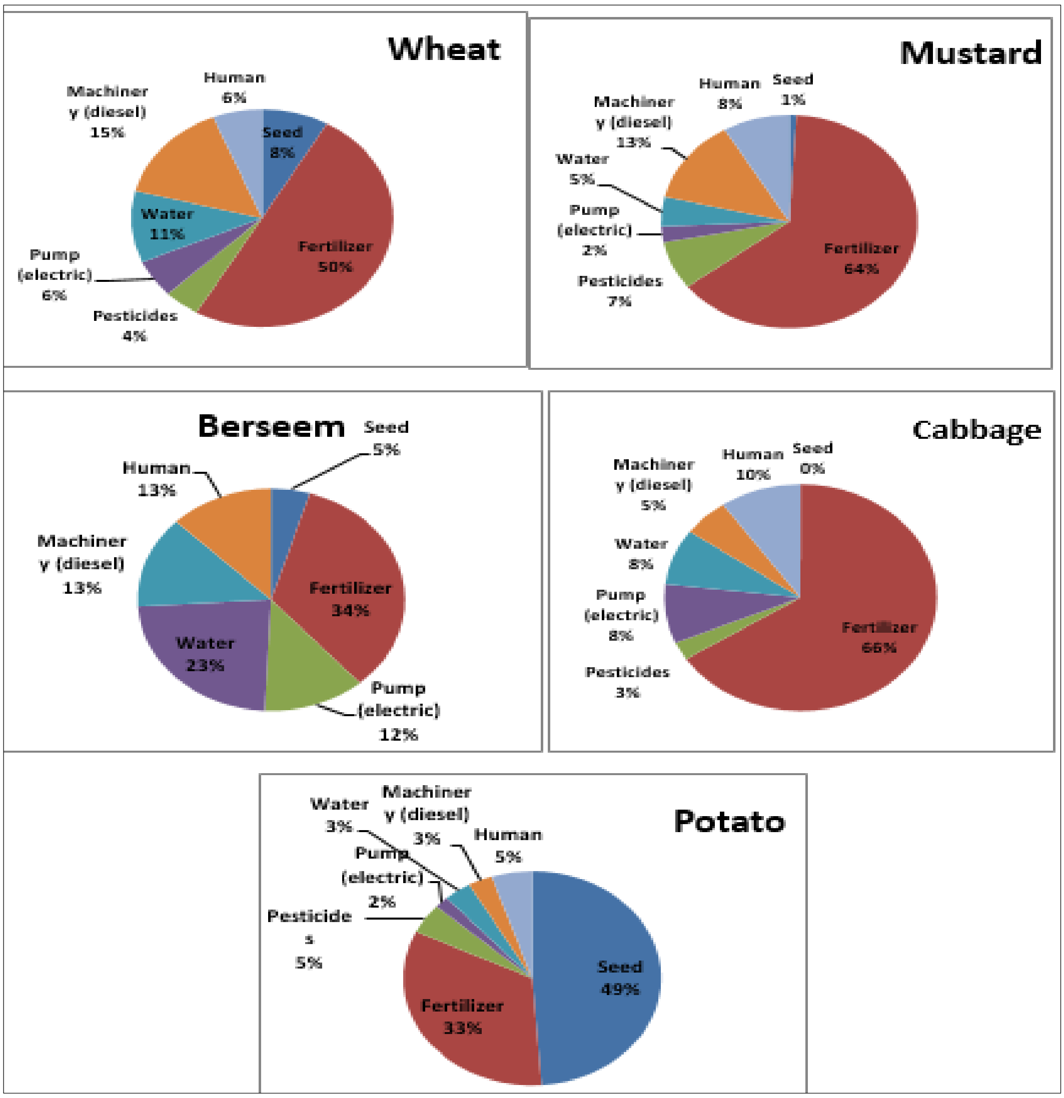

Fig 1: Source wise energy requirement in different winter crops (%)

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