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Energetics of winter crops under rice (*Oryza sativa* L.) based cropping sequences in irrigated condition of Chhattisgarh plains

Chetna Sinha, Dr. Sunil Kumar, Ritu Rani, Neha Singh Kashyap and Ashwan Jaiswal

Abstract
A field experiment was conducted on "Identification of profitable, resource efficient and sustainable rice based cropping system for Chhattisgarh plains under irrigated condition" at the Research cum Instructional Farm, I.G.K.V., Raipur (Chhattisgarh) during the *kharif*, *rabi* and *summer* season of 2018-2019 and 2019-2020 to study the energetics of winter crops under rice (*Oryza sativa* L.) based cropping sequences in irrigated condition of Chhattisgarh plains. Results revealed that energy output, net energy and energy intensity was found significantly higher with Wheat grown in rice-wheat-dhaincha (T1) cropping system recorded significantly maximum energy output and net energy during 2018-19, which was comparable to sweet corn grown in rice – sweet corn - cowpea (v) (T6), while during 2019-20 and on mean basis, sweet corn grown in rice – sweet corn - cowpea (v) (T6) recorded significantly highest energy output and net energy among the all rabi crops, However, it was at par with rice-wheat-dhaincha (T1) on mean basis. Rice – cabbage – green gram (T4) recorded lowest energy output and net energy during both the years and on mean basis. Significantly highest energy intensity was recorded in wheat grown as a rabi crop in rice-wheat-dhaincha (T1) cropping system over rest of the rabi crops during both the years and on mean basis. Rice – cabbage – green gram (T4), recorded the lowest energy intensity during 2018-19. Similarly, rice - onion + coriander - cowpea (s) cropping system recorded lowest energy intensity during 2019-20 and on mean basis. Significant influence on energy output: input ratio during both the years and on mean basis. Sweet corn grown in rice – sweet corn - cowpea (v) (T6) recorded significantly higher energy output: input ratio which remained comparable to each other during both the years and on mean basis. However it was at par with rice-wheat-dhaincha (T1) and rice – sweet corn – cluster bean (T3) during 2018-19. Rice – cabbage – green gram (T4) recorded the lowest energy output: input ratio during both the years and on mean basis. Significantly highest energy use efficiency was recorded in rice – sweet corn - cowpea (v) (T6), over rest of the rabi crops during both the years and on mean basis. However it was at par with rice – sweet corn – cluster bean (T3) during 2018-19. Rice – wheat – dhaincha (T1) recorded lowest energy use efficiency during 2018-19. Similarly, rice – safflower – cowpea (f) (T7) recorded the lowest energy use efficiency during 2019-20 and on mean basis. Significantly highest specific energy was recorded in rice-wheat-dhaincha (T1) over rest of the rabi crops during both the years and on mean basis. However, it was at par with rice – safflower – cowpea (f) (T7) during 2019-20. Nevertheless, lowest specific energy was recorded in rice - onion + coriander - cowpea (s) cropping system during both the years and on mean basis.

Keywords: Rice based cropping sequence, energy intensity, energy use efficiency, energy output, net energy and energy output: input ratio

Introduction
The kind of sequence of crops grown on a land area over a period of time is called cropping system. In India, Agriculture is largely in rice-based cropping system which has been recognized as an effective strategy for achieving the objectives of food security, nutritional security, income growth, poverty alleviation, employment generation, judicious use of land and water resources, sustainable agricultural development and environmental improvement (FAO, 2001 and Singh, 2001) [5]. But, fragmented and small land holdings with inadequate operational resources are predominant and thus, rice -based cropping system approach becomes very much important for improving the productivity, generating additional income, employment and condition of the small and marginal farmers. Also, it has put a tremendous pressure on rice growers to make rice farming economically viable and ecologically sustainable due to rise in input costs, rapid degradation of rice ecologies due to imbalance use of fertilizers and injudicious water management, high competition in international market for

rice and problems of managing buffer food grain stock in India. It is in this context, intensification along with better use of resources for remunerative crops in rice ecology through system perspective is essential. Cereals are the most widespread group of crops across the world occupying 20% of the global land or 61% of the total cultivated land. About 2/3 of the world's cropland area is predominantly occupied by wheat, maize, barley, rice and millets. Rice is the second most important crop at global level (around 11% of global cultivated area) and is the most important crop in South and Southeast Asia being also cultivated in the Amazon Basin, the southern United States, and southern Australia (Kumpawat *et al.*, 2001) [6]. Rice is the second most important food crop, being cultivated in more than 100 countries in 163 million ha with current rice production of 740.9 million tons compared to the global demand of 765 million tons by 2025. Rice is cultivated two or three times in a year in diverse environments and cropping systems starting with sole cropping systems in rainfed and irrigated conditions (temperate and tropical regions) to predominant mono cropping in irrigated regions (at tropics) (Baishya *et al.*, 2016) [4]. India is the second largest producer and consumer of rice in the world. In India, rice is grown on an area of 43.99 M ha with a production of 112.910 M tonnes and productivity of 2578 kg ha-1 (Anonymous 2018) [3]. In Chhattisgarh, rice is grown on 3.75 m ha area with a production of 7.49 m tonnes and productivity of 1322 kg ha^{-1} (Anonymous 2016) [3]. The rice in Chhattisgarh is mainly grown by transplanting under puddled field and direct seeding through seed drill and broadcasting of seeds on unpuddled field and their after beushening. The growing of second crops after rice is a concern due to field preparation, proper crop establishment method, shortage of moisture specially at upper soil layer and poor germination and thus cropping intensity is very low (138%).

Materials and Methods

A field experiment on "Identification of profitable, resource efficient and sustainable rice based cropping system for Chhattisgarh plains under irrigated condition." was undertaken at Research cum Instructional Farm, I.G.K.V., Raipur C. G. during *kharif, rabi* and *summer* season of 2018-2019 and 2019-2020. The major objectives of the experiment were to evaluate the productive potential, economic viability, resource and energy efficiency of different rice based cropping systems. The soil of the experimental field was silty clay (Inceptisol) in texture, locally known as "Matasi" and neutral in pH and having low organic carbon and low available nitrogen, medium in available phosphorus and potassium. The climate of the region is dry moist, sub-humid with an average annual rainfall of 1200-1400 mm. The experiment was laid out in randomized block design with three replications on fixed plots. Treatment comprised eight rice based cropping system *viz.*, T1 - rice – wheat – dhaincha, T2 - rice – chickpea - cowpea (v), T3 - rice – sweet corn – cluster bean, T4 - rice – cabbage – green gram, T5 - rice - radish + marigold – green gram, T6 - rice – sweet corn - cowpea (v), T7 - rice – safflower – cowpea (f) and T8 - rice - onion + coriander - cowpea (s). The present investigation was a part of a long-term experiment of All India Coordinated Research Project on Integrated Farming Systems. All the crops were grown with recommended package of practices under irrigated condition of Chhattisgarh. 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.

Energy output input ratio

$$\text{Energy output input ratio} = \frac{\text{Energy Output (EO)}}{\text{Energy Input (EI)}}$$

Energy output (MJ ha^{-1})

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

Energy use efficiency

$$\text{Energy use efficiency (Kg MJ}^{-1}) = \frac{\text{Total produce (kg)}}{\text{Energy input (MJ x } 10^{-3})}$$

Energy intensity

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

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

	Inputs (Used in crop production)	Energy equivalent
1.	Adult man	1.96 MJ/ Man- hour
2.	Diesel	56.31 MJ/ L
3.	Water	1.02 MJ/ M^3
4.	Electricity	11.93 MJ/KWh
5.	Electric motor	64.8 MJ/kg
6.	Farm machinery	62.7 MJ/kg
7.	Tractor	180 MJ/kg
8.	Thresher	17.4 MJ/kg
9.	Heavy- duty cultivator	220 MJ/ ha^{-1}
10.	Sprayer	129 MJ/kg
11.	Equipment of fertilizing	138 MJ/kg
12.	Disc plough	149 MJ/kg
13.	Nitrogen	60.60 MJ/kg
14.	Phosphate (P_2O_5)	11.1 MJ/kg
15.	Potash (K_2O)	6.7 MJ/kg
16.	Microelements	120 MJ/kg
17.	Zinc sulphate	20.9 MJ/kg

18.	FYM	0.30 MJ/kg
19.	Manure	303.1 MJ/tons
20.	Insecticide	237 MJ/ kg *ai*.
21.	Herbicide	288 MJ/kg *ai*
22.	Fungicide	196 MJ/kg *ai*
23.	Biocides	120 MJ/kg
Output (As output of crop production)		
1.	Rice	14.7 MJ/kg
2.	Wheat	14.7 MJ/kg
3.	Safflower	27.20 MJ/kg
4.	Green gram	13.96 MJ/kg
5.	Dhaincha	14.7 MJ/kg
6.	Sweet corn	14.7 MJ/kg
7.	Cabbage	0.8 MJ/kg
8.	Coriender	0.8 MJ/kg
9.	Radish	1.6 MJ/kg
10.	Onion	1.6 MJ/kg
11.	Cowpea (F)	18.0 MJ/kg
12.	**By products**	
13.	Rice hull	13.8 MJ/kg
14.	Stover (dry mass)	12.5 MJ/kg
15.	Rice straw	12.5 MJ/kg
16.	Wheat straw	18.9 MJ/kg
17.	Sweet corn (F)	18.0 MJ/kg
18.	Oil seed stalks	19.4 MJ/kg
19.	Vegetable stalks	19.4 MJ/kg

Results and Discussion

Energy input (10^3 × MJ ha^{-1})

Data on energy input of different *rabi* season crops under various cropping systems are presented in Table-2. The maximum energy input was recorded in cabbage grown in systems *viz.* rice – cabbage – green gram **(**T_4) during both the year and on mean basis. This may be due to higher inputs *viz.* fertilizer, irrigation, agro-chemicals and labour required for cultivation of the cabbage over the rest of the *rabi* crops. However, the lowest energy was incurred in chickpea crop grown in rice – chickpea - cowpea (v) (T_2) during both the years and on mean basis. Rice-rice system required the highest energy input (27.35 x 10^3 MJ ha^{-1}) while, it has lowest in rice-chickpea (17.7 x 10^3 MJ ha^{-1}). However, rice-rice system produced the highest output energy followed by rice-groundnut. These findings confirmed by Parihar *et al*. (1999) [7].

Energy output (10^3 × MJ ha^{-1})

A perusal of the data Table-2 indicate that different crops grown in *rabi* season had significant influence on energy output during both the years and on mean basis. Wheat grown in rice-wheat-*dhaincha* (T_1) cropping system recorded significantly maximum energy output during 2018-19, which was comparable to sweet corn grown in rice – sweet corn – cowpea (v) (T_6), while during 2019-20 and on mean basis, sweet corn grown in rice – sweet corn - cowpea (v) (T_6) recorded significantly highest energy output among the all *rabi* crops, However, it was at par with rice-wheat-*dhaincha* (T_1) on mean basis. Rice – cabbage – green gram (T_4) recorded lowest energy output during both the years and on mean basis.

Net energy (103 × MJ ha^{-1})

A perusal of the data Table-2 indicate that different crops grown in *rabi* season had significant influence on net energy during both the years and on mean basis. Wheat grown in rice-wheat-*dhaincha* (T_1) cropping system recorded significantly highest net energy during 2018-19, which was comparable to rice – sweet corn - cowpea (v) (T_6) cropping system, while during 2019-20 and on mean basis, sweet corn grown in rice – sweet corn - cowpea (v) (T_6) recorded significantly maximum net energy output among the all *rabi* crops, However it was at par with rice-wheat-*dhaincha* (T_1) on mean basis. This may be due to higher output energy was recorded in the above cropping system. Rice – cabbage – green gram (T_4) recorded the lowest net energy during both the years and on mean basis.

Energy output: input ratio

A perusal of the data Table-2 indicate that different crops grown in *rabi* season had significant influence on energy output: input ratio during both the years and on mean basis. Sweet corn grown in rice – sweet corn - cowpea (v) (T_6) recorded significantly higher energy output: input ratio which remained comparable to each other during both the years and on mean basis. However it was at par with rice-wheat-*dhaincha* (T_1) and rice – sweet corn – cluster bean (T_3) during 2018-19. Rice – cabbage – green gram (T_4) recorded the lowest energy output: input ratio during both the years and on mean basis. Amount of energy consumed and obtained on unit area basis had also been helpful in comparing the various crop systems Diversification and intensification of rice – wheat system by including oilseed, pulses and other vegetable crop is beneficial than cereals after cereals. (Kumpawat, 2001 and Raskar *et al.,* 2001) [6].

Energy intensity (MJ Rs^{-1})

Data pertaining to energy intensity of *rabi* crops summarized in Table-3 clearly indicate that significantly highest energy intensity was recorded in wheat grown as a *rabi* crop in rice-wheat-*dhaincha* (T_1) cropping system over rest of the *rabi* crops during both the years and on mean basis. Rice – cabbage – green gram (T_4), recorded the lowest energy intensity during 2018-19. Similarly, rice - onion + coriander - cowpea (s) cropping system recorded lowest energy intensity during 2019-20 and on mean basis.

Energy use efficiency (kg MJ^{-1}): Data pertaining to energy use efficiency of *rabi* crops summarized in Table-3 clearly indicate that significantly highest energy use efficiency was recorded in rice – sweet corn - cowpea (v) (T_6), over rest of the *rabi* crops during both the years and on mean basis. However it was at par with rice – sweet corn – cluster bean (T_3) during 2018-19. Rice – wheat – *dhaincha* (T_1) recorded lowest energy use efficiency during 2018-19. Similarly, rice-safflower – cowpea (f) (T_7) recorded the lowest energy use efficiency during 2019-20 and on mean basis.

Specific energy

Data on specific energy of rice presented in Table-3 clearly indicate that significantly highest specific energy was recorded in rice-wheat-*dhaincha* (T_1) over rest of the *rabi* crops during both the years and on mean basis. However, it was at par with rice – safflower – cowpea (f) (T_7) during 2019-20. Nevertheless, lowest specific energy was recorded in rice - onion + coriander - cowpea (s) cropping system during both the years and on mean basis.

Table 2: Energy input, energy output, net energy and energy output: input ratio of rabi crops as influenced by different rice based cropping systems

Cropping system	Energy input (MJ ha^{-1} × 10^3)			Energy output (MJ ha^{-1} × 10^3)			Net energy (MJ ha^{-1} × 10^3)			Energy output: input ratio		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T_1: Rice – Wheat - *Dhaincha*	16.06	16.06	16.06	156.63	135.61	146.12	140.57	119.55	130.06	9.75	8.44	9.10
T_2: Rice – Chickpea - Cowpea (v)	8.01	8.01	8.01	33.18	24.13	28.66	25.18	16.13	20.65	4.15	3.01	3.58
T_3: Rice - Sweet corn - Cluster bean	13.77	13.77	13.77	132.79	127.56	130.18	119.02	113.80	116.41	9.65	9.27	9.46
T_4: Rice – Cabbage - Green gram	17.48	17.48	17.48	20.16	21.87	21.01	2.68	4.39	3.54	1.15	1.25	1.20
T_5: Rice - Radish + Marigold – Green gram	10.11	10.11	10.11	30.88	31.50	31.19	20.77	21.39	21.08	3.05	3.12	3.08
T_6: Rice – Sweet corn - Cowpea (v)	13.77	13.77	13.77	141.69	155.13	148.41	127.92	141.36	134.64	10.29	11.27	10.78
T_7: Rice – Safflower - Cowpea(f)	12.58	12.58	12.58	98.45	55.75	77.10	85.86	43.17	64.52	7.82	4.43	6.13
T_8: Rice - Onion + Coriander - Cowpea (s)	15.40	15.40	15.40	25.72	26.57	26.15	10.32	11.17	10.75	1.67	1.73	1.70
S.Em±	-	-	-	3.97	3.36	2.99	3.97	3.36	2.99	0.29	0.26	0.22
CD(P=0.05)	-	-	-	11.79	9.98	8.91	11.79	9.98	8.91	0.86	0.75	0.67

Table 3: Energy intensity, energy use efficiency and specific energy of *rabi* crops as influenced by different rice based cropping systems

Cropping system	Energy intensity (MJ Rs^{-1})			Energy use efficiency (kg MJ^{-1})			Specific energy		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T_1: Rice – Wheat - *Dhaincha*	5.88	4.68	5.26	0.58	0.50	0.54	4.39	5.02	4.68
T_2: Rice – Chickpea - Cowpea (v)	1.59	1.04	1.30	0.59	0.44	0.51	2.14	2.92	2.47
T_3: Rice – Sweet corn – Cluster bean	2.69	2.43	2.55	1.45	1.43	1.44	1.78	1.74	1.76
T_4: Rice – Cabbage – Green gram	0.38	0.38	0.38	0.72	0.80	0.76	2.68	2.36	2.51
T_5: Rice - Radish + Marigold – Green gram	0.81	0.74	0.78	0.94	0.96	0.95	1.74	1.70	1.71
T_6: Rice – Sweet corn - Cowpea (v)	2.69	2.66	2.68	1.55	1.74	1.64	1.67	1.44	1.54
T_7: Rice – Safflower - Cowpea(f)	4.18	2.12	3.09	0.71	0.24	0.47	2.68	4.67	3.40
T_8: Rice - Onion + Coriander - Cowpea (s)	0.39	0.36	0.37	0.89	0.93	0.91	1.51	1.46	1.48
S.Em±	0.12	0.09	0.09	0.04	0.04	0.03	0.09	0.16	0.10
CD(P=0.05)	0.35	0.26	0.26	0.12	0.11	0.09	0.28	0.49	0.30

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