Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2582-2845.8122

ISSN: 2582 – 2845

Ind. J. Pure App. Biosci. (2020) *8*(3), 183-192

Research Article

Indian Journal of Pure & Applied Biosciences

Peer-Reviewed, Refereed, Open Access Journal

Assessment of Energetics of Summer Rice with Irrigation Regimes and Staggered Transplanting in South Odisha

Sarath Kumar Duvvada*, G. C. Mishra, B. Supriya, Sagar Maitra and Tanmoy Shankar

M.S Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi, 761211, Odissa, India

*Corresponding Author E-mail: sarathkumarduvvada010@gmail.com

Received: 2.05.2020 | Revised: 27.05.2020 | Accepted: 3.06.2020

ABSTRACT

The experiment was carried out during summer season at Agriculture Research Farm, Bagusala, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi, Odisha in 2018-19. The experimental soil was sandy clay loam in texture, acidic in reaction with low in available nitrogen and high in both phosphorus and potassium. The twelve treatments with combination of irrigation regime and dates of transplanting were tested in split-plot design with three replications. In main plot, the treatments were consisted of three irrigation regimes namely continuous ponding, continuous soil saturation and saturation after hair crack. Four different transplanting dates such as 23rd and 31st January and 6th and 13th February were assigned in sub plots. The experiment results revealed that all the energy parameters like gross energy output, net energy, energy productivity, energy use efficiency and energy intensity in term of economics were significantly influenced by irrigation regimes, dates of transplanting and their interaction effect. The highest value of energy input, gross energy output and net energy were noticed with continuous ponding while energy use efficiency and energy productivity were recorded under saturation after hair crack. The energy intensity in term of economics was enhanced on continuous soil saturation. Transplanting of rice on 31st January produced maximum all energetic parameters over other dates of transplanting.

Keywords: *Summer rice, Energy input, Gross output energy, Net energy, Energy use efficiency, Energy productivity, Energy intensity in economics term*

INTRODUCTION

Rice (*Oryza sativa* L.) is considered as most important staple food cereal crop of South-East Asia. It serves for major food source to more than one third of global population (Sarkar et al., 2017). In Asia, More than two billion people receive 60-70 % of their energy requirement from rice in South East Asia (Sridhar et al., 2019). In India, summer rice is cultivated in an area of 43.17 million ha with the total annual production of 163.70 million tonnes (Agricultural research data book, ICAR 2019). At growth rate of 3 million tonnes per annum, additional yield of 50 million tonnes of rice is needed to be produced in our country to feed 1523 million people by 2030 (Singh et al., 2019).

Cite this article: Duvvada, S.K., Mishra, G.C., Supriya, B., Maitra, S., & Shankar, T. (2020). Assessment of Energetics of Summer Rice with Irrigation Regimes and Staggered Transplanting in South Odisha, *Ind. J. Pure App. Biosci.* *8*(3), 183-192. doi: http://dx.doi.org/10.18782/2582-2845.8122

In an agricultural system, energy is the one of the important input which is more valuable and contributes an important role in improvement of mankind (Khambalkar et al., 2010). Agriculture is a good energy consumer and it is supplied in the form of bio-energy. The solar energy was converted into useful form of energy by different photosynthetic pathways to produce a good yield. The agricultural production can be increased by using the proper energy in a proper way. Energy use efficiency is the key factor in the modern agriculture. Hence, proper energy management can be enhanced after gathering all the information from the rural energy resources and their consumption. It is regarded as key factor for farmers as well as for policy makers.

Energy was devoted in different aspects like farm equipment, seed, labour, fertilizer, irrigation, plant protection chemicals and other management practices (Singh et al., 2016). The energy spent for different operations is not constant because it differs from one farmer to another. Compared to past days, the cost of energy is increasing day by day in a greater manner (Energy Information Administration 2007). In the recent years, inadequate availability of less labour during the peak stage of cultural operation in the crop is leading to increase in usage of machinery to a greater extent compared to animal power. To save energy and water for nourishing the growing world population, there is need of broad analysis of energy water usage in agriculture. Henceforth, energy budgeting is vital for effective usage of resources for better agricultural production. By keeping the above facts, the present study was undertaken for assessment of energetics of summer rice with irrigation regimes and staggered transplanting in South Odisha.

MATERIALS AND METHODS

A field experiment was performed during summer season of 2018-19 at Agricultural Research Farm, Bagusala, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi, Odisha. The average minimum and maximum temperature varied from 18.05 to 25.43 °C and 29.70 to 38.69 °C, respectively. During the crop growing period, the total rainfall of 124.7 mm was received. The soil of experimental field was sandy clay loam in texture, slightly acidic in reaction (pH 6.4), low in available nitrogen (208 kg ha^{-1}) and high in available phosphorous (139 kg ha^{-1}) and potassium (390 kg ha^{-1}). The experiment was adopted in split plot design with three replications allocating irrigation treatments in main plot and dates of transplanting in subplots. The main plot treatments were comprised of three irrigation levels such as I_1 (Continuous ponding with 5±2 cm depth), I_2 (Continuous soil saturation with 3 cm depth) and I_3 (Saturation after hair crack with 3 cm depth). The sub plot treatments were four transplanting dates like D_1 (Transplanting on 23rd January), D_2 (Transplanting on 31st January), D_3 (Transplanting on 6th February) and D_4 (Transplanting on 13th February). Before transplanting, the field was ploughed and levelled properly. The 33 days old seedlings of rice variety MTU 1010 was transplanted at the spacing of 20 cm from row to row and 15 cm from clump to clump at different specified dates. Just before final land preparation, well decomposed farm yard manure @ 5 t ha^{-1} was applied to soil and incorporated. The transplanted rice during summer season was fertilized with recommended fertilizer dose of 120:60:60 kg N: P_2O_5: K_2O ha^{-1}. The source of fertilizer for nitrogen, phosphorus, potassium was urea, single super phosphate and muriate of potash, respectively. As basal, 50% N and total P_2O_5 and K_2O were applied by broadcasting method and incorporated in soil before transplanting. Remaining 50% N was top dressed in two equal splits during tillering and panicle initiation stage. The energy input was worked out by adding of energy equivalents for all inputs used in system represented in Table 1. The gross output energy was calculated by multiplying the produce with grain and straw energy. The energy indices were determined by using the following formula.

$$\text{Energy efficiency (\%)} = \frac{\text{Gross energy output (GJ ha}^{-1})}{\text{Total energy input (GJ ha}^{-1})}$$

$$\text{Energy productivity (Kg GJ}^{-1}) = \frac{\text{Grain + Straw yield (Kg ha}^{-1})}{\text{Total energy input (GJ ha}^{-1})}$$

$$\text{Energy intensity in Economic terms (MJ Rs.}^{-1}) = \frac{\text{Gross energy output (MJ ha}^{-1})}{\text{Cost of cultivation (Rs. ha}^{-1})}$$

Net energy = Gross energy output (GJ ha^{-1}) – Energy input (GJ ha^{-1})

The data obtained for above parameters were statistically analysed in Microsoft Office Excel 2010 software for split plot design. The analysis procedure as suggested by Gomez and Gomez, 1984 was followed. Statistical significance was tested by computing the F value at 5% level of probability and critical difference was calculated for comparison of treatments mean.

Table 1: Energy equivalents for various input and output energy forms

Component	Unit	Energy equivalent (MJ/h)	Source
Cultivator	Hour (h)	3.135	Nassiri and Singh (2009)
Rotavator	Hour	10.283	Nassiri and Singh (2009)
Tractor	Hour	64.80	Devasenapathy et al. 2009
Sprayer	Hour	0.502	Nassiri and Singh (2009)
Adult male	Man per hour	1.96	Soni et al. (2013)
Adult female	Female per hour	1.60	Soni et al. (2013)
Diesel	L	56.30	Nassiri and Singh (2009)
N	Kg	60.60	Kuswardhani et al. (2013)
P_2O_5	Kg	11.10	Chaudhary et al. (2009)
K_2O	Kg	6.70	Chaudhary et al. (2009)
FYM	Kg	0.30	Kizilaslan (2009)
Insecticides	Kg	199.0	Brar et al. (2015)
Irrigation	m^3	1.02	Tuti et al. (2012)
Seed	Kg	14.70	Tuti et al. (2012)
Grain	Kg	14.70	Tuti et al. (2012)
Straw	Kg	12.50	Tuti et al. (2012)
Thresher	H	7.524	Nassiri and Singh (2009)

RESULTS AND DISCUSSION

Energetics

Energetics like energy input (GJ ha^{-1}), Gross energy output (GJ ha^{-1}), Net energy (GJ ha^{-1}), Energy use efficiency (%), Energy productivity (Kg GJ^{-1}) and Energy intensity in economic terms (MJ Rs.$^{-1}$) of summer rice were significantly influenced by irrigation regimes and dates of transplanting and their interaction which were calculated and represented in Table 2, 3 and 4 and Figures 1 to 6.

Energy input

Effect of irrigation regimes

Significantly higher energy input was recorded in continuous ponding (28.09 GJ ha^{-1}) followed by continuous soil saturation (26.52 GJ ha^{-1}) and the minimum energy input noticed in saturation after hair crack (22.29 GJ ha^{-1}). This is due to more number and amount of irrigation were higher in continuous ponding compared to other treatments.

Effect of dates of transplanting

The input energy was higher when rice transplanted on 31st January (26.08 GJ ha^{-1}) followed by 23rd January (25.98 GJ ha^{-1}), 6th February (25.65 GJ ha^{-1}) and lower input energy in 13th February (24.81 GJ ha^{-1}).

Interaction effect

The highest input energy was observed when the rice transplanted on both 23rd January and 31st January with irrigation regime of continuous ponding with depth of ± 5 cm (28.76 GJ ha^{-1}) and the lowest input energy observed when the rice transplanted on 13th February with irrigation regime of irrigation after hair crack (21.89 GJ ha^{-1}).

Gross energy output

Effect of irrigation regimes

The gross energy output was recorded higher with continuous ponding (160.27 GJ ha^{-1}) which was being at par with continuous soil saturation (158.48 GJ ha^{-1}) and lower gross energy output noticed under saturation after hair crack (143.57 GJ ha^{-1}). The higher straw and grain yield in continuous ponding increases the gross energy output.

Effect of dates of transplanting

The gross energy output was noticed higher when rice transplanted on 31st January (165.98 GJ ha^{-1}) which was at par with transplanting date of 23rd January (162.63 GJ ha^{-1}) and lower input energy with transplanting date of 13th February (139.09 GJ ha^{-1}).

Interaction effect

Transplanting of rice on 31st January with irrigation regime of continuous ponding (177.04 GJ ha^{-1}) results higher gross energy output which was statistically similar with transplanting date of 23rd January with irrigation regime of continuous ponding (175.12 GJ ha^{-1}) and lower gross energy output was recorded with transplanting date of 13th February with saturation after hair crack irrigation regimes (135.40 GJ ha^{-1}).

Net energy

Effect of irrigation regimes

The highest value of net energy was recorded with continuous ponding (132.18 GJ ha^{-1}) which was being at par with continuous soil saturation (131.96 GJ ha^{-1}). This is ascribed to enhancement in gross output energy with considerable amount of input energy. The minimum net energy was noticed under saturation after hair crack (121.28 GJ ha^{-1}). These results are in conformity with the findings of Thirupathi et al. (2018).

Effect of dates of transplanting

The transplanting of rice on 31st January gave the maximum net energy (139.90 GJ ha^{-1}) being at par with transplanting date of 23rd January (136.65 GJ ha^{-1}). The input energy values were reduced with late transplanting dates of 6th February (123.07 GJ ha^{-1}) and 13th February (114.28 GJ ha^{-1}). The enhancement of net energy with early dates of transplanting was resulted in due increase in gross output energy with appreciable investment of input energy.

Interaction effect

Transplanting of rice on 31st January with irrigation regime of continuous ponding (148.28 GJ ha^{-1}) resulted in the highest net energy which was statistically similar with transplanting date of 23rd January under irrigation regime of continuous ponding (146.36 GJ ha^{-1}). This is because of improvement in gross energy output by those treatments with use of considerable quantities of energy input. The lowest net energy was recorded with transplanting date of 13th February with irrigation regime of saturation after hair crack development in soil (113.51 GJ ha^{-1}) which was ascribed to lower values of gross output energy with marginal decrease in input energy.

Energy use efficiency

Effect of irrigation regimes

The energy use efficiency was recorded with highest value of 6.44 % with saturation after hair crack. It was followed by continuous soil saturation and continuous ponding giving the continuous ponding values of 5.97 % and energy use efficiency noticed fewer than 5.69 %. The reason behind it was mainly due to reduced use of energy input with appreciable level of energy output. Similar favourable effect of reduced level of irrigation in enhancing the energy use efficiency was reported by Thirupathi et al. (2018).

Effect of dates of transplanting

The energy use efficiency was noticed maximum when rice transplanted on 31st January (6.39%) which was at par with transplanting date of 23rd January (6.27 %). The delay in transplanting of rice in the dates of 6th February and 13th February registered the reduced energy use efficiency values of 5.84% and 5.64 %, respectively. This greater value of energy use efficiency with early transplanting dates of transplanting was ascribed to increase in energy output with acceptable use of energy input.

Interaction effect

Transplanting of rice on 31st January with irrigation regime of saturation after hair crack recorded the highest energy use efficiency (6.77 %). The next best result was obtained with transplanting date of 23rd January with irrigation regime of saturation after hair crack (6.45 %). This happened so owing to it's favourable of interaction effect in producing the considerable amount of energy output with investment of appreciable quantity of energy input. The minimum energy use efficiency was noticed in transplanting date of 13th February with irrigation regime of continuous ponding (5.17 %).

Energy productivity

Effect of irrigation regimes

The energy productivity was recorded maximum under saturation after hair crack (488.32 Kg GJ^{-1}) which was followed by continuous soil saturation (449.31 Kg GJ^{-1}). This was possible owing to appreciable output energy obtained with reduced input energy investment. This result was in line with the findings of Thirupathi et al. (2018). The minimum energy productivity noticed under continuous ponding (427.06 Kg GJ^{-1}). This happened so due to increase in input energy in that treatment responsible for reduction in energy productivity.

Effect of dates of transplanting

The energy productivity was noticed maximum in early transplanting of rice on 31st January (480.92 Kg GJ^{-1}) which was at par with transplanting date of 23rd January (470.13 Kg GJ^{-1}). The energy productivity was lowered with delayed transplanting dates of 6th February (440.93 Kg GJ^{-1}) and 13th February (427.61 Kg GJ^{-1}). The increase in energy productivity with the earlier dates of transplanting was possible due to increase in biological yield with investment of considerable amount of energy input.

Interaction effect

Significantly the highest energy output was registered in transplanting of rice on 31st January applied with irrigation regime of saturation after hair crack (512.86 Kg GJ^{-1}). It was followed by transplanting date of 23rd January with irrigation regime of saturation after hair crack (486.76 Kg GJ^{-1}). The minimum energy productivity was noticed in transplanting date of 13th February with irrigation regime of continuous ponding (388.63 Kg GJ^{-1}). The positive interaction of early dates of transplanting with irrigation regime of saturation after hair crack formation in soil was attributed due to favourable environmental condition in increasing the grain and straw yield of rice with investment of appreciable quantity of energy input that resulted in enhancement of energy productivity.

Energy intensity in term of economics

Effect of irrigation regimes

The energy intensity in economic term was recorded maximum with continuous soil saturation (3.53 MJ $Rs.^{-1}$) which was statistically similar with continuous ponding (3.41 MJ $Rs.^{-1}$). These results were substantiated by the findings of Thirupathi et al. 2018. The reduced value of energy intensity in economic terms was noticed under saturation after hair crack (3.25 MJ $Rs.^{-1}$) compared with other irrigation regimes. This was ascribed to reduction in values of energy output and cost of cultivation was not decreased to considerable amount.

Effect of dates of transplanting

Transplanting of rice on 31st January recorded the highest energy intensity in economic terms (3.64 MJ $Rs.^{-1}$) being at par with transplanting date of 23rd January (3.57 MJ $Rs.^{-1}$). The lowering in values of energy intensity in term of economic was noticed with transplanting date of 6th February (3.29 MJ Rs.$^{-1}$) and 13th February (3.10 MJ Rs.$^{-1}$). It happened so due to increase in gross energy output obtained with standard value of cost of cultivation.

Interaction effect

The interaction effect of transplanting of rice on 23rd January with irrigation regime of continuous soil saturation and transplanting date of 31st January with continuous ponding (3.74 MJ Rs.$^{-1}$) recorded the similar highest energy intensity in economics term. They were at par with transplanting date of 31st January with continuous soil saturation (3.73 MJ Rs.$^{-1}$) and transplanting date of 23rd January with continuous ponding (3.70 MJ Rs.$^{-1}$). The improvement in gross energy output with appreciable amount of cost of cultivation resulted in increasing the energy intensity in term of economics.

Table 2: Energy input (GJ ha^{-1}) and Gross energy output (GJ ha^{-1}) of summer rice as influenced by irrigation regimes and dates of transplanting and their interaction

Treatment	Energy input (GJ ha^{-1})				Gross energy output (GJ ha^{-1})			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
D_1	28.76	26.75	22.43	25.98	175.12	167.96	144.81	162.63
D_2	28.76	26.85	22.64	26.08	177.04	167.60	153.29	165.98
D_3	28.20	26.55	*22.21*	25.65	151.31	154.07	140.78	148.72
D_4	26.62	25.92	21.89	24.81	137.60	144.27	135.40	139.09
Mean	28.09	26.52	22.29	25.63	160.27	158.48	143.57	154.10

	Irrigation regimes	Dates of transplanting	Interaction	Irrigation regimes	Dates of transplanting	Interaction
SEm (±)	-	-	-	1.61	1.24	2.15
CD	-	-	-	6.33	3.69	6.39

Table 3: Net energy (GJ ha^{-1}) and Energy use efficiency (%) of summer rice as influenced by irrigation regimes and dates of transplanting and their interaction

Treatment	Net energy (GJ ha^{-1})				Energy use efficiency (%)			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
D_1	146.36	141.21	122.38	136.65	6.09	6.28	6.45	6.27
D_2	148.28	140.75	130.65	139.90	6.16	6.24	6.77	6.39
D_3	123.11	127.53	118.57	123.07	5.37	5.80	6.34	5.84
D_4	110.98	118.36	113.51	114.28	5.17	5.57	6.18	5.64
Mean	132.18	131.96	121.28	128.47	5.69	5.97	6.44	6.03

	Irrigation regimes	Dates of transplanting	Interaction	Irrigation regimes	Dates of transplanting	Interaction
SEm (±)	1.61	1.24	2.15	0.06	0.05	0.08
CD	6.33	3.69	6.39	0.24	0.15	0.25

Table 4: Energy productivity (Kg GJ^{-1}) and energy intensity in term of economics (MJ Rs.$^{-1}$) of summer rice as influenced by irrigation regimes and dates of transplanting and their interaction

Treatment	Energy productivity (Kg GJ^{-1})				Energy intensity in economic terms (MJ Rs.$^{-1}$)			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
D_1	453.21	470.42	486.76	470.13	3.70	3.74	3.26	3.57
D_2	461.90	468.01	512.86	480.92	3.74	3.73	3.45	3.64
D_3	404.48	437.24	481.07	440.93	3.24	3.43	3.19	3.29
D_4	388.63	421.59	472.61	427.61	2.98	3.23	3.08	3.10
Mean	427.06	449.31	488.32	454.90	3.41	3.53	3.25	3.40

	Irrigation regimes	Dates of transplanting	Interaction	Irrigation regimes	Dates of transplanting	Interaction
SEm (±)	4.40	3.97	6.88	0.04	0.03	0.05
CD	17.26	11.80	20.45	0.14	0.08	0.14

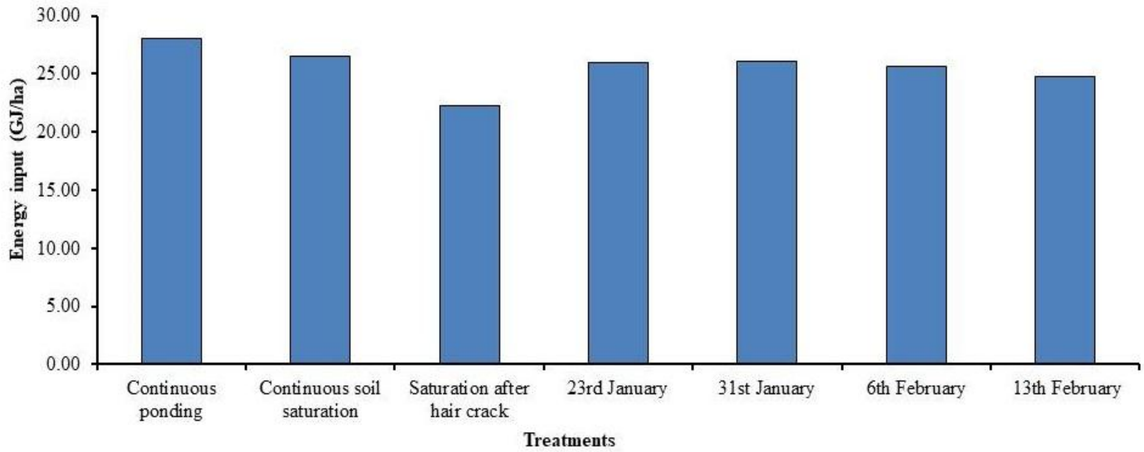

Fig. 1: Energy input (GJ ha^{-1}) of summer rice as influenced by irrigation regimes and dates of transplanting

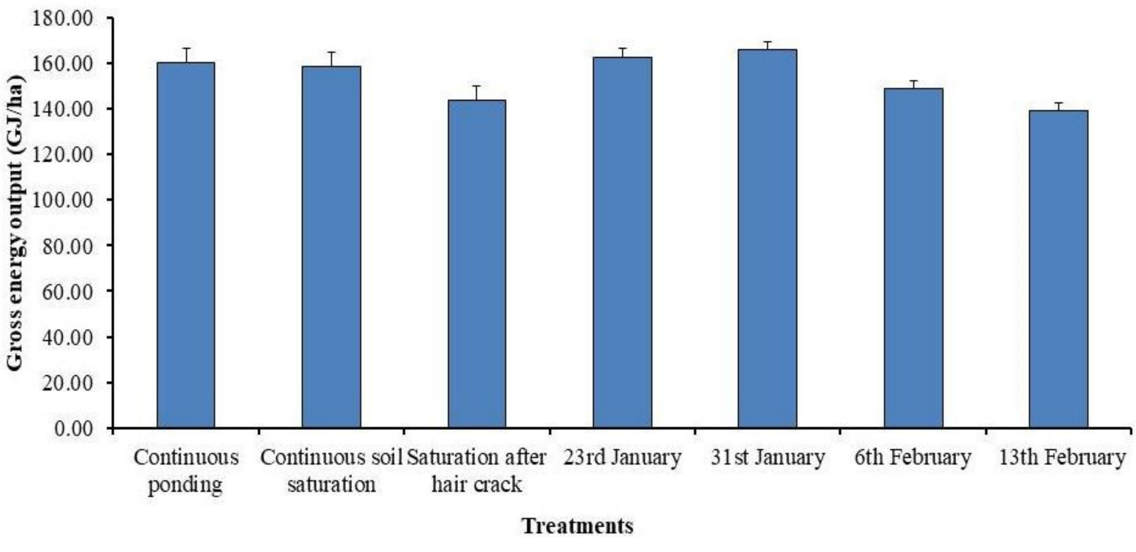

Fig. 2: Gross energy output (GJ ha^{-1}) of summer rice as influenced by irrigation regimes and dates of transplanting

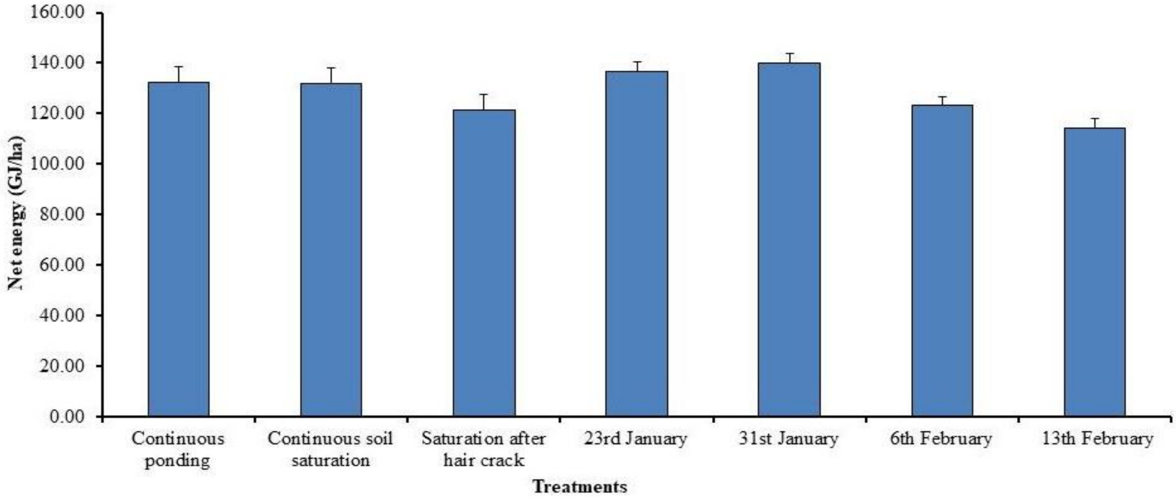

Fig. 3: Net energy (GJ ha^{-1}) of summer rice as influenced by irrigation regimes and dates of transplanting

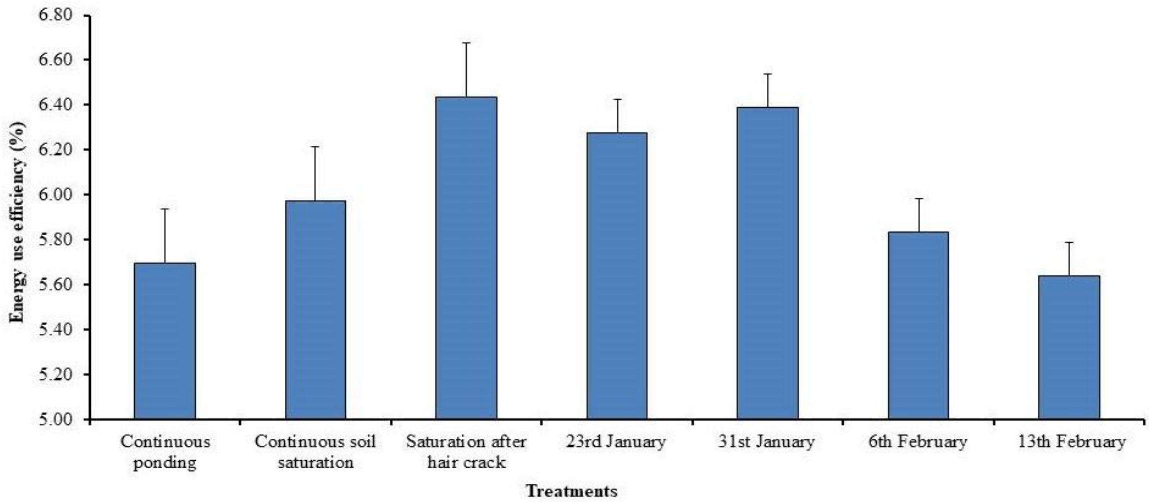

Fig. 4: Energy use efficiency (%) of summer rice as influenced by irrigation regimes and dates of transplanting

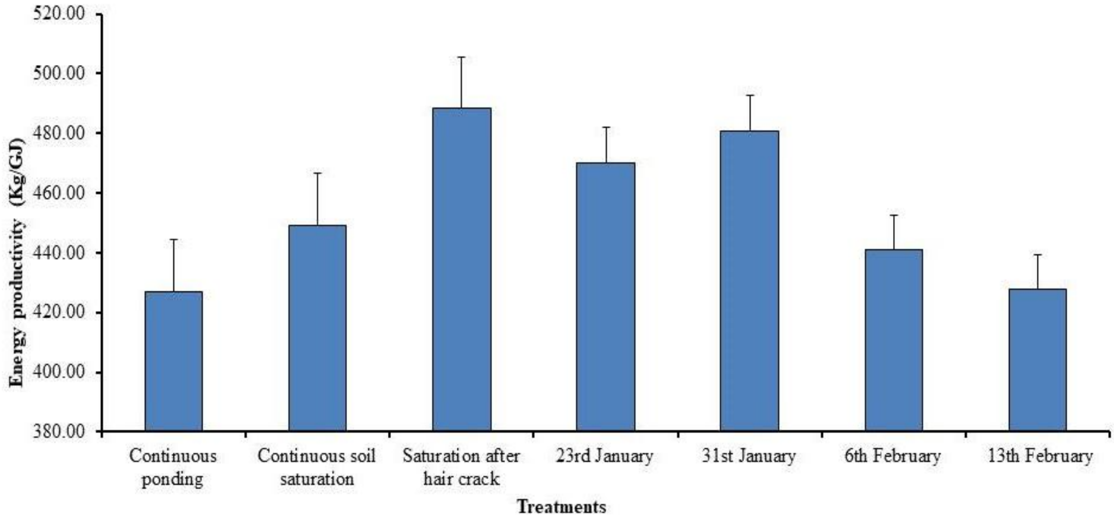

Fig. 5: Energy productivity (Kg GJ^{-1}) of summer rice as influenced by irrigation regimes and dates of transplanting

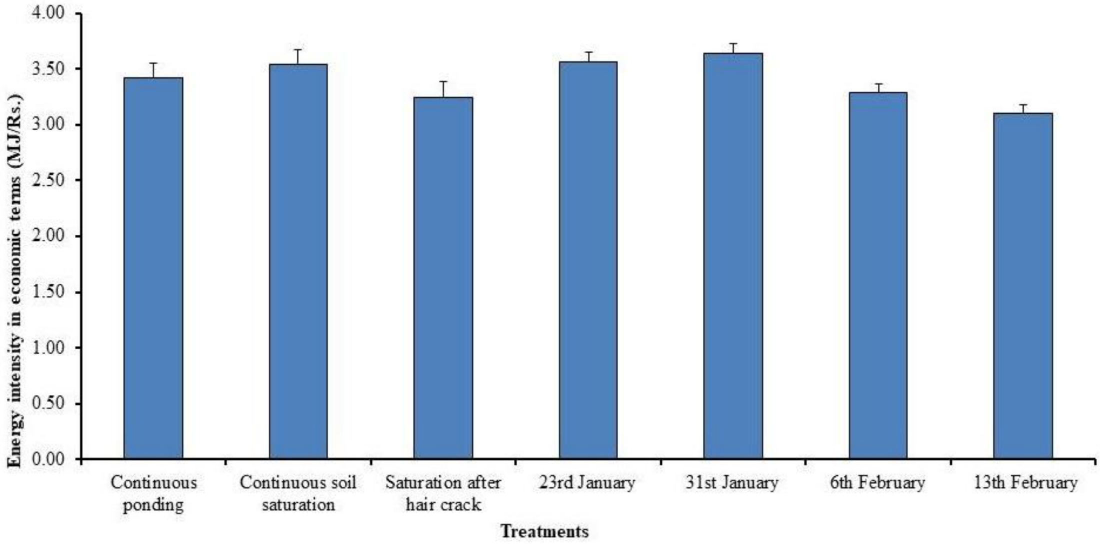

Fig. 6: Energy intensity in economic terms (MJ Rs.$^{-1}$) of summer rice as influenced by irrigation regimes and dates of transplanting

CONCLUSION

Transplanting of rice on 31st January with irrigation regime of continuous ponding was resulted in maximum input energy (28.76 GJ ha^{-1}), gross output energy (177.04 GJ ha^{-1}) and net energy (148.28 GJ ha^{-1}) along with energy intensity in economics term (3.74 MJ Rs.$^{-1}$). The highest energy productivity (512.86 Kg GJ^{-1}) and energy use efficiency (6.77 %) were obtained in transplanting of rice on 31st January applied with irrigation regime of saturation after hair crack.

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