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Effect of Water Management, Systems of Cultivation on Grain Yield and Energy Budget of Rice Varieties

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims of Study: This research focused on assessing the grain yield and energy performance of four rice cultivars under different irrigation regimes and systems of cultivation–for suitability of Andhra Pradesh and Telangana.
Experiment Design: The split-split plot design with three replications was performed for this study. The treatment comprised of two irrigation regimes *viz.,* Alternate Wetting and Drying (AWD) and saturation as the main plot treatments, three systems of cultivation *viz.,* System of Rice Intensification (SRI), Drum Seeding (DS) and Normal Transplanting (NTP) as the subplot treatments, and four cultivars namely DRR Dhan 42, DRR Dhan 43, MTU-1010, and NLR-34449 as the sub-sub plot treatments.
Place and Duration of Study: An experiment was conducted at the Indian Institute of Rice Research, Hyderabad, during the *Autumn 2017* and 2018.
Result: Among the irrigation regimes, AWD recorded higher grain yield than saturation, Gross output energy, and net energy as compared to saturation. SRI significantly recorded higher grain

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yield over the NTP method. Among the different rice cultivars, DRR Dhan 43 registers remarkably higher grain yield than other cultivars during 2017 and 2018. The cultivar DRR Dhan 43 recorded higher gross output energy, net energy compared to other rice cultivars.

Keywords: Rice; input energy; net energy; energy use efficiency, grain and straw yield.

1. INTRODUCTION

Rice is grown in an area of 44.5 M ha with a production of 115.60 M t and productivity of 2800 kg ha^{-1} in India [1]. Primary field preparation and nursery require bountiful measures of water and transplanting of rice manually is laborious, time taking and causes drudgery. Lack of timely availability of labor for transplanting many times ends up in late planting leading to poor yields [2]. Besides, the conventional submerged irrigation is laborious and time-consuming water expends a huge amount of labor, time, and energy for the increased pumping water in flooded fields [3]. To produce 1 kg of the un milled rice grain, the virtual water use was up to 5,000 liters [4]. Among the various techniques, the most extensively promoted one for the cultivation of rice is AWD irrigation [5]. Therefore, rice might face a threat due to water shortage and hence it's needed to follow water-saving strategies in rice cultivation so that production and productivity levels are elevated despite the looming water crisis. Among the strategies for rice cultivation, the system of rice intensification method envisages on alternate wetting and drying could facilitate to chop back water losses and improve productivity.

The growing worldwide demand for energy by the agricultural sector to meet the food demand of more than 7 billion people results in detrimental effects on the environment and the health of the farmers. If the energy in the agricultural sector is used judiciously, it will not only reduce the environmental impacts in terms of greenhouse gases (GHG) emissions and other hazardous effects but will also lead to a desirable sustainable form of agriculture [6]. A higher input of energy accounts for higher energy costs, which significantly reduces the net return of the farms and is a challenging issue for the policymakers. In many advanced agricultural systems, an increase in yield is the result of an augmented energy input that is directly related to the use of improved mechanized tools and the introduction of high-yield crop varieties. In most developing nations, agriculture is the mainstay of the economy and a source of employment for a large proportion of the population. Mechanization reduces human drudgery, ensures timeliness of farm-related activities, and increases farm output in terms of productivity [7]. In Indian agriculture, there is agro ecological diversity in soil, rainfall, temperature, and cropping systems. To meet the need for operational energy and reduce the share of animal power, the contribution of mechanical energy increased substantially, which directly resulted in increased use of fossil fuels, mainly diesel [8]. The key drivers of energy use in the agricultural sector in India are agricultural production, the extent of arable land used for crop production, and the penetration of efficient technologies, such as irrigation facilities and improved mechanization means [9]. Currently, cropping systems are increasing their energy inputs; therefore, there is a need to ascertain the efficiency of the system in terms of energy use. In this context, it is imperative to thoroughly budget the energy use of the widely followed cropping systems to identify the processes and systems that are the most energy-consuming and can be replaced with other low input-energy-consuming practices, to conserve energy and achieve sustainable cropping systems [10].

There has always been a lot of debate on the economic and environmental performance of smaller farms as compared to larger farms. The study also intends to report the performance of marginal, small, and medium farms, in terms of energy indicators and eco-efficiency. Therefore, to assess key energy indicators, such as Energy input, gross energy output, Net Energy, and Energy use efficiency (EUE). Among the varied production factors, a varietal choice at any location plays an important role. Several rice cultivars vary in their performance under different systems of cultivation. One option is to identify rice genotypes that will adapt to specific locations and soil textures. Hence, this study was conducted using 4 rice cultivars which grown under different systems of cultivation. Recently some of the high yielding rice cultivars viz., DRR Dhan 42, DRR Dhan 43, MTU-1010 and NLR-34449, *etc.,* were released for Telangana and Andhra Pradesh. Precise crop management depends on the growth characteristics of different varieties to get maximum yields.

2. MATERIALS AND METHODS

Two Field experiments were carried out during *Autumn,* 2017, and 2018 in field No. 5 of B-block, at Indian Institute of Rice Research (IIRR), Rajendranagar, Hyderabad. The soil samples were randomly collected from the experimental field from 0-30 cm depth and analyzed for their physicochemical properties by adopting standard procedures. Texturally clay loam with an average of 8.05 soil pH, 0.185 Electrical conductivity (dSm^{-1}), 0.485 organic carbon (%) 226.4, 27.25, and 508kg ha^{-1} available nitrogen, phosphorus, and potassium respectively. The treatments consisted of two irrigation regimes alternate wetting and drying (AWD) and saturation as main plot treatments, three systems of cultivation *viz.,* a system of rice intensification (SRI) with a spacing of 25 cm x 25 cm, drum seeding (DS) with the spacing of 20 cm x 10 cm and normal transplanting (NTP) with the spacing of 20 cm x 15 cm as subplot treatments and four cultivars namely DRR Dhan 42, DRR Dhan 43, MTU-1010 and NLR-34449 as sub-sub plot treatments laid out in split-split plot design with three replications. The area of each gross plot was 7 x 3 m^2. Seedlings were transplanted with an average of one seedling per hill in the SRI method of planting. FYM at @ 10 t ha^{-1} was uniformly applied to all the plots before final puddling and leveling. The recommended dose of phosphorus @ 60 kg P_2O_5 kg ha^{-1} as single super phosphate (SSP) was applied to all the treatments uniformly as basal and potassium @ 40 kg K_2O ha^{-1} as muriate of potash (MOP) was applied in two splits, 75 percent as basal and the remaining 25 percent at 75 DAS/DAT. The recommended dose of nitrogen (120 kg ha^{-1}) was applied through urea in three splits, 50 percent as basal, 25 percent at 50 DAS/DAT, and the remaining 25 percent at 75 DAS/DAT.

2.1 Total Number of Tillers

Five plants were selected and randomly tagged in each net plot, the total tillers were counted $hill^{-1}$ and expressed like the total number of tillers m^{-2} in four stages viz., 30, 60, 90 DAS/DAT, and at harvest.

2.2 Grain Yield and Straw Yield

Plants within the net plot area were harvested separately in each plot, threshed and the grains were separated, dried under the sun and the grain yield per plot was recorded after cleaning. From this, the yield per hectare was computed and expressed in kg ha^{-1}. After threshing the grain, the leftover straw was dried under the sun and the yield per plot was recorded and the yield per hectare was computed and expressed in kg ha^{-1}.

2.3 Total Input Energy

Direct energy inputs include the total quantity of fossil fuel used in land preparation, harvesting, human labor, and electricity, while indirect energy inputs are, energy used in the production of machinery and raw materials like mineral fertilizers, pesticides, and seed inputs and transportation [11]. A complete inventory of all the crop inputs (fertilizers, seeds, plant protection chemicals, fuel, human labor, irrigation water, and machinery power) and outputs of both grain and straw yields were recorded. The energy input in different treatments was computed by multiplying the input with the corresponding energy coefficients and summing up all these coefficients. The indirect energy use of agricultural machinery was calculated by using the following equation.

$$E_{im} = (MTR \times M) / (L \times C_e)$$

Where: E_{im}= Machinery input energy in MJ ha^{-1}
MTR = Energy used to manufacture, transport, and repair (for tractor, 76 MJ kg^{-1} and farm machinery, 111 MJ kg^{-1})
M = Mass of machinery kg)
L= Life of machinery (h)
C_e = Effective field capacity of farm machinery (h ha^{-1})

2.3.1 Total output energy

The output energy from the main product (grain) and byproduct (straw) was calculated by multiplying the amount of production and the corresponding energy equivalent and expressed as GJ ha^{-1}.

2.4 Net Energy (GJ ha^{-1})

The net energy was calculated by using the following formula

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

2.5 Total Energy Use Efficiency

The total energy use efficiency was calculated using the following formula.

$$EUE_t = \frac{\text{Total energy output (GJ ha}^{-1})}{\text{Net Energy (GJ ha}^{-1})(\text{GJ ha}^{-1})}$$

2.6 Statistical Analyses

The information obtained on the various growth and yield parameters and yield were statistically analyzed by the method of analysis of variance as per the procedure outlined for the split-split plot design given by Gomez and Gomez [12]. The statistical implication was tested by F value at 0.05 level of probability and the critical difference was figured out where ever the consequences were significant.

3. RESULTS AND DISCUSSION

3.1 Number of Tillers m^{-2}

The average number of tillers m^{-2} of rice linearly increased up to 60 DAS/DAT, and thereafter it was slightly declined, which could be due to self-thinning mechanism, resource constraint, or intra plant competition [13 and 14]. More number of tillers m^{-2} was recorded in 2018 due to timely sowing and transplanting as compared to 2017. The number of tillers m^{-2} of rice as influenced by the different irrigation regimes, systems of cultivation and cultivars were statistically analyzed and presented in Table (1). Between the irrigation regimes, there was no significant difference in the number of tillers m^{-2} at 30 DAS/DAT during 2017 and 2018. However, significantly a greater number of tillers m^{-2} were recorded (339, 309, and 297 in pooled means, respectively) in AWD at 60, 90 DAS/DAT, and harvest. This was comparably lower with saturation (325, 295, and 284 in pooled means respectively). Alternate wetting and drying created favorable moisture regimes which enabled the crop to grow lavishly by providing conducive microclimate and increased absorption, translocation, and assimilation of nutrients by the plant for different physiological processes [15] and in turn, helped the plants to boost their growth through the supply of more photosynthates which caused to produce a greater number of tillers $plant^{-1}$. The above results align with the results of Pandey *et al*. [16], Kumar *et al*. [17], and Kumar *et al*. [18].

Among the different systems of cultivation, the system of rice intensification recorded a significantly superior number of tillers m^{-2} at 30, 60, 90 DAS/DAT and at harvest (138, 357, 332, and 320 tillers m^{-2} respectively in pooled means of both the years) as compared to normal transplanting (NTP) (121, 294, 269 and 257 tillers m^{-2} respectively in pooled means of both the years) and drum seeding (125, 342, 317 and 305 tillers m^{-2}, respectively in pooled means of both the years). The number of tillers m^{-2} of rice cultivars was found to be significantly varied at all the growth stages of rice. Transplanting of younger seedlings might have improved the tillering capacity of the crop in the SRI [19]. This could be attributed to better aeration and less competition between plants because of wider spacing for nutrients and light. These results corroborate with the findings of Hugar *et al*. [20], Mohanty *et al*. [21], Sudhakara [22], and Thirupathi [23]. At 30 DAS/DAT a significantly higher number of tillers, m^{-2} was observed with NLR-34449 (148, 143, and 145 tillers m^{-2} during 2017, 2018, and in pooled means, respectively) over other cultivars. However, DRR Dhan 42, DRR Dhan 43, and MTU-1010 were on for with each other at 30 DAS/DAT. At 60, 90 DAS/DAT, and harvest the considerably higher number of tillers m^{-2} was recorded with NLR-34449 (369, 344, and 332 tillers m^{-2}, respectively in pooled means of both years) over other cultivars. Whereas the lowest number of tillers m^{-2} was recorded with DRR Dhan 42during 2017 and 2018. The interaction effect on the number of tillers m^{-2} during both years of the study was statistically non-significant among the different irrigation regimes, systems of cultivation, and cultivars at all the stages of the crop growth period (Table 1). The variation in the number of tillers m^{-2} among the varieties was due to the genetically inherent character of the cultivars. These results corroborate with the findings of Sharath [24] and Vijay [25].

3.2 Grain Yield

Despite the treatment differences, higher grain yield was recorded during the second year than the first year and it may be attributed to congenial weather conditions such as solar radiation and temperature, timely sowing, and yield attributes during *Autumn* 2018. The grain yield was significantly influenced by different irrigation regimes, systems of cultivation, and cultivars during 2017 and 2018 (Table 2).

Among the irrigation regimes, AWD irrigation practice throughout the crop growth period recorded higher grain yield (5755, 5952 and 5854 kg ha^{-1} in 2017, 2018 and pooled means, respectively) than saturation (5346, 5491 and 5439 kg ha^{-1} in 2017, 2018, and in pooled means, respectively). This could be because of favorable vegetative growth and development as they received intermittent and sufficient moisture at the proper amount and critical stages during the entire period of growth. Thus, maintained favorable soil water balance under alternate wetting and drying helped the crop plants to improve performance over-saturation because water plays a vital role in the carbohydrate metabolism, protein synthesis, cell division, cell enlargement, and partitioning of photosynthates to sink for enhanced development of growth characters. Frequent irrigations created favorable moisture regimes which enabled the crop to grow lavishly by providing conducive micro-climate and increasing solubility, absorption, translocation, and assimilation of nutrients by the plants for various physiological processes. The favorable growth traits enhanced the yield attributing characters with a higher source to sink exchange that resulted in higher grain yield. The above result is by the earlier reports of Thiyagarajan *et al*. [26] and Geethalakshmi *et al.* [27]. On the other way, hairline crack formation in AWD techniques of irrigation resulted in a higher level of yield. These results were earlier confirmed by Kumar *et al.* [28], and Majid [29].

Among the different systems of cultivation, the SRI recorded significantly higher grain yield (5953, 6129, and 6041 kg ha^{-1} during 2017, 2018, and in pooled means, respectively) over the normal transplanting method (5144, 5259 and 5202 kg ha^{-1} during 2017, 2018 and in pooled means, respectively). This was however on par with the drum seeding method (5784, 5826, and 5805 kg ha^{-1} during 2017, 2018, and in pooled means, respectively). The SRI method provides wider spacing, better aeration, and limited competition, which enabled the plants to grow lavishly. The enhanced seed yield in the SRI can be attributed to the more root growth that enabled them to access nutrients from a larger volume of soil. Similar results were revealed earlier by Thiyagarajan *et al*. [26] and Rajendran *et al*. [30]. Adequate vegetative growth with efficient dry matter accumulation and effective partitioning to panicles resulted in a higher number of panicles m^{-2} and grains $panicle^{-1}$, in the SRI method, wherein crop was transplanted at a younger seedling stage which was reflected in its grain yield. These findings are in agreement with the earlier reports of Manjunatha *et al.* [31] and Venkateswarlu *et al.* [19]. The yield attributing characters *viz.,* number of grains $panicles^{-1}$, number of filled grains $panicles^{-1}$ were higher in an SRI method than in drum seeding and normal transplanting, which are responsible for the increased grain yield [32, 33, 34 and 21].Among the different rice cultivars, DRR Dhan 43 registered notably higher grain yield than other cultivars during 2017 and 2018.Higher grain yield was noticed in DRR Dhan 43 (6055, 6122 and 6089 kg ha^{-1} during 2017, 2018 and in pooled means, respectively) followed by MTU-1010 (5631, 5733 and 5682 kg ha^{-1} during 2017, 2018 and in pooled means, respectively) and NLR-34449 (5476, 5590 and 5533 kg ha^{-1} during 2017, 2018 and in pooled means, respectively). However, significantly lower grain yield was recorded in DRR Dhan 42 (Table 2). The rice cultivars which produce a greater number of tillers m^{-2} (Table 1) produce the higher seed yield.

3.3 Straw Yield

The straw yield was influenced by different irrigation regimes, systems of cultivation, and cultivars during in 2017 and 2018 (Table 2). Within irrigation regimes, alternate wetting and drying methods significantly recorded higher straw yield (6287, 6558, and 6423 kg ha^{-1} during 2017, 2018, and in pooled means, respectively) than saturation (5878, 6011 and 5995 kg ha^{-1} in 2017, 2018, and pooled means, respectively). This is because of adequate moisture availability that contributed to enhanced dry matter production and accumulation. A similar outcome was revealed by Sariam and Anuar [35], Rahaman and Sinha [36], and Kumar *et al*. [18]. Among the different systems of cultivation, the SRI method recorded higher straw yield (6246-6546, and 6396 kg ha^{-1} during 2017, 2018, and in pooled means, respectively) over other systems of cultivation. This might be due to a higher number of tillers $hill^{-1}$ because of transplanting younger seedlings in case of a system of rice intensification. NTP method recorded the lowest straw yield than other systems of cultivation which was due to uneven plant stand and and less number of tillers per unit area. The above result is following the results of Manjappa and Kataraki [37], and Jayadeeva and Shetty [38]. Among the different rice cultivars, DRR Dhan 43 recorded significantly higher straw yield than other cultivars (6459, 6981, and 6620 kg ha^{-1} during 2017, 2018, and in pooled means, respectively). The lower straw yield was observed in DRR Dhan 42 (5710, 5899, and 5805 kg ha^{-1} during 2017, 2018, and in pooled means, respectively). However, cultivars MTU - 1010, NLR -34449, and DRR Dhan 42 were on par with each other during 2017 and 2018 (Table 2).

Table 1. Number of tillers m^{-2} of rice as influenced by different irrigation regimes, systems of rice cultivation and cultivars during *Autumn* 2017 and 2018

Treatments	Number of tillers m^{-2}											
	30 DAS/DAT			60 DAS/DAT			90 DAS/DAT			At harvest		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
Irrigation regimes (I)												
I_1 : AWD	129	130	129	338	340	339	307	310	309	295	298	297
I_2 : Saturation	126	127	126	326	326	325	294	295	295	281	287	284
SEm ±	1.2	3.1	1.1	4.1	4.4	3.3	4.1	4.4	4.3	3.4	3.6	3.5
C.D (P = 0.05)	NS	NS	NS	11	11	10	12	13	12	10	11	10
Systems of rice cultivation (S)												
S_1 : SRI	137	138	138	360	354	357	335	329	332	323	317	320
S_2 : DS	127	123	125	345	339	342	320	314	317	308	302	305
S_3 : NTP	119	122	121	285	302	294	260	278	269	248	266	257
SEm ±	1.5	1.9	1.6	5.6	5.7	5.6	4.5	6.2	5.1	3.6	4.4	4.1
C.D (P = 0.05)	5	5	5	14	15	14	13	15	15	11	12	12
Cultivars (C)												
C_1 : DRR Dhan 42	118	122	120	308	311	309	283	286	285	271	274	273
C_2 : DRR Dhan 43	125	124	125	360	354	357	335	329	332	323	317	319
C_3 : MTU-1010	120	122	121	321	320	321	297	295	296	285	283	284
C_4 : NLR-34449	148	143	145	370	367	369	346	343	344	333	331	332
SEm ±	2.9	1.8	2.0	5.9	3.3	3.5	4.2	4.2	3.5	5.1	4.2	4.5
C.D (P = 0.05)	6	5	6	14	10	11	13	12	10	15	10	12
Interactions	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: SEm- Standard error of mean, C.D- Critical difference, NS- Non Significant

Table 2. Grain yield and straw yield of rice as influenced by different irrigation regimes, systems of rice cultivation and cultivars during *Autumn* 2017 and 2018

Treatments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	2017	**2018**	**Pooled**	**2017**	**2018**	**Pooled**
Irrigation regimes (I)						
I_1 : Alternate Wetting and Drying	5755	5952	5854	6287	6558	6423
I_2: Saturation	5346	5491	5439	5878	6111	5995
SEm ±	112.3	122.1	131.9	125.6	127.1	121.7
C.D (P = 0.05)	363	386	374	362	368	365
Systems of rice cultivation (S)						
S_1 : System of Rice Intensification	5953	6129	6041	6246	6546	6396
S_2 : Drum Seeding	5784	5826	5805	5881	6129	6005
S_3 : Normal Transplanting	5144	5259	5202	5629	5870	5750
SEm ±	122.6	138.9	130.4	169.1	155.4	162.4
C.D (P = 0.05)	334	413	374	421	433	427
Cultivars (C)						
C_1: DRR Dhan 42	4940	5179	5060	5710	5899	5805
C_2: DRR Dhan 43	6055	6122	6089	6459	6981	6620
C_3: MTU-1010	5631	5733	5682	6301	5939	5920
C_4: NLR-34449	5476	5590	5533	5826	6152	5989
SEm ±	166.8	189.5	203.1	212.2	196.9	191.8
C.D (P = 0.05)	488	539	513	603	559	204
Interactions	NS	NS	NS	NS	NS	NS

Note: SEm- Standard error of mean, C.D- Critical difference, NS- Non Significant

Table 3. Energetics of rice cultivation as influenced by different irrigation regimes, systems of rice cultivation and cultivars during *kharif* 2017 and 2018

Treatments	Energetics (GJ ha^{-1})											
	Energy input (GJ ha^{-1})			Gross energy output (GJ ha^{-1})			Net energy (GJ ha^{-1})			Energy use efficiency (%)		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
Irrigation regimes (I)												
I_1 : AWD	17.8	16.6	17.2	184.8	178.4	181.6	167.0	161.8	164.4	1.11	1.10	1.10
I_2 : Saturation	18.4	17.5	18.0	166.1	161.2	163.6	147.7	143.7	145.7	1.12	1.12	1.12
SEm ±	0.14	0.12	0.13	1.46	1.41	1.44	1.26	1.19	1.23	0.17	0.14	0.16
C.D (P = 0.05)	0.4	0.4	0.4	4.4	4.2	4.3	3.8	3.5	3.7	0.5	0.4	0.5
Systems of rice cultivation (S)												
S_1 : SRI	15.4	14.5	15.0	185.0	178.1	181.6	169.6	163.6	166.6	1.09	1.09	1.09
S_2 : DS	16.6	15.7	16.2	181.1	173.2	177.2	164.5	157.5	161.0	1.10	1.10	1.10
S_3 : NTP	18.8	17.9	18.4	172.5	170.7	171.6	153.7	152.8	153.3	1.12	1.12	1.12
SEm ±	0.16	0.13	0.15	1.52	1.48	1.50	1.18	1.14	1.16	0.16	0.13	0.15
C.D (P = 0.05)	0.5	0.4	0.4	4.5	4.4	4.5	3.5	3.4	3.5	0.5	0.4	0.4
Cultivars (C)												
C_1 : DRR Dhan 42	18.7	18.2	18.5	172.5	170.8	173.1	153.8	152.6	154.7	1.12	1.12	1.12
C_2 : DRR Dhan 43	14.7	13.8	15.3	183.2	180.6	181.9	168.4	166.7	166.6	1.09	1.08	1.09
C_3 : MTU-1010	17.8	16.9	17.4	180.1	179.7	179.9	162.3	162.8	162.5	1.11	1.10	1.11
C_4 : NLR-34449	17.6	16.3	17.0	179.0	176.1	177.6	161.4	159.8	160.6	1.11	1.10	1.11
SEm ±	0.20	0.20	0.20	1.49	1.42	1.46	1.25	1.21	1.23	0.19	0.12	0.16
C.D (P = 0.05)	0.6	0.6	0.6	4.4	4.2	4.3	3.7	3.6	3.7	0.6	0.4	0.5
Interactions	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: SEm- Standard error of mean, C.D- Critical difference, NS- Non Significant

3.4 Input Energy

Between the irrigation regimes, saturation recorded significantly higher input energy (18.4, 17.5, and 18.0 GJ ha^{-1} during 2017, 2018, and in pooled means, respectively) over alternate wetting and drying. This was mostly due to a higher number and amount of irrigations given in saturation than the AWD method. The input energy required was significantly higher in normal transplanting (18.8, 17.9, and 18.4 GJ ha^{-1} during 2017, 2018, and in pooled means, respectively) as over drum seeding and SRI methods. In drum seeding labor energy used was minimal, but in the case of normal transplanting, the usage of more labor resulted in increased total input energy used than other systems of cultivation. Significant variations in grain and straw yields brought out dissimilarity in gross output energy among the different irrigation regimes, systems of cultivation, and cultivars during 2017 and 2018 (Table 3). Among the rice cultivars, significant differences were found regarding input energy during 2017 and 2018. DRR Dhan 42 noticed appreciably higher input energy (18.7, 18.2, and 18.5 GJ ha^{-1} during 2017, 2018, and in pooled means, respectively) over other cultivars. However lower input energy was observed in DRR Dhan 43 (Table 3).

3.5 Gross Output Energy

AWD method of irrigation registered significantly higher gross output energy (184.8, 178.4, and 181.6 GJ ha^{-1} during 2017, 2018, and in pooled means, respectively) than saturation. Higher gross output energy was attributed to higher grain and straw yields under alternate wetting and drying. This result conforms to the findings of Alam *et al*. [39] and Thirupathi [23]. SRI recorded appreciably higher gross output energy (185.0, 178.1, and 181.6 GJ ha^{-1} during 2017, 2018, and in pooled means, respectively) over normal transplanting and drum seeding. The higher grain and straw yields in the SRI method led to higher gross output energy. This result conforms to the reports of Jayadeva *et al*. (2010). Among the different cultivars, DRR Dhan 43 resulted in significantly superior gross output energy (183.2, 180.6, and 181.9 during 2017, 2018, and pooled means, respectively) compared to other rice cultivars (Table 3). It is because of higher grain and straw yields in DRR Dhan 43 which led to higher gross output energy.

3.6 Net Energy

In irrigation regimes, alternate wetting and drying significantly recorded higher net energy (167.0, 161.8, and 164.4 GJ ha^{-1} during 2017, 2018, and in pooled means, respectively) than saturation. This was due to higher grain and straw yields which led to higher net energy in AWD. Among the systems of cultivation, SRI significantly recorded higher net energy (169.6, 163.6, and 166.6 GJ ha^{-1} during 2017, 2018, and in pooled means, respectively) than normal transplanting and drum seeding. This was mainly due to higher grain yield and straw yield which resulted in higher net energy in the SRI over other systems of cultivation. This result conforms to the reports of Jayadeva *et al*. [40] and Babu *et al*. [41] Sudhakara [22] and Thirupathi(2017). Among the different rice cultivars, DRR Dhan 43 obtained considerably higher net energy (168.4, 166.7, and 166.6 GJ ha^{-1} during 2017, 2018, and pooled means, respectively) than other rice cultivars (Table 3). Due to higher grain and straw yields in DRR Dhan 43 led to higher net energy.

3.7 Energy Use Efficiency

In irrigation regimes, saturation recorded higher energy use efficiency (1.12, 1.12, and 1.12 % during 2017, 2018, and in pooled means, respectively) than AWD. This might be due to lower net energy response for output energy. The energy use efficiency recorded was significantly higher in the NTP (1.12, 1.12, and 1.12 % in 2017, 2018, and in pooled means, respectively) than other (Table 3). This was mainly due to lower grain and straw yields coupled with lower net energy. Higher energy use efficiency under the system of rice intensification method was reported by many research workers (42, 40,41]. Among the different rice cultivars, DRR Dhan 43 recorded appreciably higher energy use efficiency (1.12, 1.12, and 1.12 % during 2017, 2018, and pooled means, respectively) over other cultivars.

4. CONCLUSIONS

- ✓ The irrigation regime of AWD performed well with respect to grain yield, and straw yield as compared to saturation. Saturation significantly recorded higher input energy. Gross output energy, net energy was higher with AWD as compared to the saturation
- ✓ The SRI was better in terms of grain and straw yields over the normal transplanting method. The normal transplanting method required higher input energy. The gross energy output, net energy was significantly superior in SRI than other systems of cultivation.

- ✓ DRR Dhan 43 cultivar significantly registered higher growth parameters, grain and straw yields than other rice cultivars. However, DRR Dhan 43 recorded higher gross output energy, net energy, and energy use efficiency as compared to other rice cultivars.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. ASG. Directorate of Economics and Statistics, Department of Agriculture and Cooperation. Agricultural Statistics at a Glance, Ministry of Agriculture, Government of India, New Delhi. 2019;79-81.
2. Awan TH, Ali I, Safdar ME, Ahmad M, Akhtar MS. Comparison of parachute, line, and traditional rice transplanting methods at a farmer's field in the rice-growing area. Pakistan J. Agric. Sci. 2008;45(4):432:438.
3. Mahajan G, Chauhan BS, Timsina J, Singh PP, Singh K. Crop performance and water- and nitrogen-use efficiencies in dry-seeded rice in response to irrigation and fertilizer amounts in northwest India. Field Crops Res. 2012;134:59-70.
4. Cantrell RP, Hettel GP. New challenges and technological opportunities for rice-based production systems for food security and poverty alleviation in Asia and the Pacific. *FAO Rice Conference,* 12-13 February 2004, FAO, Rome, Italy. 2004;247-251.
5. Cabangon RJ, Castillo EG, Tuong TP. Chlorophyll meter-based nitrogen management of rice grown under alternate wetting and drying irrigation. Field Crops Res. 2011;121:136-146.
6. Nasso DNN, Bosco S, Bene DC, Coli A, Mazzoncini M, Bonari E. Energy efficiency in long-term Mediterranean cropping systems with different management intensities. Energy. 2011;36:1924-1930.
7. Soni P, Rajeev S, Sylvain R. Energy use and efficiency in selected rice-based cropping systems of the Middle-Indo Gangetic Plains in India. Energy Reports. 2018;4:554-564.
8. Kulkarni S. Country Paper- India Agricultural Mechanization- Present Scenario and Perspective. Central Institute of Agricultural Engineering, Bhopal;2010.
9. Chaudhary VP, Gangwar B, Pandey DK, Gangwar KS. Energy auditing of diversified Paddy-wheat cropping systems in Indo-Gangetic plains. Energy. 2009;34:1091-1096.
10. Hatirli SA. Energy inputs and crop yield relationship in greenhouse tomato production. Renew. Energy. 2006;31:427–438.
11. Singh S, Mittal JP. The energy in Production Agriculture. Mittal Publications, New Delhi, India;1992.
12. Gomez KA, Gomez AA. Statistical procedures for agricultural research. (2 ed.). John Wiley and Sons, New York;1984..
13. Harish H, Deshpande, Devasenapathy P. Effect of different organic sources of nutrients and green manure on growth and yield parameters of rice (*Oryza sativa*) grown under lowland conditions. *Crop Res.* 2011;41(1, 2 &3):1-5.
14. Pallakonda R. Influence of planting methods and integrated nutrient management on growth, yield, and quality of rice. *Ph.D. Thesis*. Professor Jayashankar Telangana State Agricultural University, Hyderabad;2014.
15. Dass A, Chandra S. Effect of different components of SRI on yield, quality, nutrient accumulation, and economics of rice (*Oryza sativa*) in *the Tarai*belt of northern India. Ind. J. Agron. 2012;57 (3): 250-254.
16. Pandey N, Verma AK, Tripathi RS. The response of hybrid rice to the scheduling of nitrogen and irrigation during the dry season. Oryza. 2010;47(1): 34-37.
17. Kumar S, Singh RS, Yadav L, Kumar K. Effect of moisture regime and integrated nutrient supply on growth, yield, and economics of transplanted rice. Oryza. 2013;50(2):189-191.

18. Kumar S, Singh RS, Kumar K. Yield and nutrient uptake of transplanted rice (*Oryza sativa*) with different moisture regimes and integrated nutrient supply. Current Adv. Agric. Sci. 2014;6(1): 64-66.
19. Venkateswarlu E, Sambasiva RN, Rama PD. On-farm evaluation of mechanical transplanting of rice (*Oryza sativa* L.) against the traditional method. The Andhra Agri. J. 2011;58(1): 9-11.
20. Hugar AY, Chandrappa H, Jayadeva HM, Sathish A, Mallikarjun GB. Comparative performance of different rice establishment methods in the Bhadra command area. Karnataka J. Agric. Sci. 2009;22(5):992-994.
21. Mohanty AK, Islam M, Kumar GAK, Kumar A. Enhancing rice (*Oryza sativa*) productivity through demonstrations of the SRI method of cultivation in the mid-altitude region of Indo Himalayan Belt of Sikkim. Ind. Res. J. Ext. Edu. 2014;14 (3):88-92.
22. Sudhakara TM. Evaluation of irrigation regimes and nitrogen management practices on the production potential of rice (*Oryza sativa* (L.) under mechanized SRI and SRI methods. *Ph.D. Thesis,* Professor Jayashankar Telangana State Agricultural University, Hyderabad;2015.
23. Thirupathi I. Assessment of production potential and greenhouse gas emissions from rice fields with irrigation regimes and nitrogen management practices under different establishment methods. *Ph.D. Thesis,* Professor Jayashankar Telangana State Agricultural University, Hyderabad;2017.
24. Sharath CM. Performance of different rice (*Oryza sativa* (L.) varieties under alternate wetting and drying method in puddled soil. *M.Sc. (Ag.) Thesis,* Professor Jayashankar Telangana State Agricultural University, Hyderabad;2017.
25. Vijay KP. Different duration rice (*Oryza sativa* L.) varieties as influenced by varied levels of nutrients application under irrigated ecology. *M.Sc. (Ag.) Thesis.* Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh;2018.
26. Thiyagarajan TM, Velu V, Ramaswamy SD, Govindarajan K, Priyadarshini R, Sudha Lakshmi C, Senthil Kumar K, Nisha PT, Gayathry G, Hengsdijk H, Bindraban PS. Effect of SRI practice on hybrid rice performance in Tamil Nadu, India. In: Water-Wise Rice Production, IRRI. 2002;119-127.
27. Geethalakshmi V, Ramesh T, Azhapalamuthirsolai, Lakshmanan A. Productivity and water usage of rice as influenced by different cultivation systems. Madras Agric. J. 2009;96(7-12):349-352.
28. Kumar RP, Singh GK, Singh AK. Irrigation scheduling for better growth, development, and yield of hybrid rice (*Oryza sativa* L.). Crop Res. 2006;32(9): 6-10.
29. Majid A. Water use efficiency, irrigation management, and nitrogen utilization in rice production in the North of Iran. APCBEE Procedia. 2014;8:70-74.
30. Rajendran K, Raja KG, Balasubramanian R. Evaluation of crop establishment techniques and weed management practices under the system of rice intensification. Madras Agric. J. 2013;100 (7-9):698-702.
31. Manjunatha MV, Reddy BG, Shashidhar SD, Joshi VR. Studies on the performance of self-propelled rice transplanter and its effect on crop yield. Karnataka J. Agric. Sci. 2009;22(2):385-387.
32. Hameed KA, Jaber FA, Hadi AY, Elewi JAH, Uphoff N. Application of system of rice intensification (SRI) methods on the productivity of jasmine rice variety in southern Iraq. Jordan J. Agric. Sci. 2011;7(3): 471-481.
33. Nyamai M, Mati BM, Home PG, Odongo B, Wanjogu R, Thuranira EG. Improving land and water productivity in basin rice cultivation in Kenya through the System of Rice Intensification (SRI). Int. J. Agric. Eng. 2012;14(2): 1-9.
34. Thakur AK, Rath S, Mandal KG. Differential responses of the system of rice intensification (SRI) and conventional flooded rice management methods to the application of nitrogen fertilizer. *Plant and Soil*. 2013;370:59-71.
35. Sariam O, Anuar AR. Effects of irrigation regime on irrigated rice. J. Tropic. Agric. and Food Sci. 2010;38(1):1-9.
36. Rahaman S, Sinha AC. Effect of water regimes and organic sources of nutrients for higher productivity and nitrogen use efficiency of summer rice (*Oryza sativa*). African J. Agr. Res. 2013;8(48):6189-6195.
37. Manjappa K, Kataraki NG. Use of drum seeder and transplanters for increasing rice (*Oryza sativa*) profitability. Ind. J. Agri. Sci. 2004;74(1): 19-20.

38. Jayadeeva HM, Shetty TKP. Influence of crop establishment techniques and sources of nutrients on productivity, energetic and economics of rice. *Oryza.* 2008;45(2):166-168.
39. Alam MM, Rezaul K, Ladha JK. Integrating best management practices for rice with farmers' crop management techniques: A potential option for minimizing rice yield gap. Field Crops Res. 2013;144: 62-68.
40. Jayadeva HM, Prabhakara STK, Bandi AG, Gowda, R.C. 2010. Water use efficiency, energetics, and economics of rice as influenced by crop establishment techniques and sources of nitrogen. *Crop Res.* 39 (1, 2 & 3): 14-19.
41. Babu S, Singh R, Avasthe RK, Yadav GS, Chettri TK. Production potential, economics, and energetics of rice (*Oryza sativa*) genotype under different methods of production in organic management conditions of Sikkim, Himalayas. *Ind. J. Agron*. 2014;59(4):602-606.
42. Kumar RM, Surekha K, Padmavathi C, Rao LVS, Latha PC, Prasad MS, Viraktamath BC. Research experiences on System of Rice Intensification and future directions. J. Rice Res. 2009;2:61-73.

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