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Research Paper

Effect of water regimes on productivity, profitability and energetics of rice (*Oryza sativa*) cultivars under non- puddled conditions of Eastern India

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ABSTRACT

The investigation was carried out to study the effect of various irrigation water regimes on productivity of different rice (*Oryza sativa* L.) cultivars under non- puddled establishment conditions during dry season (Jan-May) of 2014 and 2015 at Bhubaneswar. The treatment comprised establishment methods, viz. direct seeded rice (DSR) and non-puddled transplanted rice (NPTR); 3 water regimes, viz. no stress, 10 and 40 kPa; and 5 cultivars, viz. 'Lalat', 'Sahbhagi Dhan', 'Arize® 6129', 'US 323', and 'Arize® 6444'. Experiment was conducted in 3 times replicated split-split plot design. Under no stress treatment irrigation was done as soon as the ponded water disappeared and in other 2 treatments, irrigation was given when tensiometer readings were 10 kPa and 40 kPa. Results showed that similar grain yield was recorded in DSR and NPTR. Higher grain yield was obtained under no stress (7.0 t/ha) followed by 10 kPa (6.2 t/ha) and 40 kPa (4.6 t/ha). Among the varieties 'Arize® 6444' recorded maximum grain yield (6.6 t/ha), straw yield (7.6 t/ha) and harvest index (46.6). The DSR recorded the highest net returns (₹384,000/ha), benefit: cost ratio (1.8) and economic efficiency (₹312/ha/day). 'Arize® 6444' gave higher net returns and benefit: cost ratio under no stress condition. The nitrogen uptake, internal-use efficiency and partial-factor productivity was significantly high under no stress. In cultivars, 'Arize® 6444' recorded the highest energy efficiency, energy productivity and profitability under no stress conditions. The result revealed that yield under no stress was on higher side, but irrigation savings with good yield was obtained under 10 kPa. Hence, 'Arize® 6444' grown under DSR could be considered a better option in this area.

***Key words* :** Direct seeded rice, Economic efficiency, Energy productivity, Energy profitability, Non-puddled transplanted rice

Rice is one of the staple food crops for approximately half of the global population. The slogan "Rice is life" during International Year of Rice 2006 reflects the importance of rice as primary source of food. It is estimated that by the year 2025, it will be necessary to increase rice production by approximately 60% over current levels with 1.2% growth per year (Normile, 2008). Rice is also one of the greatest consumers of water among all crops and consumes approximately 80% of the total irrigated fresh water resources in Asia. Declining availability of water resources is threatening the sustainability of the irrigated rice-based production system. Exploring approaches to produce more rice with high irrigation water productivity (WP_I) is essential for food security and sustaining environmental health. It has been reported that, alternate wetting and drying (AWD) can maintain or even increase grain yield (Lampayan *et al*., 2015) or decrease (Belder *et al*., 2004), when compared with continuously submerged conditions. Obviously, it remains a major challenge to reduce irrigation water input without compromising yield and to optimize water management in rice production.

The conventional methods of rice establishment in Odisha are manual transplanting of seedlings in to puddle soil and *beushening*. Puddling which requires 10–54 cm water results in complete breakdown of soil aggregates, destruction of macro pores and formation of hard pan at shallow depth. Beushening operation also requires a high seed rate (~100 kg/ha) and a standing water of 15–20 cm. These 2 methods are water, labor and energy intensive.

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Alternatively rice can be transplanted on non-puddled soil where the field is maintained with a standing water of 5 cm without puddling. Non puddle transplanted rice (NPTR) saves significant amount of power, fuel, water and time. Input water savings of 35–57% have been reported for dry direct-seeded rice sown into non-puddled soil compared with puddled soil (Sharma *et al.*, 2002). Mondal *et al.*, (2016) found that omission of puddling improved the physical properties of soil like bulk density, penetration resistance, aggregate stability and cracking behaviour. Dry drill-seeded rice (DSR) is another resource conservation technology that saves water upto 25% and energy up to 27%. The labor requirement in direct seeding is about 34% that of transplanted rice (Ho Nai Kin and Romli, 2002).

Energy is one of the most valuable inputs in agriculture system. Agriculture itself is energy user and supplier in the form of bio–energy. Crop yield is result of conversion of solar energy into metabolisable forms of energy and nutrients through photosynthetic pathways. Sufficient availability of right energy and its effective and efficient use are pre-requisites for improved agricultural production. Saving in water also saves electricity and diesel. Hence, energy budgeting is important for efficient management of resources for improved agricultural production. Considering these points in mind, this experiment was planned to study the effect of water regimes on productivity, profitability and energetics of rice cultivars under different establishment methods.

MATERIALS AND METHODS

The field experiment was carried out during dry seasons (January-May) of 2014 and 2015 at research farm of Orissa University of Agriculture and Technology (OUAT), Bhubaneswar (20°15'N, 85°48' E, 30.6 m above mean-sea level). The soil is sandy clay loam with slightly acidic *p*H of 6.4, normal EC of 0.18 dS/m and organic carbon 4 g/kg soil. The nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) were 144, 38 and 117 kg/ha, respectively. At experimental site, total rainfall was 786.1 and 648.4 mm during cropping season of 2014 and 2015, respectively (Fig. 1).

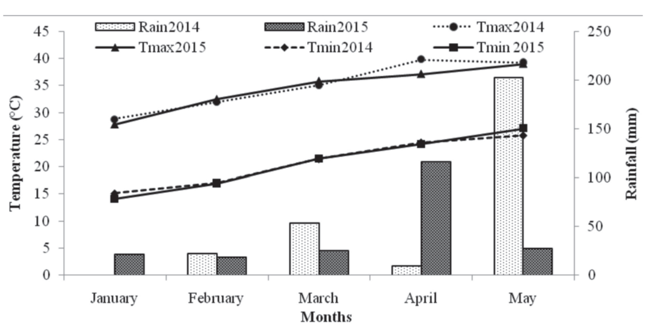

Fig. 1. Weather parameters during the experiment

Although number of rainy days in 2015 (17) was greater than 2014 (11), the total rainfall received during 2014 was 137.7 mm higher than 2015. The maximum temperature in 2014 and 2015 was 34.9°C and 34.4°C and minimum temperature in both the years was 21°C.

The field experiment was laid-out in split-split plot design with 3 replications. The main plots received 2 crop establishment methods, viz. dry direct-seeded rice (DSR) and non-puddled transplanted rice (NPTR). In sub-plots, 3 water regimes, viz. no stress (irrigation upto 5 cm depth was applied to the field as soon as the ponded water disappeared) and irrigation at 10 kPa and 40 kpa (irrigation was applied based on the tensiometer data, which was installed in every sub-plots at depth of 15 cm) were assigned, while 5 rice cultivars, viz. 'Lalat', 'Sahbhagi Dhan', 'Arize® 6129', 'US 323' and 'Arize® 6444' were allocated in sub-sub-plots. 'Lalat' is a local variety of medium duration (125–130 days) and is commonly grown in most parts of Odisha. 'Sahbhagi Dhan' is a drought tolerant and short-duration cultivar (110–115 days) recommended for the eastern states of India. 'Arize® 6129' and 'Arize® 6444' are hybrids, of which 'Arize® 6129' mature in 115–120 days, while 'Arize® 6444' matures in 135–140 days with medium slender grain, higher number of productive tillers, more grains per panicle and wider adaptability with more than 70% milling. US 323 developed by US Agri-seeds is of 115–120 days duration with better tillering ability and higher yield.

After site selection, the experimental plot was cultivated and laser leveled to maintain precise depth of water in each treatment. After layout, each sub-plot was surrounded by plastic lining to a depth of 40 cm and covered by earthen bunds to cease the lateral flow of water through the bunds. DSR sowing was done on dry cultivated soil by seed drill with seed rate of 30 kg/ha and spacing of 20 cm. On the same day, mat-nursery for transplanted treatments was sown. For NPTR, a light irrigation was given and the soil was allowed to settle for 12–24 hours. Field was again replenished with 5 cm standing water one day prior to transplanting. After field preparation, 15–20-days old seedlings were transplanted at a row spacing of 23 cm and plant spacing of 14 cm (mimic of mechanical transplanting geometry) with 2 seedlings/hill. The basal dose of 18 kg N/ha, 46 kg P_2O_5/ha, 40 kg K_2O/ha and 5 kg Zn/ha was applied through DAP, MOP and zinc sulphate before sowing in DSR or final cultivation in NPTR. Top dressing of N was done 4 times at fortnight interval with 33 kg N through urea, starting at active tillering stage and ending with the panicle initiation stage.

DSR was sown on 8 January during both the seasons, whereas NPTR was transplanted on 24 January in 2014 and 30 January in 2015. Weeds in DSR were controlled with pre-emergence application of pendimethalin 1,000 g a.i./ha at 2 DAS and post-emergence application of bispyribac-sodium 25 g/ha at 25 DAS. In NPTR, weeds were controlled with pretilachlor 500 g/ha one DAT and bispyribac 25 g/ha at 12 DAT. Weeds that escaped these treatments were removed manually at 45 DAS/45 DAT. In the first season, 'Lalat' was infested with blast. As per visual scoring, the percentage of blast incidence surpassed 75%, and was effectively controlled by spraying tricyclazole 75WP 0.6 g/L of water, 'Sahbhagi Dhan' was infested with bacterial leaf blight and was controlled by spraying a mixture of propiconazole 1,500 g/ha with streptomycin at 15 g/ha.

Irrigation water was applied using polyvinyl chloride pipes of 10-cm diameter with a separate outlet for each plot. The volume of irrigation applied to each plot was measured using a HWE Woltman type flow meter. For each irrigation cycle, the plots were topped up to 50-mm standing water depth measured with a ruler installed in each plot. Irrigation was scheduled based on the average reading of tensiometer established in subplots at a depth of 15 cm. The tensiometer reading was taken every morning at 8 AM to determine the irrigation need for the day. The quantity of water applied and the actual depth of irrigation were computed by dividing the volume of irrigation by the area of the plot.

Grain yield was determined by harvesting the plant sample manually from the center of the plot from an area of 6 m^2 (3 m × 2 m) in DSR and 6 m^2 (2.94 m × 2.07 m) in NPTR. Grain moisture content was measured for each plot using a moisture meter, and grain yield was expressed as t/ha at 14% moisture content. The straw yield was determined by deducting the grain yield from the total biomass yield. Harvest Index was computed by dividing the economic yield (grain) by biological yield (grain + straw) expressed in %. Grain filling efficiency (%) is ratio of filled grain by total number of grains expressed in per cent.

Gross returns of each crop establishment methods and cultivars were calculated from sale price of rice grain (according to minimum support price declared by Government of India) and straw during their respective rice-growing seasons 2014 and 2015. Net returns were calculated with gross returns subtracted by cost of production, whereas benefit: cost ratio (B: C) was calculated using formula, gross returns divided by cost of production.

Crop productivity (kg grain/ha/day) and economic efficiency (/ha/day) was calculated as suggested by Kumawat *et al*., (2012). Economic yield of rice was converted to equivalent value of carbohydrate (t/ha) as suggested by Gopalan *et al*. (2004). Irrigation water productivity (WP_I) was computed by grain yield divided by the irrigation input and input water productivity (WP_{I+R}) was computed by dividing grain yield by the amount of rainfall and irrigation applied.

The nitrogen uptake by grain was determined by multiplying the nitrogen content (determined by Kjeldahl method) by grain yield and expressed in kg/ha. Nitrogen harvest index was expressed as the ratio of grain (paddy) N uptake to the total plant N uptake. Internal N-use efficiency (IE) was computed as the ratio of amount of grain (kg) produced to the amount of N uptake (kg). Partial factor productivity (PFP) of N was computed as ratio of the amount of grain (kg) produced to the amount of N applied (kg).

The energy values were determined based on energy inputs and energy production as given by Gundogmus (2006) and Tuti *et al*., (2012). Inputs and outputs were converted from physical to energy unit measures through published conversion coefficients. Energy output of grain and straw was estimated by multiplying the amount of grain / straw with corresponding equivalent energy.

Net energy (GJ/ha) = Total energy output (GJ/ha) – Total energy input (GJ/ha)

Energy efficiency = Total energy output (GJ/ha) / Total energy input (GJ/ha)

Energy productivity (kg/MJ) = Grain yield (kg/ha) / Total energy input (MJ/ha)

Energy profitability (MJ/kg) = Net energy return (MJ/ha) / Grain yield (kg/ha)

Human energy profitability = Total energy output (GJ/ha) / Labor energy (GJ/ha)

Table 1. Energy equivalents of inputs and outputs in agricultural production

Particulars	Unit	MJ/unit
Direct Energy		
Labor	MH	1.96
Diesel	Lt	56.31
Electricity	kWh	11.93
Indirect Energy		
Seed	kg	14.7
N	kg	60.6
P_2O_5	kg	11.1
K_2O	kg	6.7
$ZnSO_4$	kg	20.9
Herbicide	kg	238
Insecticide	kg	199
Fungicide	kg	92
Irrigation	m^3	1.02
Machinery	h	62.7
Output Energy		
Grain	kg	14.7
Straw	kg	12.5

Source: Gundogmus, 2006 and Tuti *et al*., 2012

Data of crop establishment methods, 3 water regimes and 5 cultivars for 2 years were pooled and statistically analyzed using F-test. Significant difference between treatments mean were compared with critical differences at 5% levels of probability.

RESULTS AND DISCUSSION

Crop productivity

There was no significant effect of establishment methods on yield of rice (Table 2), which was also reported by Ali *et al*., (2006), who indicated that both the establishment methods are equally acceptable. Water regimes and varieties had significant effect on grain yield, straw yield and harvest index. Grain yield with no stress was 7 t/ha, which was 13 and 55% higher than 10 kPa and 40 kPa, respectively. The straw yield and harvest index was the maximum under no stress, viz. 8 t/ha and 46.7%, respectively. The yield decline was primarily associated with reduced above ground biomass, which could be explained by reduced chlorophyll content with an increase in stress due to electrolyte leakage. Maheswari *et al.* (2007) found that increasing water stress in rice resulted in many anatomical changes in the plant, such as a decrease in cell volume, cell division, intercellular spaces, and thickening of the cell wall, which limit overall plant growth. Bouman and Tuong (2001) reported that rice performs best when grown under continuous flooding or in saturated soil, and that yield declines as the soil dries below saturation, with a critical threshold of around 10 kPa. The higher yield in no stress may be because of the availability of water that enhanced the nutrient uptake, and better translocation of dry matter. Even the grain filling efficiency was significantly higher under no stress, which may also be a reason for higher yield. Grain yield, straw yield and harvest index was significantly higher in 'Arize® 6444' (6.6 t/ha, 7.6 t/ha and 46.6%, respectively). It may be because of higher yield attributes and better nitrogen uptake that contributed to higher yield. In general, hybrids outperform inbreds in terms of yield perhaps because of better sink regulation and higher average grain weight. The crop productivity was significantly higher under no stress (56.5 kg/ha/day) (Table 3) and in 'US 323' (51 kg/ha/day). The grain filling efficiency was the maximum in 'Arize® 6129' (76.3%).

Significantly higher amount of carbohydrate was found under no stress condition (Table 2). Similar result was obtained by Rahman *et al*., (1985), who found that increase in water stress decreased the carbohydrate content. Generally carbohydrates accumulate in the form of starch in the leaf sheath and culm before flowering and in the panicle at maturity. The carbohydrate equivalent was significantly higher in 'Arize® 6444' which was also a nitrogen responsive variety in our experiment.

Table 2. Effect of establishment methods, water regimes and cultivars on crop productivity and economic efficiency of rice (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Grain filling efficiency (%)	Crop productivity (kg/ ha/ day)	Carbohydrate equivalent (t/ ha)	Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio	Economic efficiency (₹/ ha/day)
Establishment method (M)										
DSR	6.0	7.1	45.2	73.1	48.5	4.6	88.8	38.9	1.8	312.2
NPTR	5.9	7.4	43.9	71.5	47.2	4.6	87.6	33.7	1.6	277.5
SEm±	0.04	0.1	0.4	1.1	0.4	0.03	0.6	0.6	0.01	4.8
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	2.3	0.1	18.8
Water regime (W)										
No stress	7.0	8.0	46.7	74.7	56.5	5.4	103.3	48.6	1.9	395.2
10 kPa	6.2	7.5	45.3	74.2	50.2	4.8	92.3	40.7	1.8	323.7
40 kPa	4.6	6.4	41.8	67.9	36.8	3.6	69.1	19.7	1.4	165.7
SEm±	0.08	0.1	0.6	1.5	0.6	0.1	1.0	1.0	0.02	9.9
CD (P=0.05)	0.2	0.3	1.7	4.4	1.9	0.2	3.1	3.1	0.1	29.7
Cultivar (V)										
'Lalat'	5.9	7.2	43.2	68.8	44.4	4.4	83.9	34.5	1.5	219.7
'Sahbhagi Dhan'	5.2	7.0	42.6	73.0	44.5	4.1	78.2	28.5	1.6	258.3
'Arize® 6129'	5.9	7.1	45.3	76.3	49.5	4.6	88.4	35.2	1.7	300.7
'US 323'	6.2	7.4	45.3	71.1	51.0	4.8	92.0	38.9	1.8	352.1
'Arize® 6444'	6.6	7.6	46.6	72.2	49.8	5.2	98.6	44.4	1.8	343.4
SEm±	0.1	0.1	0.6	1.1	0.8	0.1	1.4	1.4	0.03	13.6
CD (P=0.05)	0.3	0.4	1.8	3.2	2.4	0.2	3.9	3.9	0.1	38.1

Water productivity

The irrigation input was significantly higher in DSR compared to NPTR. There was no significant effect of establishment method on irrigation water productivity (WP_I) and input water productivity (WP_{I+R}) (Table 3). There was a significant increase in water productivity with increasing soil moisture tension up to 40 kPa, which may be due to the reduction in evapo-transpiration and irrigation values without any adverse effect on grain yield. Irrigation and input water productivity was higher than no stress, by factors of 1.2 (WP_I) and 1.1 (WP_{I+R}) in 10 kPa and 1.6 (WP_I) and 1.4 (WP_{I+R}) in 40 kPa. WP_{I+R} were lower than WP_I in all treatments because rainfall was usually a large component of input. Input water productivity of establishment methods was similar (within irrigation treatments). The water productivity of 'Arize® 6444' was higher in both years, which might be because of higher yield per unit of water applied. Similar result was obtained by Raj *et al*., (2017), who concluded that 'Arize® 6444' recorded the highest water productivity compared to other cultivars in the experiment and across the establishment methods and also higher yield potential leads to higher water productivity.

Nitrogen productivity

There was no significant effect of establishment methods on nitrogen harvest index, internal use efficiency and partial factor productivity (Table 4). Similar results were obtained by Sudhir-Yadav *et al*., (2014). There was significant effect of water regimes and varieties on nitrogen uptake, internal use efficiency and partial factor productivity. The increase in nitrogen uptake was higher at higher moisture regime, which was due to cumulative effect of increase in grain and straw yields as well as increased nitrogen content. Similar increase in nitrogen uptake with increase in moisture regime was reported by Nayak *et al*., (2015). Highest N uptake was observed 'Arize® 6444' (148 kg/ha), which may be because of longer duration of variety PFP was 39.4, which is in line with Ali *et al*., (2006). On an average IE is 51.4, which is positively correlated with the grain yield showing the efficiency of nitrogen uptake.

Profitability

There was significant effect of establishment methods on net returns and benefit: cost ratio and the highest was obtained under DSR (Table 2). Among the water regimes significantly the highest economic benefit was obtained with no stress followed by 10 kPa and 40 kPa. The B: C ratio under no stress was 6% and 36% higher than 10 kPa and 40 kPa, respectively. Similar result was observed by Show *et al*., (2014) who showed that when the crop was grown under saturation condition, the gross returns and net returns were higher compared to alternate wetting and drying. Significantly higher gross returns and net returns were found in 'Arize® 6444', which may be owing to higher grain yield. The B: C ratio was the highest in both 'Arize® 6444' and 'US 323' (1.8), which was at par with

Table 3. Effect of establishment methods, water regimes and varieties on water productivity (pooled data of 2 years)

Treatment	Irrigation input (mm)	Rainfall (mm)	Irrigation water productivity (kg/ha/mm)	Input water productivity (kg/ha/mm)
Establishment method (M)				
DSR	700	113	9.2	7.7
NPTR	659	127	9.6	7.8
SEm±	9.8	1.6	0.2	1.0
CD (P=0.05)	38.3	6.4	NS	NS
Water regime (W)				
No stress	942	119	7.4	6.6
10 kPa	703	123	8.9	7.6
40 kPa	393	120	11.9	8.9
SEm±	7.2	1.9	0.2	1.3
CD (P=0.05)	21.5	5.8	0.5	4.0
Cultivar (V)				
'Lalat'	676	122	9.0	7.3
'Sahbhagi Dhan'	653	96	8.6	7.2
'Arize® 6129'	689	124	9.3	7.6
'US 323'	689	126	9.7	7.9
'Arize® 6444'	689	134	10.4	8.4
SEm±	2.5	2.4	0.2	1.7
CD (P=0.05)	7.1	6.8	0.5	4.9

'Arize® 6129'. Raj *et al*., (2017) found that 'Arize® 6444' showed an increase in gross returns, net returns and B: C ratio compared to other cultivars ('IPB 1', 'PNR 381', 'P 834' and 'P S5'). In general the net returns and benefit: cost ratio was higher in hybrids compared to inbreds.

Energetics

Energy is one of the most important indicators of crop production. The direct energy input (labor, diesel and electricity) contributed 39% and rest was contributed by indirect sources (seed, fertilizer, pesticide, irrigation and machinery). The comparison of energy use pattern in differ-

Table 4. Effect of establishment methods, water regimes and varieties on nitrogen productivity (pooled data of 2 years)

Treatment	N uptake (kg/ha)	Nitrogen harvest index (kg N uptake in grain/kg plant N uptake)	Internal-use efficiency (kg grain kg/plant N uptake)	Partial factor productivity (kg grain kg/ plant N applied)
Establishment method (M)				
DSR	120	0.51	51.6	39.7
NPTR	116	0.54	51.3	39.0
SEm±	2.0	0.01	0.3	0.3
CD (P=0.05)	NS	NS	NS	NS
Water regime (W)				
No stress	133	0.54	53.8	46.3
10 kPa	121	0.54	52.9	41.2
40 kPa	100	0.49	47.6	30.5
SEm±	2.6	0.01	0.5	0.5
CD (P=0.05)	7.7	NS	1.5	1.5
Cultivar (V)				
'Lalat'	118	0.50	47.8	37.2
'Sahbhagi Dhan'	99	0.52	54.2	34.6
'Arize® 6129'	111	0.53	54.1	39.5
'US 323'	114	0.53	55.6	41.2
'Arize® 6444'	148	0.54	45.5	44.2
SEm±	2.8	0.01	0.7	0.7
CD (P=0.05)	7.8	NS	1.9	1.9

Table 5. Effect of crop establishment methods, water regimes and varieties on energy input and output (pooled mean of 2 years)

Treatment	Energy Input (GJ/ha)	Energy output (GJ/ha)	Net energy GJ/ha)	Energy efficiency	Energy productivity (kg/MJ)	Energy profitability (MJ/kg)	Human energy profitability
Establishment methods (M)							
DSR	21.1	480.0	458.9	22.7	0.28	21.7	816.4
NPTR	20.3	528.9	508.7	26.0	0.29	25.0	771.0
SEm±	0.04	37.2	37.2	1.9	0.002	1.9	48.6
CD (P=0.05)	0.1	NS	NS	NS	NS	NS	NS
Water regimes (W)							
No stress	21.7	590.5	568.8	27.3	0.32	26.3	931.4
10 kPa	20.8	493.0	472.3	23.8	0.30	22.8	772.3
40 kPa	19.6	429.8	410.3	22.0	0.23	21.0	677.3
SEm±	0.03	8.4	8.4	0.4	0.004	0.4	18.7
CD (P=0.05)	0.1	25.2	25.2	1.3	0.01	1.3	56.2
Cultivars (V)							
'Lalat'	20.7	494.7	473.9	23.8	0.27	22.8	777.5
'Sahbhagi Dhan'	20.7	478.5	457.9	23.1	0.25	22.1	753.8
'Arize® 6129'	20.7	499.1	478.4	24.1	0.29	23.1	782.0
'US 323'	20.7	514.2	493.6	24.8	0.30	23.8	811.1
'Arize® 6444'	20.8	535.9	515.2	25.8	0.32	24.8	844.0
SEm±	0.01	10.0	10.0	0.5	0.005	0.5	20.3
CD (P=0.05)	0.03	28.0	28.0	1.3	0.01	1.3	56.9

ent crop establishment methods reveals that the energy input was 4% higher in DSR than NPTR (Table 5). The energy efficiency parameters were similar in DSR and NPTR. Significantly higher net energy, energy efficiency, energy productivity, energy profitability, human energy profitability were found under no stress. The energy efficiency declined by 15% and 24% in 10 kPa and 40 kPa compared to no stress. The energy productivity and profitability under no stress was 0.32 kg/MJ and 26.3 MJ/kg, respectively. The reduction in 10 kPa and 40 kPa was because of the reduction in number of irrigations and hence electricity consumption for irrigation. The electricity input energy reduction in 10 kPa and 40 kPa was 25% and 58%, respectively when compared to no stress.

The present study indicated that the performance of direct seeded rice and transplanted rice under non-puddled condition were at par in terms of economics. Even though the yield was better under no stress but there was significant water saving with 10 kPa. 'Arize® 6444' being a hybrid performed better than other cultivars.

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