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Energetics of Rice under different Land Leveling Practices and Establishment Methods

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ABSTRACT

A field experiment was conducted during the *Rabi* season (November to April) 2020-2021 at Regional Agricultural Research Station, Jagtial, PJTSAU, Telangana state, India with an objective to study the energetics of rice under different land levelling practices and establishment methods. The treatments include three land levelling practices as main plot treatments viz., laser land levelling (M_1), conventional levelling (M_2) and unlevelled (M_3) and four sub-plot treatments viz., Semi dry rice (S_1), Wet direct seeding (S_2), Conventional transplanting (S_3) and Machine transplanting (S_4) in strip plot design and replicated thrice. Experimental results revealed that the laser and leveling was found to be more energy efficient with energy use efficiency of 3.45 compared to conventional leveling (2.86) and unleveled field (2.80). Similarly, the maximum energy productivity of 0.14 kg MJ^{-1} and profitability of 2.45 were recorded with laser land levelling. Under laser land levelling, the reduced specific energy (0.52MJ kg^{-1}) indicated a lower energy requirement to achieve unit grain production. Among the establishment methods conventional transplanting recorded maximum energy use efficiency (4.09), energy efficiency ratio (2.47), energy productivity (0.17) and energy profitability (3.09) and was significantly superior to machine transplanting, wet direct seeding and semi dry rice. While, the minimum specific energy was recorded with conventional transplanting (0.41 MJ Kg^{-1}) over other establishment methods.

Key words: *Laser land leveling, Machine transplanting, Direct seeded rice, Energetics*

Introduction

Energy is a vital input in production agriculture and one of the most important measures of crop success. Agriculture is both an energy consumer and a source of energy in the form of bio energy. The type of crop and the methods employed to develop it determine the amount of energy required and the amount of energy that can be produced. Energy productivity is declining in tandem with rising input costs, with no corresponding increase in agricultural output (Singh *et al*., 2016). Rice cultivation requires many energy consuming operations such as tillage, transplanting, irrigation, application of fertilizers, agro-chemicals for plant protection, harvesting, transportation *etc*., (Mohanty *et al*., 2014). Effective

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energy usage is necessary to support agricultural production since it delivers ultimate financial savings, preservation of fossil resources, and reduction of environmental distortion (Demircan *et al.,* 2006). The rising demand for rice grain as the world's population grows, people's changing energy habits, the recent oil crisis, and the amount of pollution generated by the fuel used in various agricultural operations have all highlighted the need for energy-focused research in various rice establishment methods.

The importance of energy in national growth cannot be overstated. If energy is used effectively in agriculture, it will not only minimise greenhouse gas (GHG) emissions and other negative effects on the environment, but it will also contribute to a more desirable sustainable agriculture (Dalgaard *et al.,* 2001; Nasso *et al.,* 2011). At present, the productivity and profitability of agriculture depends on energy consumption (Esengun *et al.,* 2007). 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 policy makers. Energy analysis, therefore, is necessary for efficient management of scarce resources for improved agricultural production (Babu *et al.,* 2014). Identification of energy efficient resource use and rice cultivation system is important for food security and sustainable intensification.

Materials and Methods

A field experiment was carried out at Regional Agricultural Research Station, Jagtial under Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana state, India during *rabi* i.e. November to April 2020–2021. The experimental, area is located at Polasa, Jagtial with an altitude of 234.4m above mean sea level (MSL) at 18°49'40" N latitude and 78°56'45"E. The composite soil of experimental site is clay loam in texture, low in available N (195 kg ha^{-1}), high in available P (46 kg ha^{-1}) and available K (354 kg ha^{-1}) with neutral in reaction (pH 7.24) and electrical conductivity 0.24 ds/m.

The experiment was laid out in a strip plot design with 12 treatments comprising of three land levelling methods *viz*. laser land levelling, conventional and un levelled with four establishment methods *viz.* semi dry rice, wet direct seeding, conventional transplanting and machine transplanting replicated thrice. The experimental site was initially dry ploughed with tractor drawn mould board plough followed by cultivator and rotavator operations to get fine tilth. Later, as per the main plot treatments i.e. laser land levelling , conventional, the land was leveled with laser guided leveler, with jumbo drawn cultivator respectively and no levelling operation performed in Unlevelled control plot.

Under establishment methods in case of semi dry rice the dry seeds @ 75 kg ha^{-1} were sown in solid rows directly in the soil under un-puddled condition. The spouted seeds (75 kg ha^{-1}) were sown in solid rows under puddled condition in main filed under wet direct seeding. In conventional transplanting the sprouted seeds (65 kg ha^{-1}) were broadcasted uniformly in a well prepared and levelled raised seed bed. The seedlings were maintained for period of 25 days in nursery and then transplanted in the puddled main field. Under machine transplanting the sprouted seeds were broadcasted uniformly on each tray which already filled with well prepared soil approximately @ 140g per tray then covered with thin layer of soil and sprinkled water regularly up to six days then trays were shifted to field nursery bed where water was applied through channel till transplanting. During transplanting (15 days old seedlings), the mats were lifted from the trays and placed directly in the seedling channel of transplanter and transplanting done with machine transplanter by running length wise in puddle field.

A fertilizer dose of 150:60:40 kg ha^{-1} N, P_2O_5 and K_2O were applied to all the plots. Pre-emergence application of pretilachlor @ 2.5 ml l^{-1} water followed by hand weeding was done at 30, 45 and 60 days after seeding to keep the experimental plot weed free in semi dry and wet direct seeding. In machine and conventional transplanted rice treatments one hand weeding was done at 45 days after transplanting.

In puddle plots a thin film of water was maintained at the time of transplanting. Later, a submergence depth of 5±2 cm was maintained up to physiological maturity. In semi dry rice pre sowing irrigation was given and grown as irrigated dry crop up to 30 DAS and there after converted to wet and 5±2 cm standing water was maintained up to the harvesting stage of the crop. Necessary plant protection measures carried out throughout crop period.

The energy analysis in the study compared the energy performance of crop establishment methods under different land levelling practices managed according to different input intensities. Energy fluxes of the cropping systems were estimated using crop management i.e., machinery operations, amount of inputs used and grain production records along with by-products. Inputs and outputs were converted from physical to energy unit measures through published conversion coefficients (Table 1)

Energy equivalents for all inputs were summed to provide an estimate of total energy inputs. Energy output from the economic yield (grain) and by-products was calculated by multiplying the amount of production by its corresponding energy equivalent.

Various energy use indices were computed by using following formula as suggested by Burnett (1982).

Net energy return ($MJ.ha^{-1}$) = Total output energy ($MJ.ha^{-1}$) - Total input energy ($MJ.ha^{-1}$)

$$\text{Energy use efficiency} = \frac{\text{Total Output Energy } (MJ.ha^{-1})}{\text{Total Input Energy } (MJ.ha^{-1})}$$

$$\text{Energy efficiency ratio} = \frac{\text{Total Output Energy in main product } (MJ.ha^{-1})}{\text{Total Input Energy } (MJ.ha^{-1})}$$

$$\text{Specific energy} = \frac{\text{Total Input Energy } (MJ.ha^{-1})}{\text{Total main product yield } (kg.ha^{-1})}$$

$$\text{Energy productivity} = \frac{\text{Total main product yield } (kg.ha^{-1})}{\text{Total Input Energy } (MJ.ha^{-1})}$$

$$\text{Energy profitability} = \frac{\text{Net energy returns } (MJ.ha^{-1})}{\text{Total Input Energy } (MJ.ha^{-1})}$$

Results and Discussion

Energy requirements

Among land levelling methods, higher energy input requirement was recorded with conventional land leveling (33.85) followed by un levelled treatment (33.19) and laser land leveling (32.80). However, higher energy output and net energy return was recorded with laser land leveling (114.39) and was significantly superior to conventional land levelling (97.79) and un levelled treatment (93.90).

The lower input energy requirement under laser land leveling might be due to less amount of water applied compared to conventional leveling and unleveled field. The higher input energy requirement under conventional leveling is due to more fuel and machinery over unleveled field.

Among establishment methods, maximum energy input was recorded with machine transplanting (34.37) and was comparable with conventional transplanting (34.31) and significantly superior to wet direct seeding (33.69) and semi dry rice (30.74), which in turn recorded the lowest energy input. Whereas, maximum energy output and net energy returns were recorded with conventional transplanting (140.14) followed by machine transplanting (126.32) and wet direct seeding (81.14). Lowest was recorded with semi dry rice (60.52).

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

Component	Energy equivalent	Reference
Direct Energy		
Labor (h)	1.96	Mittal and Dhawan (1988)
Diesel (l)	56.31	Mittal and Dhawan (1988)
Electricity (KWh)	11.93	Mittal and Dhawan (1988)
Indirect energy		
Seed (kg)	14.7	Nassiri and Singh (2009)
N (kg)	60.6	Kuswardhani *et al*. (2013)
P2O5 (kg)	11.1	Chaudhary *et al*. (2009)
K2O (kg)	6.7	Chaudhary *et al*. (2009)
Herbicide (kg)	288	West and Marland (2002)
Insecticide (kg)	237	West and Marland (2002)
Fungicide (kg)	196	West and Marland (2002)
Irrigation (m^3)	1.02	Singh *et al*.(2008)
Machinery (h)	62.7	Dagistan *et al*. (2009)
Output energy		
Grain (kg)	14.7	Nassiri and Singh (2009)
Straw (kg)	12.5	Kitani (1999)

The lower energy requirement under semi dry rice might be due to minimum land preparation resulted in reduced machinery, fuel and less amount of water applied.

Yield and yield attributing characters

Among land levelling methods, laser land leveling had significant effect on production of number of effective tillers m^{-2}, spikelets $panicle^{-1}$, number of filled grains $panicle^{-1}$.

Among establishment methods, higher number of effective tillers m^{-2} were produced from conventional transplanting (S_3), however machine transplanting (S_4) recorded higher number of spikelets panicle, number of filled grains $panicle^{-1}$ (S_4) and was significantly superior to conventional transplanting (S_3), wet direct seeding (S_2) and semi dry rice (S_1) which in turn, recorded the lowest number of filled grains $panicle^{-1}$.

Data obtained on panicle length (cm) from investigation was analyzed statistically and presented in Table 4. Both land levelling practices and establishment methods of rice did not exert any significant influence on panicle length (cm).

Significantly higher test weight (g) was noticed with laser land levelling (M_1) over conventional land levelling (M_2) and unlevelled treatment (M_3) which in turn, recorded the lowest test weight. Establishment methods didn't showed significant influence on test weight (g) of rice.

Among land leveling methods, laser land leveling significantly recorded higher grain yield and straw yield. Significantly among establishment methods, higher grain and straw yield were recorded with conventional transplanting (S_3) followed by machine transplanting (S_4), wet direct seeding (S_2) and semi dry rice (S_1).

Energy indices

Among land levelling methods the maximum energy use efficiency, energy efficiency ratio, energy productivity and energy profitability were recorded in laser land levelling (3.45, 2.08, 0.14 and 2.45) and was significantly superior to conventional land levelling (2.86, 1.71, 0.12 and 1.86) followed by un levelled treatment (2.80, 1.66, 0.11 and 1.80). Whereas, the minimum value of specific energy was recorded in laser land leveling (0.52).

Maximum energy use efficiency, energy efficiency ratio, energy productivity and energy profitability were found with conventional transplanting

Table 2. Input energy requirement (MJ ha^{-1})

Treatments/ Particulars	M_1S_1	M_1S_2	M_1S_3	M_1S_4	M_2S_1	M_2S_2	M_2S_3	M_2S_4	M_3S_1	M_3S_2	M_3S_3	M_3S_4
Direct energy												
Labour	705.6	580.2	862.4	517.4	705.6	580.2	862.4	517.4	705.6	580.2	862.4	517.4
Diesel	5631.0	7038.8	7038.8	7742.6	5631.0	7038.8	7038.8	7742.6	4223.3	5631.0	5631.0	6334.9
Electricity (kWh)	2405.1	2290.6	2405.1	2405.1	2634.1	2519.6	2634.1	2634.1	2863.2	2748.7	2863.2	2863.2
Total	8741.7	9909.5	10306.2	10665.2	8970.7	10138.5	10535.3	10894.2	7792.1	8959.8	9356.6	9715.5
Indirect energy												
Seed	1102.5	1102.5	918.8	441.0	1102.5	1102.5	918.8	441.0	1102.5	1102.5	918.8	441.0
N	9090.0	9090.0	9090.0	9090.0	9090.0	9090.0	9090.0	9090.0	9090.0	9090.0	9090.0	9090.0
P	666.0	666.0	666.0	666.0	666.0	666.0	666.0	666.0	666.0	666.0	666.0	666.0
K	268.0	268.0	268.0	268.0	268.0	268.0	268.0	268.0	268.0	268.0	268.0	268.0
Herbicide (kg)	345.6	345.6	345.6	345.6	345.6	345.6	345.6	345.6	345.6	345.6	345.6	345.6
Fungicide (kg)	235.2	235.2	235.2	235.2	235.2	235.2	235.2	235.2	235.2	235.2	235.2	235.2
Irrigation (m^3)	8568.0	10200.0	10608.0	10608.0	9384.0	11016.0	11424.0	11424.0	10200.0	11832.0	12240.0	12240.0
Machinery (h)	1254.0	1410.8	1410.8	1567.5	1254.0	1410.8	1410.8	1567.5	940.5	1097.3	1097.3	1254.0
Total	21529.3	23318.1	23542.3	23221.3	22345.3	24134.1	24358.3	24037.3	22847.8	24636.6	24860.8	24539.8
Grand Total	30271.0	33227.5	33848.5	33886.5	31316.0	34272.6	34893.6	34931.5	30639.9	33596.4	34217.4	34255.3

(4.09,2.47,0.17 and 3.09) which was significantly superior to machine transplanting (3.68, 2.18, 0.15 and 2.68), wet direct seeding (2.41, 1.43, 0.10 and1.41) and semi dry rice (1.97, 1.18, 0.08 and 0.97). While, the minimum specific energy was recorded with conventional transplanting (0.41) over other establishment methods. Lower value of specific energy symbolized greater efficiency of the system.

Table 3. Effect of land levelling practices and crop establishment methods on energy requirements of rice

Treatments	Energy input ($\times 10^3$ MJ ha^{-1})	Energy output ($\times 10^3$ MJ ha^{-1})	Net energy return ($\times 10^3$ MJ ha^{-1})
Land leveling practices (M)			
Laser levelling	32.80	114.39	81.59
Conventional leveling	33.85	97.79	63.94
Un levelled	33.19	93.90	60.72
S.Em±	0.02	2.42	2.42
CD(P=0.05)	0.07	9.51	9.51
Establishment methods (S)			
Semi dry rice	30.74	60.52	29.77
Wet direct seeding	33.69	81.14	47.44
Conventional transplanting	34.31	140.14	105.82
Machine transplanting	34.37	126.32	91.96
S.Em±	0.02	1.86	1.70
CD(P=0.05)	0.08	5.54	5.90
Interactions (M x S)			
Factor (B) at same level of A			
S.Em±	0.05	3.35	3.35
CD(P=0.05)	NS	NS	NS
Factor (A) at same level of B			
S.Em±	0.05	3.78	3.78
CD(P=0.05)	NS	NS	NS

Table 4. Yield and yield attributes of rice as influenced by land levelling practices and establishment methods

Treatments	Number of effective tillers m^{-2}	Number of Spikelet's panicle^{-1}	Number of filled grains panicle^{-1}	Panicle length (cm)	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Land leveling practices (M)							
Laser levelling	311	114.5	100.2	19.9	22.7	4697	3628
Conventional levelling	286	99.3	86.7	19.6	22.5	3968	3157
Un levelled	271	87.9	76.1	19.3	22.1	3780	3066
S.Em±	4.0	3.1	3.4	0.9	0.04	102	76
CD(P=0.05)	14	12.0	13.4	NS	0.2	400	300
Establishment methods (S)							
Semi dry rice	223	71.2	62.5	18.4	21.9	2470	1936
Wet direct seeding	252	86.4	77.5	19.4	22.4	3265	2652
Conventional transplanting	401	109.5	95.6	19.0	22.6	5761	4436
Machine transplanting	281	135.0	115.0	21.6	22.7	5097	4112
S.Em±	4.0	1.9	2.0	1.0	0.2	78	75
CD(P=0.05)	12	6.7	6.5	NS	NS	190	259
Interactions (M x S)							
Factor (B) at same level of A							
S.Em±	7.0	3.7	3.4	1.8	0.1	152	103
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS
Factor (A) at same level of B							
S.Em±	7.0	4.4	4.5	1.8	0.1	167	118
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 5. Energy indices of rice as influenced by land levelling practices and crop establishment methods

Treatments	Energy use efficiency	Energy efficiency ratio	Specific energy (MJ kg^{-1})	Energy productivity (kg MJ^{-1})	Energy profitability
Land leveling practices (M)					
Laser levelling	3.45	2.08	0.52	0.14	2.45
Conventional levelling	2.86	1.71	0.64	0.12	1.86
Un levelled	2.80	1.66	0.67	0.11	1.80
S.Em±	0.07	0.04	0.02	0.003	0.07
CD(P=0.05)	0.28	0.17	0.06	0.01	0.28
Establishment methods (S)					
Semi dry rice	1.97	1.18	0.86	0.08	0.97
Wet direct seeding	2.41	1.43	0.72	0.10	1.41
Conventional transplanting	4.09	2.47	0.41	0.17	3.09
Machine transplanting	3.68	2.18	0.47	0.15	2.68
S.Em±	0.05	0.02	0.01	0.005	0.05
CD(P=0.05)	0.18	0.08	0.04	0.001	0.18
Interactions (M x S)					
Factor (B) at same level of A					
S.Em±	0.09	0.06	0.02	0.004	0.09
CD(P=0.05)	NS	NS	NS	NS	NS
Factor (A) at same level of B					
S.Em±	0.11	0.07	0.02	0.004	0.11
CD(P=0.05)	NS	NS	NS	NS	NS

Conclusion

The use of laser land levelling in conjunction with conventional transplanting improved the sustainability performance of the tested paddy field. Following the implementation of land levelling with conventional transplanting, improvements in yield and energy performance were seen. Furthermore, our investigation revealed that technological adoption resulted in increased energy efficiency and agricultural profitability.

Future Scope

Effect of laser land leveling on performance of different crops and profitability can be studied at farmer's field condition in different crops.

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