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ENERGETICS OF RICE PRODUCTION AS AFFECTED BY CROP ESTABLISHMENT METHODS UNDER PUDDLED SOIL

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ABSTRACT

A field experiment was conducted during kharif season, 2015 at Ranchi, Jharkhand to evaluate the effect of crop establishment methods under puddled soil on productivity and energetics of rice. Results revealed that conventional transplanting produced grain and straw yield (44.18 and 68.43qha^{-1}, respectively) significantly higher over rest of establishment methods except drum seeding of sprouted seeds (43.70 and 67.90qha^{-1}, respectively) and mechanical transplanting (39.8 and 63.76 q ha^{-1}, respectively). Gross energy output , net energy output, and energy-use efficiency by biomass and specific energy recorded in conventional transplanting (150.48x10^{3}MJha^{-1}, 139.0 x10^{3} MJha^{-1} , 13.06, 2628.16 MJt^{-1}, respectively) was on par with drum seeding (149.12x10^{3}MJha^{-1}, 137.9x10^{3}MJha^{-1},13.25 and 2590.59 MJt^{-1}, respectively) and mechanical transplanting (138.21x 10^{3} MJha^{-1}, 126.7 x10^{3} MJha^{-1}, 11.96, 2925.21MJt^{-1}, respectively) but was significantly higher over rest of establishment methods. Specific energy under drum seeding (2590.59MJt^{-1}) was significantly lower by 19.0 and 16.8 % than broadcasting of either dry (3081.90MJt^{-1}) or sprouted seeds (3024.75 MJt^{-1}), respectively. Hence, for higher productivity and energy conservation establishment of rice through drum seeding can be a viable alternative as it gives as high yield as conventional transplanting

KEY WORDS
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INTRODUCTION

Rice *(Oryza sativa* L.*)*, a high calorie kharif cereal is an essential diet constituent for the people of eastern state of Jharkhand. It contributed 471.09 million tonnes (2015-16) in the global food grain basket from an area of 161.2 million hectares (mha), thus occupying the second position among the cereals. In India, this crop covered about 42 mha during the recent past 2015-16 and accounts for about 103.36 million tonnes of the country's total foodgrain production (Anonymous, 2016). Jharkhand, a traditionally rice growing state covering 14.94 lakh hectares under rice cultivation has a productivity of 2.57 t ha^{-1} during 2014-15, which is far behind the national average (4.57 t ha^{-1}) (Anonymous, 2015). The reason for very low productivity in Jharkhand also centres round the fact that rice cultivation is mostly monsoon dependent, which is extremely erratic in onset, distribution, intensity and cessation. Late monsoon usually delays seedling raising and transplanting operation thus resulting in lower yield. In such circumstances, direct seeding comprising of drum seeding, broadcasting of either dry or sprouted seeds under puddled condition may be an alternative to conventional transplanting in boosting the rice production in Jharkhand. Further, farmers of Jharkhand face problem in rice establishment through conventional transplanting particularly due to shortage of labours during the peak period, water, escalating fuel prices, high energy consumption which contribute in increasing the cost of cultivation. Therefore rice which is the stable crop of this region needs to be grown through the method of crop establishment which is more efficient and requires less labour, water and energy intensive to enable the farmers to produce higher yields with less cost of production.

Energy, one of the most important indicators of crop performance is one of the valuable inputs in production agriculture. Agriculture itself is energy user and energy supplier in the form of bio energy (Alam *et al.*, 2005). Energy requirement and its production potential largely depends on the nature of crop and the establishment methods used. Energy productivity is decreasing with the escalating input cost without proportionate improvement in output of particular crop (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). In order to sustain agricultural production, effective energy use is required, since it provides ultimate financial saving, preservation of fossil resources and reduction of environment distortion (Demircan *et al.,* 2006). The increasing demand for rice grain with increase in population, the changing energy use habits of the people, the recent oil crisis and the measure of pollution generated by the fuel used in different agricultural operation has emphasized the need for energy oriented research in different rice establishment methods. Solar radiation provides the basic energy for the photosynthetic activity of plants in both the primitive (direct seeding) and modern (transplanting) methods of rice establishment, which in turn depends on the plant population, orientation of leaves and the amount of solar energy entrapped in it. The efficient photosynthetic performance of rice is probably due to the increased 'cytokinin' content in their roots at later growth stages contributing to higher grain yields (Tiwari *et al.,* 2014) which is ensured by wider spacing that allows better access to light and air thereby creating better environment for uninhibited root and shoot growth (Nandhakumar *et al.,* 2015). Plant geometry plays an important role in yield maximization of rice (Siddiqui *et al.,* 1999). Optimum plant density ensures the plants to grow properly with their aerial and underground parts by utilizing more solar radiation and soil nutrients (Miah *et al.,* 1990). Different rice establishment methods can therefore be compared for the gross energy output on the basis of the solar energy conversion into biochemical energy. The world-wide energy crisis compelled the researchers to think in the area of efficient energy utilization and conservation for agricultural production especially rice. Energy analysis ,therefore, is necessary for efficient management of scarce resources for improved agricultural production (Babu *et al.,* 2014). Direct seeding of seeds on to puddled soil (wet seeding by drum seeder or broadcasting of either sprouted or dry seeds) holds special significance in the present day production systems by saving time, labour, energy and increasing profitability (Subbaiah and Balsubramanian, 2000) therefore, considered more economical as compared to transplanting. Keeping this in view, a field experiment was conducted to evaluate the effect of different establishment methods under puddled soil on yield and energetics of rice.

MATERIALS AND METHODS

A field experiment was conducted at agronomical research farm of Birsa Agricultural University, Ranchi (23°17´ N latitude and 85°10´ E longitude with an altitude of 625 m above the mean sea level) during *kharif* season of 2015, in the clay - loam soil, slightly acidic in reaction (pH 6.1), low in organic carbon (3.6 g/kg) as well as in available nitrogen (200.7 kg/ha), high in available phosphorus (33.54 kg/ha) and medium in potassium (187.04 kg/ha). The climate of the experimental site, Ranchi is sub humid with large water deficiency and is characterized by hot summer and cold winter. The agronomical research farm of Ranchi falls under sub zone V of Agro-climatic zone VII of India *i.e.* Eastern Plateau and Hill Region. This place receives rainfall from both the streams of monsoon *i.e.* South-West monsoon and North-East monsoon. The experiment was laid out in Randomized Block Design with four replication and the rice variety used was Naveen (CR-749-20-2). The treatments comprised of five different rice establishment methods – conventional transplanting, mechanical transplanting, drum seeding of sprouted seeds, broadcasting of sprouted seeds and broadcasting of dry seeds. Uniform fertilization (120: 60: 40 kg N: P_2O_5: K_2O ha^{-1}) was done for all the rice establishment methods through urea, diammonium phosphate and muriate of potash, respectively. After ploughing and leveling, layout of field was done which followed puddling with the help of tractor drawn puddler, 5 days before as well as on the day of sowing/transplanting and then leveling was done.

In main field half dose of nitrogen and full dose of phosphorus and potassium were applied as basal. Rest of the nitrogen was top dressed in two equal splits at 25 days after sowing/ transplanting (tillering stage) and at 50 days after sowing/ transplanting (panicle initiation stage). Whereas, in nursery fertilizers were applied @ 12: 6: 4 kg N: P_2O_5: K_2O per 1000 sq m. In conventional transplanting, half dose of N and full dose of P_2O_5 and K_2O were applied as basal and remaining N was top dressed at 15 DAS. While, in case of rice nursery for mechanical transplanting full dose of N was applied as basal. For conventional transplanting, seeds were sown in nursery and seedlings were raised by wet nursery method and 2-3 seedlings/hill (21 days old) were transplanted at 20 x 15 cm spacing. Whereas, in case of mechanical transplanting seedlings were prepared on mat type nursery and 4-5 seedlings/hill (15 days old) were transplanted at 25 x 15 cm spacing. Sprouted seeds were used for direct seeding by broadcasting and drum seeding with 20 cm row spacing. Direct seeding was done on the same day i.e. the day seeds were placed in nursery.

Crop yield was recorded as per the standard procedures. All the energetics index were estimated with reference to the standard values and methods prescribed by Paneshar and Bhatnagar (1994). The input energy was divided into direct and indirect and renewable and non-renewable forms for estimation (Hatirli *et al.,* 2006). The direct energy consists of diesel, human power and electricity, while the indirect energy contains seed, farmyard manure and machinery (Singh *et al.,* 2007). Quantity /numbers of all inputs used in form of labour, seed and manures used in the different establishment methods were taken into consideration. The input energy (MJ ha^{-1})and its conversion to energy equivalents was done by multiplying their per unit energy equivalents as suggested by Paneshar and Bhatnagar (1994). The standard energy coefficients for seed and straw were multiplied with their respective yields and summed up to obtain the gross energy output (MJ ha^{-1}). The net energy output (MJ ha^{-1}) was calculated by subtracting energy input from gross energy output. Based on the energy equivalents of inputs and output, the energy indices such as energy use efficiency ratio and specific energy was estimated in MJ t^{-1}. Collected data on yield and energetics were statistically analyzed as per the standard of Gomez and Gomez, 2003 by using the analysis of variance method to draw a valid conclusion.

Energy used in harvesting, transportation threshing and winnowing were calculated as follows :

Human Energy (MJ ha^{-1}) = Number of person × Energy equivalent × time in hour

Gross energy output (MJ ha^{-1}) = [{Grain yield (q/ha) x energy equivalent for seed} + {Straw yield (q ha^{-1}) x energy equivalent for straw}])

Net energy output (MJ ha^{-1}) = [Gross energy output (MJ ha^{-1}) Energy input (MJ ha^{-1})]

Energy use efficiency = [Energy output (MJ ha^{-1}) / Energy input (MJ ha^{-1})]

Specific energy (MJ t^{-1}) = [Energy input (MJ ha^{-1}) /grain yield (t ha^{-1})]

RESULTS AND DISCUSSION

Grain yield

Different rice establishment methods under puddled condition significantly influenced the grain yield. Rice established through conventional transplanting, drum seeding and mechanical transplanting had similar grain yield (Table 1). However, both the transplanting methods *i.e.*, conventional (where 21 days old seedlings were transplanted) and mechanical transplanting (where 15 days old seedlings were transplanted) had similar grain yield (44.18 and 39.80 q ha^{-1}, respectively). Similar results were also observed by Nandhakumar *et al.,* 2015. Conventional transplanting showed edge of 19 and 21 %, respectively over broadcasting of either sprouted (37.13 q ha^{-1}) or dry seeds (36.50 q ha^{-1}) whereas drum seeding of sprouted seeds (43.70 q ha^{-1}) was significantly higher by 17.7 and 19.7 %, respectively over broadcasting of either sprouted (37.13 q ha^{-1}) or dry seeds (36.50 q ha^{-1}) in grain production . Further, among the direct seeded rice, broadcasting of dry seeds being similar to broadcasting of sprouted seeds recorded the lowest grain yield. The comparatively high paddy yield in both the transplanting methods and drum seeding could have been due to efficient utilization of resources and less inter and intra space competition among widely spaced plants in transplanting as well as drum seeding methods of rice establishment which is assigned as the reason for superiority in yield attributes of rice which consequently increased the yield (Nandhakumar *et al.,* 2015). This is in agreement with the findings of Baloch *et al.*, 2002. The beneficial effects of puddling in transplanting as well as in drum seeding together with uniform stand establishment, ideal rhizosphere environment and weed free condition might have contributed to higher nutrient uptake which resulted in the production of greater source and efficient translocation of photosynthates into the larger sink as indicated by higher yield attributes.

Straw yield

In case of straw yield, crop established through conventional transplanting (68.43 q ha^{-1}) and drum seeding of sprouted seeds (67.90 q ha^{-1}) showed significant edge by 15.3 and 14.5%, respectively over broadcasting of dry seeds (59.32q ha^{-1}). Further, rice established through broadcasting of dry seeds being similar to that of sprouted seeds recorded the minimum straw yield. Transplanting method of establishment recorded significantly higher straw yield compared to direct sowing of rice under puddled condition due to less crop weed competition in transplanting method which led to taller plants, more number of tillers and dry matter production which in turn resulted in higher straw yield (Parameswari and Srinivas, 2014). Subramanyam *et al.* (2007) also reported similar results.

Energetics

The comparison of energy use pattern in different establishment methods under puddled condition revealed that the conventional transplanting, drum seeding and mechanical transplanting had similar energetics. The energy requirement of crop established through drum seeding, broadcasting of either sprouted or dry seeds ranged from 11.208 x 10^3 MJ/ha to 11.255 x 10^3 MJ/ha. Further, mechanically transplanted and conventionally transplanted rice required 11.558 x 10^3 MJ/ha and 11.520 x 10^3 MJ/ha input energy, respectively. Conventionally transplanted rice (150.48$\times10^3$ MJ/ha), had 15.9 and 17.7% higher biomass gross energy output than broadcasting of either sprouted (129.83$\times10^3$ MJ/ha) or dry seeds (127.80$\times10^3$ MJ/ha), respectively. Whereas, rice established by drum seeding (149.12$\times10^3$ MJ/ha) produced 14.8 and 16.7% higher gross energy output by biomass over broadcasting of either sprouted or dry seeds, respectively. Minimum biomass gross energy output was recorded by broadcasting of dry seeds which was similar to that of sprouted seeds. Conventional transplanting (139.0 $\times10^3$ MJ/ha) had 17.2 and 19.2% higher biomass net energy output over broadcasting of either sprouted (118.6$\times10^3$ MJ/ha) or dry seeds (116.6$\times10^3$ MJ/ha), respectively. While drum seeding (137.9$\times10^3$ MJ/ha) had 16.3 and 18.3% higher biomass net energy output over broadcasting of either sprouted or dry seeds, respectively. Biomass energy-use efficiency under conventional transplanting (13.06) was significantly 14.6% higher than broadcasting of dry seeds (11.40). Whereas, drum seeding of sprouted seeds (13.25) had 14.4 and 16.2% higher biomass energy-use efficiency over broadcasting of either sprouted (11.58) or dry seeds, respectively. The higher energy use efficiency under transplanted and drum seeded rice was mainly attributed to higher energy production with relatively lesser energy requirement (Jha *et al.*, 2011). Crop established through conventional transplanting (2628.16 MJ t^{-1}) and drum seeding of sprouted seeds (2590.59 MJ t^{-1}) had similar specific energy requirement. Specific energy requirement under drum seeded rice was significantly lower by 19.0 and 16.8 % than broadcasting of either dry seeds (3081.90 MJ t^{-1}) or sprouted seeds (3024.75 MJ t^{-1}), respectively (Table 1). Whereas conventionally transplanted rice was 17.3% lower than broadcasting of dry seeds in specific energy requirement. This confirms the findings of *Mohanty et al.,* 2014.

It can be concluded that among different methods of rice

Table 1: Yield and energetics as influenced by different rice establishment methods

Treatments	Yield (q ha^{-1})		Energy input	Gross energy output (MJha^{-1} X 10^3)	(MJha^{-1} X 10^3)	Net energy output efficiency		Energy- use energy (MJt^{-1})		Specific
	Grain	Straw	(MJha^{-1} X 10^3)	Grain	Biomass	Grain	Biomass	Grain	Biomass	
T_1	44.18	68.43	11.520	64.94	150.48	53.42	139.0	5.64	13.06	2628.16
T_2	39.80	63.76	11.558	58.51	138.21	46.95	126.7	5.06	11.96	2925.21
T_3	43.70	67.90	11.255	64.24	149.12	52.98	137.9	5.71	13.25	2590.59
T_4	37.13	60.21	11.208	54.57	129.83	43.37	118.6	4.87	11.58	3024.75
T_5	36.50	59.32	11.208	53.66	127.80	42.45	116.6	4.79	11.40	3081.90
SEm ±	1.90	2.62	-	2.79	5.82	2.79	5.81	0.24	0.51	130.29
CD (P=0.05)	5.82	8.05	-	8.56	17.85	8.56	17.85	0.75	1.57	399.84

Note: All the treatments are under puddled condition; (Treatment details: T_1 Conventional Transplanting ;T_2 Mechanical Transplanting ;T_3 Drum seeding of sprouted seeds;T_4 Broadcasting of sprouted seeds;T_5 Broadcasting of dry seeds) establishment, the crop established through drum seeding, conventional transplanting and mechanical transplanting though gives similar grain yield, straw yield and energetics but rice established through drum seeding is a better alternative to conventional transplanting as it is easy in use, portability and maintenance with better energy use efficiency and requires less amount of energy to produce one tonne of grain.

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