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Effect of establishment methods and nutrient management on productivity and energetics of rice (*Oryza sativa*)

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ABSTRACT

A field experiment was carried out during *kharif* season of 2017–18 at ICAR-IARI, New Delhi to study the effect of crop establishment methods and nutrient management options on and energetics of rice (*Oryza sativa* L) (cv. Pusa *Basmati* 1509). The experiment was laid out in split-plot design with three replications. The treatments comprised two main plots, viz. aerobic rice (AR) and conventional transplanted (CT) rice and three sub-plots, viz. 100 % RDF (120:60:60 kg N: P_2O5: K_2O); 100 % RDF + biofertilizers (bf) and 125 % RDF. Results showed that plant growth and yield were significantly superior in CT rice than AR. In case of nutrient management, application of 125% RDF gave significantly higher grain (4.76 and 5.17 t/ha) and biological yields (11.77 and 12.55 t/ha) and those were at par with 100% RDF + bf. Likewise, significantly higher energy input (25.19 and 25.15 $\times 10^3$ MJ/ha), output (158.85 and 168.62$\times 10^3$ MJ /ha) was recorded in CT than AR and net energy obtained was non-significant. Among nutrient management options, significantly higher energy input were consumed in 125% RDF followed by 100% RDF +bf and 100% RDF and the energy output was also higher with 125% RDF and 100 % RDF + bf. Hence, CT rice along with 100% RDF + biofertilizers may be recommended for farmers to get higher productivity, profitability and energy values. But in case of water scarce conditions, aerobic rice can be recommended with 100% RDF+ biofertilizers with slight penalty in grain yield and net returns.

Key words: Aerobic rice, Biofertilizer*,* Conventional transplanting, Economics Energetics

Rice (*Oryza sativa* L) is predominantly grown as a transplanted crop under anaerobic soil environment. Transplanting has been identified as the most common method of crop establishment. During cultivation of rice under transplanted condition, the soil's aerobic environment changes into anaerobic environment, leading to several physical and electro-chemical transformations. As reported by many researchers as well as farmers, though transplanting has been found to be the best establishment method to attain the maximum rice productivity due to rising water crisis, labour costs, more energy consumption, and the alternative establishment methods such as aerobic rice, direct sowing and system of rice intensification need to be prasticed. Water saving technologies developed such as alternate wetting and drying, continuous soil saturation and direct seeding may reduce the water requirement of rice to some extent. But a fundamentally different approach to reduce water requirement drastically in rice cultivation is necessary for future rice cultivation. In such condition, aerobic rice culture is one of the promising options which not only reduce the water requirement but sustain the rice productivity. In aerobic rice systems, the crop is grown as an upland crop (unsaturated condition) under non–puddled, non–flooded field condition (Singh *et al.* 2008; Rajakumar *et al*. 2009; Singh 2013). The crop is supplied with adequate inputs and supplementary irrigation when rainfall is insufficient. Aerobic rice systems can reduce water requirements for rice production by over 44% relative to conventionally transplanted systems, by reducing percolation, seepage and evaporation losses, while maintaining yield at an acceptable level (Singh 2013).

Intensive agriculture with discriminate use of chemical fertilizers has resulted in deterioration of soil health (Singh *et al*. 2008). Under such situation, integrated nutrient management (INM) has assumed a greater importance for the maintenance of soil productivity. Information regarding the interactive effect of establishment methods of rice with integrated nutrient management is scanty in Indo Gangetic Plains. Therefore, keeping the above facts in view an investigation was conducted to evaluate the influence of crop establishment methods and nutrient management options on productivity, economics and energetics of rice**.**

MATERIALS AND METHODS

The field experiment was conducted during *kharif* 2017

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and 2018 at research farm of ICAR-Indian Agricultural Research Institute, New Delhi. Delhi located under sub-tropical and semi-arid type with hot and dry summer and cold winter and falls under the 'Trans-Gangatic plains'. During experimental period, there was variation in rainfall received during the first (656 mm) and second (868 mm) year of cropping. The mean maximum temperature also slightly differed from first (34°C) to second (33.2°C) seasons. The soil was alluvial, sandy clay loam in texture with moderate water holding capacity and level topography. The initial pH of the soil was 8.12 and electrical conductivity 0.21 dS/m. The soil was low in organic carbon (0.47%) and available nitrogen (168 kg/ha), medium in available phosphorous (15.25 kg/ha) and available potassium (251 kg/ha). The experiment was laid out in split-plot design with three replications. The treatments comprised two main plot treatments, viz. aerobic rice (AR) and conventional transplanted (CT) rice and three sub plot treatments, viz. 100 % RDF (120:60:60 kg N: P_2O5: K_2O); 100 % RDF + bio fertilizers (bf) and 125% RDF. Liquid formulation of *Azotobacter chroococcum,* Phosphorus Solubilizing Bacteria (PSB), Potassium Solubilizing Bacteria (KSB) and Zinc Solubilizing Bacteria (ZnSB) biofertilizers specific to rice crop were obtained from the division of microbiology, ICAR-IARI, New Delhi and seeds/seedlings were inoculated before sowing/transplanting as per the treatments.

To grow aerobic rice (AR), pre-soaked and incubated seeds (for 24 hr) of cv. Pusa *Basmati* 1509 in moist gunny cloth was taken. Before sowing the seed was treated with biofertilizers and shade dried. After one hour it was used for sowing (22 June 2017 and 18 June 2018). The field was ploughed twice with tractor drawn disc plough. Harrowing was done with rotavator to achieve desired tilth. Seeds were drilled at the depth of 4 cm with the row spacing of 22.5 cm by using seed drill and light irrigation was applied to facilitate germination. Thinning and gap filling was done at 15 days after sowing (DAS). The crop was maintained like upland crop throughout the growing season. There was no flooded or saturated condition of the field at any point of time during the entire crop growth. Because of the non-flooded condition there was higher weed emergence which was checked timely by spraying the herbicide (Pretilachlor @ 450 g/ha) and subsequently manual weeding twice. In conventional transplanted (CT) rice the field preparation consisted of harrowing followed by puddling in standing water. For transplanting, the 21 days old healthy seedlings (cv. Pusa *Basmati* 1509) were uprooted, cleaned and dipped in biofertilizer solution for one hour before transplanting. Transplanting was done on 13 July, 2017 and 10 July, 2018 by planting 2 seedlings per hill. Gap filling was done at 7 days after transplanting. The field was maintained with standing water until 10 days prior to physiological maturity of crop. From the blanket recommendation, the treatment's dose, viz. 100% of the recommended dose and 125% of the recommended dose were calculated and applied to the relevant treatment plot. The entire recommended dose of 60 kg P_2O_5/ha and 60 kg K_2O/ha was applied as basal through di ammonium phosphate (DAP) and muriate of potash (MOP), respectively except nitrogen. Recommended dose of nitrogen was supplied through the mineral fertiliser DAP and the remaining dose was compensated with urea. Nitrogen was supplied to the plant in 3 equal splits, i.e. at basal, active tillering and panicle initiation stages.

Observations on growth, grain and biological yield were recorded at harvest stages of the crop. The economics of cultivation of rice, viz. cost of cultivation, gross return, net return and B: C ratios were recorded on the basis of prevailing market prices of inputs and outputs. Energetics were calculated based on the energy equivalents values taken from various literatures given by Devasenapathy *et al*. (2009). The data obtained from the experiment were statistically analysed using the F-test.

RESULTS AND DISCUSSION

Growth and yield of rice

The growth attributes were significantly influenced by planting methods during both the years (Table 1). Conventional transplanted (CT) rice recorded significantly higher growth than aerobic rice (AR). All the growth attributes were slightly higher in 2018 than the 2017 mainly due to better weather conditions during cropping season. The better distributed rainfall and comparative lower temperature favoured better crop environment during 2018 than 2017. Higher values of growth and yield under CT rice were recorded compared to AR due to favourable environment under CT rice compared to AR conditions since there was less chance of physical, chemical and biological stress. Pooniya and Shivay (2012) also reported similar results.

Among nutrient management treatments, 125% RDF gave significantly higher growth and those were at par with 100 % RDF + bf. Plant growth were significantly lower with application of 100 % RDF compared to 125% RDF and 100 % RDF + bf. This indicated that 100 % RDF was not able to meet the optimum requirements of rice crop. Hence, 25% additional dose of fertilizers or supply of nutrients through biofertilizer was required for optimum growth of rice. The increased growth and yield attributes due to the 25% additional dose of nutrients could meet the crop requirement and this ultimately increased the accumulation of photosynthates from source to sink. Saha *et al.* (2017) also reported similar results.

Significantly higher grain (4.82 and 5.17 t/ha) and biological yields (11.85 and 12.58 t/ha) were recorded in CT rice than AR. Application of 125% RDF gave significantly higher grain (4.76 and 5.17 t/ha) and biological yield (11.77 and 12.55 t/ha) and those were statistically at par with 100% RDF + bf (Table 1). The lower yield of AR compared to CT rice might be due to more weed menace and high panicle sterility due to non-flooded condition in AR. The balanced and adequate nutrient supply favoured better crop growth which ultimately increased the yield. Similar findings were reported by Singh *et al.* (2008) and Meena *et al.* (2014). Harvest index (HI) was significantly influenced by planting

Table 1 Effect of crop establishment methods and nutrient management options on plant height, yield and economics of rice

Treatment	Plant height (cm) at harvest		Grain yield (t/ha)		Biological yield (t/ha)		Cost of cultivation (₹ ×10³/ha)		Net return (₹×10³/ha)		Net B:C ratio	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018		
Planting methods (PM)												
AR	95.0	98.7	4.43	4.87	11.16	12.02	52.78	52.78	56.79	67.22	1.08	1.27
CT	102.4	105.8	4.82	5.17	11.85	12.58	58.68	57.62	60.03	69.45	1.02	1.20
SEm±	1.20	1.24	0.02	0.03	0.07	0.08	-	-	0.34	0.36	0.005	0.006
LSD (*P*= 0.05)	7.20	7.31	0.12	0.18	0.42	0.48	-	-	2.04	2.16	0.030	0.036
Nutrient management practices (NMP)												
100% RDF	95.5	98.4	4.37	4.76	11.02	11.81	55.14	54.61	52.96	62.79	0.96	1.15
100% RDF + *bf	100.0	102.7	4.74	5.16	11.74	12.53	55.34	54.81	61.52	71.99	1.11	1.31
125% RDF	100.5	103.9	4.76	5.17	11.77	12.55	56.71	56.18	60.62	70.87	1.06	1.26
SEm±	1.19	1.22	0.01	0.02	0.05	0.07	-	-	0.37	0.40	0.003	0.004
LSD (*P*=0.05)	3.58	3.67	0.03	0.06	0.15	0.21	-	-	1.11	1.20	0.015	0.012
PM × NMP	NS	NS	NS	NS	NS	NS	-	-	NS	NS	NS	NS

AR= Aerobic rice, CT= Conventional transplanting, RDF= Recommended dose of fertilizer, *bf= biofertilzer

methods but nutrient management options had no significant effect on HI. CT rice recorded significantly higher HI than AR. Application of 125% RDF recorded highest HI than rest of the treatments but the difference among the treatments was not significant. The HI is mainly controlled by partition of photosynthates between harvesting and non-harvesting organs during crop growth period. It is evident that the economic yield is closely related to crop growth. Hence, the wider variation in partitioning of photosynthates in grain and vegetative organs of different treatments possibly caused a significant variation in HI which happened in methods of planting. Significant difference was there in economic yields due to the nutrient management practices also but perhaps differences were not wide enough to significantly influence the HI. Similar results were also reported by Jat *et al.* (2014). There were no significant interaction effects due to main and sub plot factors. It was due to the reason that there was no absolute control treatment in nutrient management practices. In compared to 100% RDF, only 25% of the additional dose was added either through chemical fertilizers or through biofertilizers. This additional 25% nutrient added was probably not sufficient to create the significant interaction effect.

Economics

The economics of rice cultivation was significantly influenced by the planting methods and nutrient management practices (Table 2). The significantly higher cost of cultivation was recorded in CT rice (₹ 58.68×10³/ha and ₹ 57.62 ×10³/ha compared to AR cultivation (₹ 52.78×10³/ha and 52.75×10³/ha). Significantly higher gross returns were obtained in CT rice than in AR cultivation. Similarly, the

Table 2 Effect of crop establishment methods and nutrient management options on energetics of rice

Treatment	Energy input (×10³ MJ/ha)		Energy output (×10³ MJ/ha)		Net energy (×10³ MJ/ha)	
	2017	2018	2017	2018	2017	2018
Method of planting(PM)						
AR	19.268	19.206	149.246	160.964	129.979	141.759
CT	25.185	25.185	158.854	168.624	133.669	143.439
SEm±	0.97	0.98	1.25	1.26	1.15	1.18
LSD (P= 0.05)	5.82	5.88	7.50	7.56	NS	NS
Nutrient management practices(NMP)						
100% RDF	21.529	22.195	147.364	158.097	125.835	135.902
100% RDF + *bf	21.534	22.200	157.053	168.102	135.519	145.902
125% RDF	23.614	24.280	157.597	168.499	133.983	144.219
SEm±	0.68	0.69	3.10	3.14	0.79	0.82
LSD (P= 0.05)	2.04	2.07	3.30	9.42	2.37	2.46
PM × NMP	NS	NS	NS	NS	NS	NS

significantly higher net returns were recorded in CT rice (₹ 60.03×10^3/ha and 69.46×10^3/ha) than AR. However, significantly higher net B: C was obtained in AR (₹ 1.08 and 1.27) than the CT rice (₹ 1.02 and 1.20). The economics of rice cultivation was also significantly influenced by the nutrient management practices. The higher cost of cultivation was recorded with 125% RDF followed by 100% RDF + bf and 100% RDF. Significantly, higher gross returns were obtained with 125% RDF and it was statistically at par with 100% RDF +bf. The gross returns from both the above treatments were significantly higher than the 100% RDF. Significantly higher net returns were obtained with 100 % RDF + bf (₹ 61.52×10^3/ha and ₹ 71.99×10^3/ha) which were at par with 125 % RDF (₹ 60.62×10^3/ha and 70.88 ×10^3/ha). Treatment with 100% RDF gave significantly lower net return. Similar trend was followed in net B: C also during both the years. The results were in conformity with other researchers (Singh *et al*. 2008; Davari and Sharma 2010; Saha *et al.* 2017).

Energetics of rice cultivation

The energetics of rice cultivation, viz. energy input and energy output were significantly influenced by crop establishment methods (Table 2). Significantly higher energy input (25.19 and 25.15 ×10^3 MJ/ha), energy output (158.85 and 168.62×10^3 MJ/ha) were recorded in CT rice than AR. Higher net energy was obtained in CT rice (133.67 and 143.44×10^3 MJ/ha) than AR (129.98 and 141.76×10^3 MJ/ha) but there was no significant difference between the CT rice and AR treatments. Among nutrient management practices, significantly higher energy input was taken in 125% RDF (23.61 and 24.28 ×10^3 MJ/ha) followed by 100% RDF +bf and 100% RDF. Energy output was also higher with 125% RDF (157.60 and 168.50 ×10^3 MJ/ ha) and it was at par with 100% RDF + bf (157.05 and 168.10×10^3 MJ/ha) followed by 100% RDF. Similar findings reported by Bohra and Kumar (2015). Unlike planting methods, nutrient management significantly influenced the net energy of rice. Significantly higher net energy was obtained with 100% RDF + bf (135.52 and 145.90×10^3 MJ/ha) and it was at par with 125% RDF (133.98 and 144.22×10^3 MJ/ha). Significantly lower net energy was obtained with 100% RDF (125.84 and 135.90×10^3 MJ/ha). The net energy of 100% RDF + bf treatment was high because it consumed comparatively lesser input energy and provided more output energy than 125% RDF. The energy requirement of biofertilizers was much lesser than the energy value of chemical fertilizers. This was responsible for higher net energy of 100% RDF +bf treatment. However, 125% RDF treatment provided higher output energy than 100% RDF +bf that equated the net energy and there was no significant difference between these two treatments.

It was concluded that the performance of rice was superior under conventional transplanted condition than aerobic rice in respect of plant growth, yield and profitability. However, cost of cultivation, consumption of energy was higher under conventional transplanting of rice than aerobic rice. In case of nutrient management, 125% RDF performed the superior but it was statistically at par with 100 RDF+ biofertilizers. Hence, the conventional transplanting of rice along with 100% RDF + biofertilizers can be recommended for farmers to get higher grain yield, net returns and energy values. In case of water scarcity conditions, aerobic rice can be recommended with 100% RDF + biofertilizers with slight penalty in grain yield and net returns.

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