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Original Research Article

Effect on yield, energetics and economics of direct seeded rice (*Oryza sativa* L.) under unpuddled condition in medium land of Jharkhand, India

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Dry direct seeded rice, *Sesbania aculeata*, Energetic, Semidry rice, Aerobic rice

A B S T R A C T

Rice is grown mostly through transplanting in India, in spite of the fact that transplanting is cumbersome practice and requires more labour. To overcome this problem, farmers are gradually switching over to direct seeding under unpuddled condition. Keeping these points in view an investigation on "Effect on yield, energetics and economics of direct seeded rice under unpuddled condition in medium land of Jharkhand" was conducted at Birsa Agricultural University, Farm, Ranchi, Jharkhand, during the *kharif* seasons of 2015 and 2016 with the objectives to find out effect of different rice establishment methods on productivity, energetics and economics of rice. The treatments comprised of six rice establishment methods- dry direct seeded rice (20cm x 15cm), dry direct seeded rice (broadcasted), aerobic rice(20cm apart), semi dry rice(20 cm apart), rice(line sowing 20cm apart) + *Sesbania aculeata* (broadcasted) and transplanted rice. The experiment was laid out in Randomized Block Design with four replications with variety Naveen. The soil was clay loam in texture and slightly acidic in reaction (pH 6.2 both years) with organic carbon 4.2 and 4.4 g/kg of soil, available soil nitrogen 210.5 and 206.3 kg/h, available phosphorous 31.35 and 30.16 kg/ha, and available potassium 185.1 and 183.5 kg/ha during June 2015 and 2016 respectively. Results revealed that rice + *Sesbania aculeata* produced maximum grain yield (50.30 q/ha) which was significantly higher than either dry direct seeded rice broadcasting (36.08 q/ha), 20cm x 15cm line sowing (40.20 q/ha), aerobic rice (41.80 q/ha) and semi dry rice (42.20 q/ha) except normal transplanting (49.20 q/ha). The gross energy output 161.47 x 103 MJ/ha, net energy output 158.01 x 103 MJ/ha and energy use efficiency 17.70 were maximum in rice + *Sesbania aculeata* being at par with normal transplanting method (165.35 x 103 MJ/ha, 155.78 x 103 MJ/ha and 17.28 respectively) and minimum specific energy 1894.86MJ/ton grain was also in case of rice (20cm apart) + *Sesbania aculeata*(broadcasted). Maximum net return ₹ 57991/ha and B: C ratio 2.08 was recorded with rice + *Sesbania aculeata*.

Introduction

Rice is the world's most important crop and is used as a staple food for more than half of the world's population. Worldwide, rice is grown on 158.89 million hectares, with an annual production of about 471.83 million tons of paddy. India ranks first in area under paddy cultivation with 43.50 million hectares and produced 104.4 million tons with 2.4 tons per hectare productivity in 2015-16. To meet out the global rice demand, it is estimated that about 114 million tons of additional milled rice need to be produced by 2035, which is equivalent to an overall increase of 26% in the next 20 years. In India rice is primarily grown by transplanting of seedling in puddled field which is very cumbersome, labour intensive and energy consumptive as it requires 30 man days/ha (Prasad *et al.*, 2001). Often, farmers fail to transplant the seedlings in time either due to prolonged dry spell or intense rainfall resulting in lower yields. Paucity of labours and increasing cost of transplanting encouraged many rice growers to switch over from transplanting to direct seeding of rice which requires less labours, shortens the crop duration by 7-10 days and can produce as much grain yield as that of transplanted crop. Dry direct seeding of rice allows early establishment of the succeeding crop and higher profit in areas with assured water supply by utilizing short duration modern varieties and cost efficient herbicides. So, there is need to search for suitable crop establishment methods to increase the productivity of rice (Farooq *et al.*, 2011) and to optimize energy consumption in agriculture.

Materials and Methods

Field investigation was carried out for two consecutive years (2015 and 2016) during *Kharif* seasons at Birsa Agricultural University Farm, Ranchi, Jharkhand. The experimental fields having clay loam soil and a pH of 6.2 (both years) having 4.2 and 4.4 g/kg organic carbon, 210.5 and 206.3 kg/ha available soil nitrogen, 31.35 and 30.16 kg/ha available phosphorous, 185.1 and 183.5 kg/ha of available potassium during June 2015 and 2016 respectively. The experiments were conducted in randomized block design with four replications with variety Naveen having maturity period of 125 days. There were six treatments viz., Dry direct seeded rice (20cm x 15cm): In this treatment well ploughed pulverized and levelled field, furrow was opened 20 cm apart and 2-3 dry seeds were placed in the furrow at 15 cm spacing then the seeds were covered with soil, Dry direct seeded rice (broadcasting): Dry seeds were broadcasted in the field and mixed thoroughly in the soil such that seeds were covered with soil properly. The field was kept in the saturation condition up to vegetative phase. Water was ponded in reproductive stage, Aerobic rice- In this treatment seeds were soaked in water for 10 hours followed by incubation for another 12 hours. After that seeds were treated with carbendazim @ 2 g/kg seed before sowing. Then, line sowing of rice was done with 20 cm row spacing. Irrigate the field immediately after sowing. Three irrigations were given as per the demand of the crop. The field was maintained near saturation without stagnation of water, Semi dry rice - Seeds were sown in lines 20 cm apart and covered with soil properly. At 15 days after sowing ponding of 2-3 cm water was done in the field. Field was maintained like transplanted rice thereafter, rice (line sowing with 20 cm row spacing) + *Sesbania aculeata* (broadcasting) - In this technique, *Sesbania aculeata* seeds @ 40 kg/ha was broadcasted in the field followed by line sowing of rice. *Sesbania aculeata* was uprooted 25 days after sowing and spread in between the rows of rice, Tansplanted rice- Twenty one days old 2-3 seedlings/hill were transplanted manually in the puddled field at a depth of 2-3 cm with a spacing of (20 cm × 15 cm).

A common fertilizer dose of 80:40:20 kg/ha NPK was applied in all the treatments. Half dose of the nitrogen and full dose of phosphorus and potash applied as basal and rest of the nitrogen was top dressed in two equal splits at 30 and 60 DAS/T.

The plants from net plot area were harvested, threshed and cleaned. After complete sun drying the grain weight of each net plot was recorded and converted to quintal/hectare. The results were expressed on 14 % moisture basis. After threshing, the cleaned grain yield was deducted from the bundle weight for obtaining straw yield of each net plot area and converted to quintals/hectare.

Energy input was calculated from the recorded data for each item of operations and expressed in MJ/ha for each treatment using standard values suggested by Paneshar and Bhatnagar (1994). The net energy output was calculated by subtracting energy input from gross energy output. It is expressed in MJ/ha. Energy use efficiency is energy produced by per unit energy consumed. It was calculated by using the following formula.

$$\text{Energy use efficiency} = \frac{\text{Energy output}}{\text{Energy input}}$$

Specific energy is the amount of energy required to produce one tonne of grain. It was calculated by using the following formula.

$$\text{Specific energy (MJ/t)} = \frac{\text{Energy input (MJ/ha)}}{\text{Grain yield of crop (t/ha)}}$$

Net return is also referred to as net profit and represents the actual income to farmer. It is calculated as follows:

Net return (₹ /ha) = Gross return (₹ /ha) – Cost of cultivation (₹ /ha).

Benefit: Cost ratio provides an estimate of the benefit derived from the expenditure incurred in adopting a particular cultivation practice. It is calculated by the following formula.

$$\text{Benefit: cost ratio} = \frac{\text{Net return (₹ /ha)}}{\text{Total cost of cultivation (₹ /ha)}}$$

Results and Discussion

Yield attributes and yield

Rice established by conventional transplanting, and under rice + *Sesbania aculeata* had similar yield attributes except 1000 grain weight (Table 1, Fig 1). However, Rice + *Sesbania aculeata* (268/m2) and conventional transplanting (256/m2) showed significant edge by 35 % and 29 %, respectively over broadcasting of dry seeds (197.75/m2) in panicle production and also superior to other treatments *viz*. dry direct seeded rice line sowing (20cm x 15cm) (228/m2), semi dry rice (231/m2) and aerobic rice (233/m2). Further, broadcasting of dry seeds recorded the lowest panicles/unit area which might be due to less availability of nutrients and moisture to the crop at panicle initiation stage resulting from the crop-weed competition (Raj *et al.* 2013). These findings are also in close conformity with those obtained by Parsad *et al.* 2001; Aslam *et al.* (2008) who reported higher yield attributes under transplanted rice than direct seeded. In line with the above-said facts, the experimental findings are also in agreement with those of Ali *et al.*2013;

Kanthi *et al.* 2014 and Mohanty *et al.* 2014. Among various establishment methods, higher filled grains /panicle were recorded in Rice + *Sesbania aculeata* (177) and conventional transplanting (173) significantly superior to dry direct seeded rice line sowing (20 cm x 15 cm) (147), aerobic rice (157) and semi dry rice (160), had edge of 26 % in filled grains /panicle, respectively over broadcasting of dry seeds. The filled grains/panicle in Rice + *Sesbania aculeata* and transplanted rice was significantly more as compared to other direct seeded crop because of more space, sunlight and nutrients availability in transplanted crop and nutrient availability in other one because of green manuring effect of dhaincha, whereas higher weed densities in direct seeded crop hinders the development of yield attributes, dhaincha suppressed weed competition in that treatment (Hussain *et al.* 2013). Grain and straw yield differed significantly by various rice establishment methods under unpuddled soil except the harvest index of rice. Rice established through Rice + *Sesbania aculeata* and conventional transplanting had similar grain and straw yield. Rice + *Sesbania aculeata* (50.30 q/ha) had edge by 39.41 % over broadcasting of dry seeds (36.08 q/ha) whereas transplanting method (49.20 q/ha) was significantly higher by 36.36 % over broadcasting of dry seeds (36.08 q/ha) in grain production. The comparatively low paddy yields in broadcasting of dry seeds as compared to conventional transplanting could have been due to exposure of seeds to pest destruction and weed competition (Dingkuhn *et al.* 1991) whereas, conventional transplanting method recorded significantly higher paddy yield because the planting distance ensure air circulation, water and light which are basic factors necessary for photosynthesis. Further, proper spacing increases tiller and yield (Baloch *et al.* 2002).Maximum paddy yield in Rice + *Sesbania aculeata* might be due to the fact that dhaincha is a crop that decomposes and provides available nutrients to the current crop throughout the life and also hindered the weeds growth and competition to rice at initial growth stages. The lowest yield attributes in terms of number of productive tillers/m2 and filled grains /panicle in broadcasting methods resulted in the lowest grain yield. Lack of uniformity in distribution despite adequate crop stand and initial setback in taking early lead in the growth might be the probable reasons for poor performance of rice established by broadcasting seeds (Kanthi *et al.* 2014). In case of straw yield, crop established through Rice + *Sesbania aculeata* (74.83 q/ha) and transplanting (74.43 q/ha) showed significant edge by 25.9 % and 25.3 %, respectively over broadcasting of dry seeds (59.40 q/ha). Rice established through broadcasting registered minimum straw yield. Rice + *Sesbania aculeata* and transplanting method of establishment recorded significantly higher straw yield compared to other treatments due to less crop weed competition which led to taller plants, more number of tillers and dry matter production which in turn resulted in higher straw yield (Parameshwari and Srinivas, 2014). However, there was no significant effect of various establishment methods on the harvest index of rice. This confirms the findings of Jha *et al.* 2011.

Energetics

Energy is one of the most important indicators of crop performance (Singh *et al.* 2008). Energy requirement and its production potential largely depend on the nature of crop. For sound planning of sustainable system it is necessary to quantify net energy and monetary return of cropping system.

Table.1 Effect of rice establishment methods on yield attributes, yield and economics (Pooled data of two years)

Treatments	Panicles/m 2	Filled grains/panicle	1000 Grain wt. (g)	Grain yield (q/ha)	Straw yield (q/ha)	H.I. (%)	Net profit (Rs./ha)	B:C ratio
T_1:Dry direct seeded rice(20cmx15cm)	228.00	147	23.53	40.20	65.00	38.31	43719	1.68
T_2:Dry direct seeded rice(broadcasting)	197.75	140	23.20	36.08	59.40	37.86	39733	1.73
T_3:Aerobic rice	233.00	157	23.30	41.80	64.82	39.21	43458	1.53
T_4:Semi dry rice	231.00	160	23.41	42.20	64.52	39.75	46442	1.79
T_5:Rice + *sesbania aculeata*	268.00	177	23.83	50.30	74.83	40.19	57991	2.08
T_6:Transplanted rice	256.00	173	23.85	49.20	74.43	39.75	54630	1.84
SEm±	7.17	3.73	0.59	1.97	3.04	1.66	2779	0.10
CD (P=0.05)	21.61	11.25	NS	5.94	9.17	NS	8377	0.31
CV%	6.08	4.70	5.05	9.11	9.05	8.50	11.66	11.47

Note: All the treatments are under unpuddled condition, H.I. - Harvest index

Table.2 Energetics as influenced by different establishment methods (Pooled data of two years)

Treatments	Energy input (MJ/ha x 103)	Gross energy output (MJ/ha x 103)		Net energy output (MJ/ha x 103)	Energy use efficiency (%)	Specific energy (MJ/t grain)
		Grain	Biomass			
T_1:Dry direct seeded rice(20cmx15cm)	8.79	59.09	140.35	131.55	15.96	2199.11
T_2:Dry direct seeded rice(broadcasting)	8.59	53.03	127.28	118.68	14.81	2397.77
T_3:Aerobic rice	9.74	61.44	142.47	132.72	14.61	2341.66
T_4:Semi dry rice	8.79	62.03	142.68	133.88	16.22	2104.09
T_5:Rice + *sesbania aculeata*	9.46	73.94	167.47	158.01	17.70	1894.86
T_6:Transplanted rice	9.57	72.32	165.35	155.78	17.28	1962.02
SEm±		2.89	4.51	4.51	0.48	98.72
CD (P=0.05)		8.73	13.61	13.61	1.46	297.49
CV%		9.11	6.12	6.52	6.02	9.18

Note: All treatments are under unpuddled cond

Fig.1 Grain and straw yield (q/ha) of rice as influenced by establishment methods

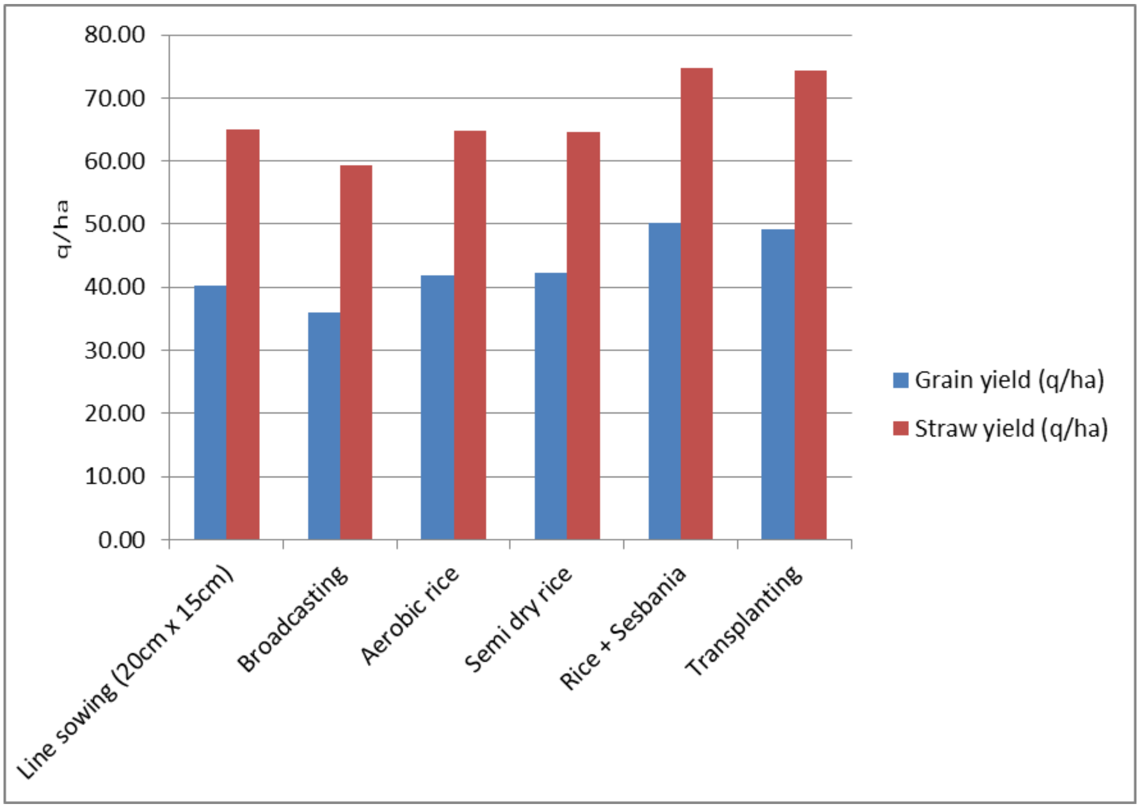


Fig.2 Economics of different rice establishment methods under unpuddled soil

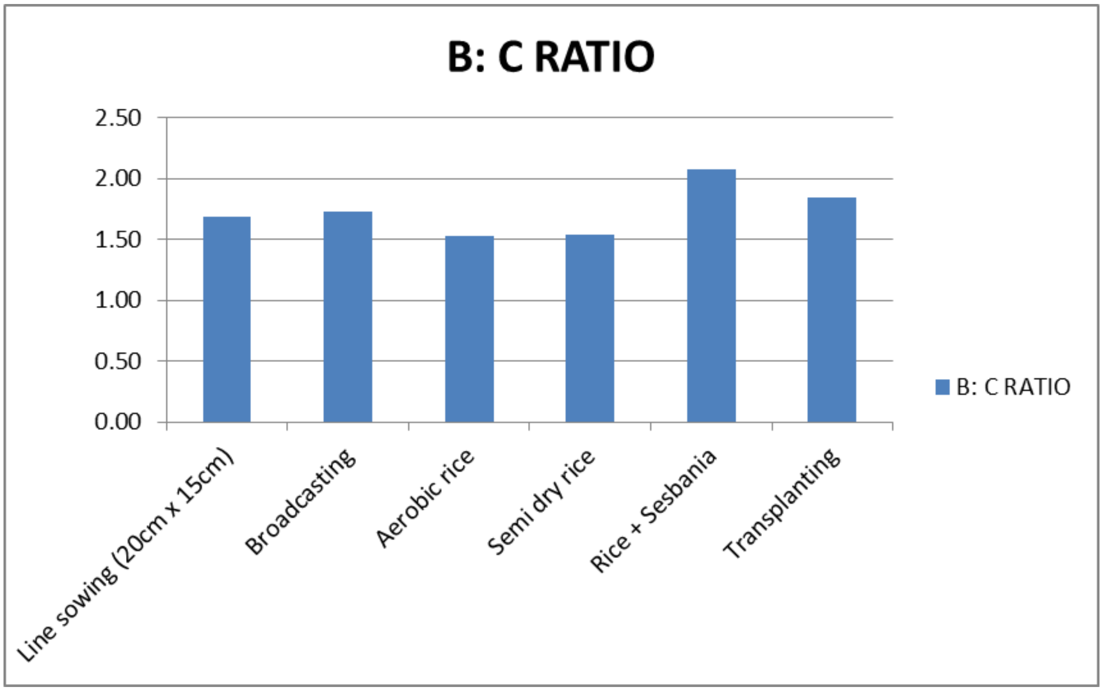
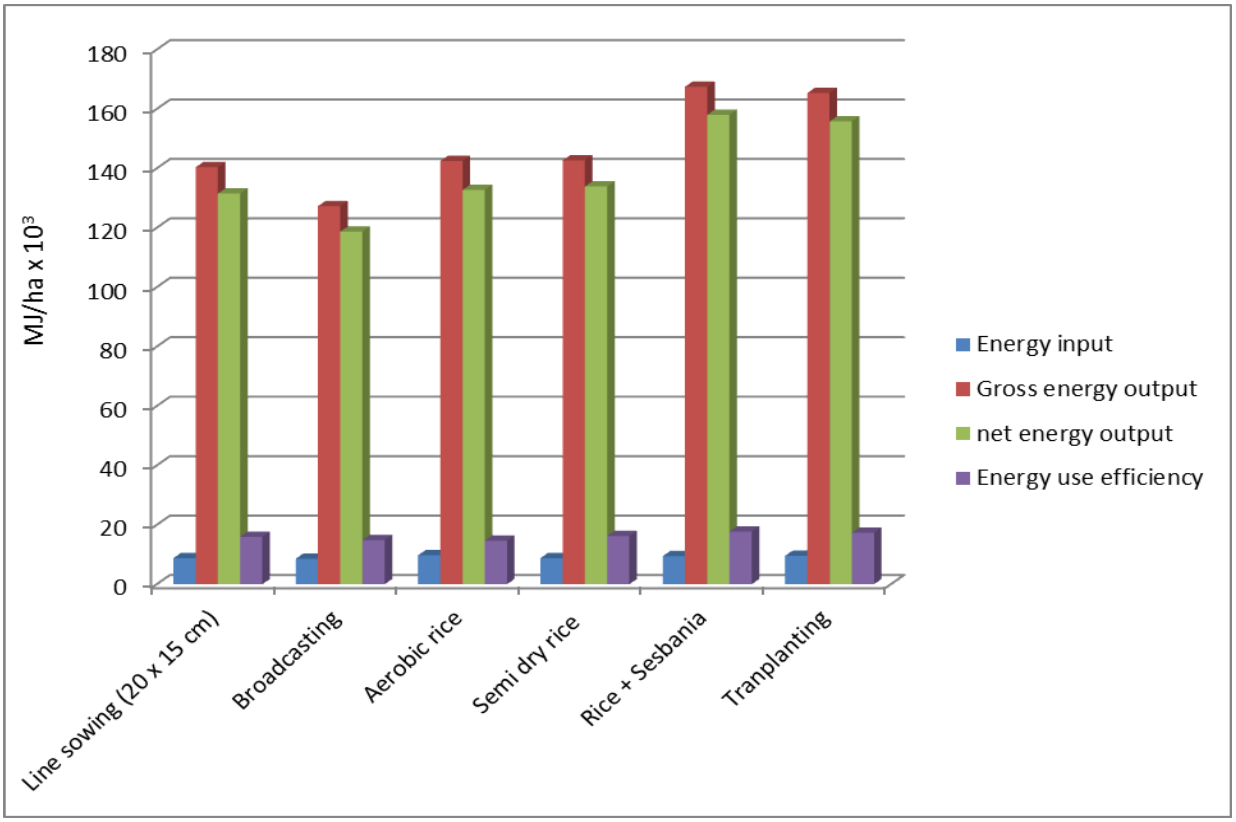


Fig.3 Energetics (MJ/ha x 103) of rice as influenced by different establishment methods



In the present investigation, the comparison of energy use pattern in different crop establishment methods of rice under unpuddled soil revealed that energy input was maximum in case of aerobic rice (9.74 MJ/ha x 103) followed by transplanting method (9.57 MJ/ha x 103), Rice + *Sesbania aculeata* (9.46 MJ/ha x 103), Dry direct seeded rice (20cm x 15cm) and Semi dry rice (8.79 MJ/ha x 103) and broadcasting of dry direct seeded rice (8.59 MJ/ha x 103). However, the gross energy output of conventionally transplanted rice had significant edge of 29.91 and 17.81 % over dry direct seeded rice either broadcasting or line sowing (20cm x 15cm), respectively. Whereas, rice established by Rice + *Sesbania aculeata* had edge of 31.57 and 19.32 % over dry direct seeding by either broadcasting or line sowing, respectively in gross energy output.

Similarly, in case of net energy output rice established through transplanting had edge by 31.29 and 18.42% over, dry direct seeding by either broadcasting or line sowing respectively, while Rice + *Sesbania aculeata* showed markedly increase of 33.17 and 20.11% over, dry direct seeding by either broadcasting or line sowing respectively. The energy-use efficiency of rice established through conventional transplanting was significantly 16.67% higher over broadcasting of dry seeds, respectively. Whereas, Rice + *Sesbania aculata* had significant edge by 19.51 and 10.90%, over, broadcasting or line sowing (20 cm x 15 cm) respectively. The higher energy use efficiency under transplanted and Rice + *Sesbania aculeata* treatments was mainly attributed to higher energy production with relatively lesser energy requirement (Jha *et al*. 2011).

The specific energy requirement under Rice + *Sesbania aculeata* was significantly lower by 20.97 and 13.83% than broadcasting of dry seeds (2397.77 MJ/t) or line sowing (2199.11 MJ/t), respectively. Whereas conventionally transplanted rice was 18.17 % lower than broadcasting of dry seeds in specific energy requirement (Table 2, Fig 3)). Similar results were also reported by Mohanty *et al.* 2014.

Economics

Economic analysis of the treatments shows the relevance to consider the practical adaptability of a particular treatment from the farmers' point of view (Jha *et al.* 2011). The agriculture practices involving lower cost of production and giving higher net return and benefit: cost ratio are preferred for adoption. Rice + *Sesbania aculeata* (57991.00 ₹ /ha) being on par with transplanting (54630 ₹ /ha) in net return showed significant edge by 45.95%, 32.64%, and 33.41% over broadcasting (39733 ₹ /ha), line sowing (43719.50 ₹ /ha). Transplanting had also significant edge by 37.49 %, 24.955, and 25.70% over broadcasting, line sowing and aerobic rice. The higher net return under Rice + *Sesbania aculeata* might be due to higher grain and straw yield of the crop (Table 1, Fig 2). Maximum benefit cost ratio recorded with Rice + *Sesbania aculeata* (2.08) followed by transplanted rice (1.84) and semi dry rice (1.79). Rice + *Sesbania aculeata* had significant edge by 35.94%, 23.80%, and 20.23% over aerobic rice (1.53), line sowing (1.68), and broadcasting (1.73).This result is in corroborative with the findings of Jha *et al.* 2011.

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