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Energy consumption, economics, yield and quality of rice (*Oryza sativa* L.) in different crop establishment methods

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ABSTRACT

A field experiment was conducted in clay loam soils of Jagtial, Telangana State during rainy season of 2015 to study the performance of rice under different establishment methods. The experiment was laid down in randomized block design with three replications. Eleven treatments were taken viz. dry and wet seeding with drum seeder at three row spacing i.e, 20, 25 and 30 cm, broadcasting of dry and sprouted seed in puddled soil, conventional transplanting, SRI and MSRI methods. The yield attributes viz. panicles m^{-2}, spikelets panicle^{-1} and per cent filled grains were found to be high in MSRI method with less chaffyness of grains. Highest grain yield was obtained with MSRI method (6848 kg ha^{-1}) followed by SRI method (6425 kg ha^{-1}) which was 31.5 and 23.4% higher than the conventional transplanting method, respectively. Drum seeding at 30 cm spacing with wet seed (pregerminated) and dry seed registered an increase of 22.1 and 17.8% in yield over conventional transplanting method, respectively. Rice crop matured 10-15 days earlier in drum seeding and 5-6 days in SRI and MSRI methods compared to conventional transplanting. The productivity day^{-1} was found to be maximum in drum seeding with pregerminated seed at 30 cm row spacing closely followed by MSRI and SRI methods and found to be superior to transplanting method. The labour requirement in transplanting was the highest and MSRI method registered the least followed by drum seeding. The energy consumption was less in drum seeding followed by SRI method compared to MSRI and broadcasting method. MSRI method fetched highest gross returns (169957 ha^{-1}), net returns (118657 ha^{-1}) and B:C ratio (2.3).

***Key words:** Crop establishment, drum seeding, SRI, MSRI, labour requirement, productivity day^{-1}, energy consumption*

In India, rice is cultivated in an area of 43.95 mha with a production of 106.54 mt and productivity of 2424 kg ha^{-1}(Ministry of Agriculture 2014). Although conventional transplanting method is reported to be the best establishment method (Mankotia *et al*. 2009; Shan *et al*. 2012; Singh *et al*. 2013; SandhyaKanthi *et al*. 2014; Mohanty *et al*. 2017), some other alternate establishment methods such as dry and wet seeding are being explored in the recent past to reduce the cost of cultivation and to catch up with the season.

Due to global warming in the recent years, there has been a shift in the regular climate changes. Besides different anthropogenic activities, lowland paddy fields with standing water are major sources of methane emission which ultimately increases the global warming potential (Mahato 2014; Kumar *et al*. 2016). It had a commendable impact on rainfall pattern. There was either late onset of monsoon or early cessation of rains. The late onset of monsoon resulted in delay of sowing due to which there were unfavourable conditions at critical growth stages thereby reducing the yields. The early cessation of rains caused water deficit during peak period of water requirement which in turn had a great impact on the yields. This led to unavailability of water to raise the crop throughout its growth period.The scarcity of water triggered the unavailability of power due to which irrigation given to the crop was hampered.

Another exemplary problem associated with raising of rice crop in traditional method is the unavailability of labour. In India, labour migration is mostly influenced by social structures and pattern of development. Uneven development is the main reason of migration along with factors like poverty, landholding system, fragmentation of land, lack of employment opportunities, large family size and natural calamities. The high-land man ratio, caste system, lawlessness and exploitation at native place speed up the breakdown of traditional socio-economic relations in the rural areas and people decide to migrate to relatively prosperous areas in search of better employment and income (Kaur *et al*. 2011).

These problems forced the farmers to find alternate methods of raising rice crop which reduces the cost of cultivation on account of high labour and water requirement. These methods include dry and wet seeding, drum seeding, SRI and mechanised SRI methods. Keeping this in view, the present study was undertaken to investigate the effect of crop establishment methods on yield, energy consumption and economics of rice in *kharif* season.

MATERIALS AND METHODS

The field experiment was carried out at Regional Agricultural Research Station Farm, Agricultural College Jagtial, Telangana State during *kharif* season, 2015. The experimental soil was clay loam with neutral pH (7.3) and electrical conductivity (0.24 d Sm^{-1}), low in organic carbon (0.38%). The soil was low in available N (220.4 kg ha^{-1}) and medium in available P (35.3kg ha^{-1}) and K (312.2 kg ha^{-1}). The cultivar 'BPT 5204' was used as the test variety. The experiment was laid in randomized block design with three replications and eleven establishment methods *viz*., dry seeding with drum seeder at 20 cm spacing between the rows (T_1), wet (pre germinated) seeding with drum seeder at 20 cm spacing between the rows (T_2), dry seeding with drum seeder at 25 cm spacing between the rows (T_3), wet seeding with drum seeder at 25 cm spacing between the rows (T_4), dry seeding with drum seeder at 30 cm spacing between the rows (T_5), wet seeding with drum seeder at 30 cm spacing between the rows (T_6), broadcasting of dry seed in puddled soil (T_7), broadcasting of sprouted seed in puddled soil (T_8), conventional transplanting (farmer's practice) (T_9), SRI method (T_{10}) and MSRI method (T_{11}). A rainfall of 340.6 mm was received during the crop growth period spread in 19 rainy days.

Soil samples were collected before planting and after harvest of the crop and analyzed for available nitrogen, available phosphorus and available potassium. Available nitrogen was estimated by alkaline potassium permanganate method (Subbaiah and Asija 1956), available phosphorus by Olsen's method (Olsen *et al*. 1954) and available potassium by flame photometry (Muhr *et al.* 1963).

For sowing in treatments from T_1 to T_6, manually operated drum seeders consisting of two drums made of fibre with openings at different spacing were used. A 20 cm spacing drum seeder provided 20 cm spacing between the rows and 7 cm spacing between the plants of the rows (T_1 and T_2). Six rows could be laid when this drum seeder was drawn across a given area. The drum seeder with 25 (T_3 and T_4) and 30 cm (T_5 and T_6) spacing between the rows could lay 4 rows at a time in a given area with 7 cm spacing between the plants of a row. The drums were filled with the seed upto three fourth of their capacity. About 3-4 seeds can be placed in a hill with the help of the drum seeder at all the row spacing. For dry seeding in T_1, T_3 and T_5, dry seeds were directly taken in the drum and sown in the puddled field. For wet seeding in T_2, T_4 and T_6, the seeds were soaked in water for 24 hours, drained and incubated for 24 hours in gunny bags and filled in the drums for sowing. Thus, the seed rate worked out was 37.5 kg ha^{-1} at 20 cm and 35 kg ha^{-1} at 25 and 30 cm row spacing. For broadcasting of dry seed (T_7), the seeds @ 100 kg ha^{-1} were directly broadcasted into the puddled field uniformly. For broadcasting sprouted (pre germinated) seed (T_8), the seeds were soaked in water, drained and incubated for 24 hours before sowing. In case of conventional transplanting (T_9), nursery was raised by broadcasting the seed @ 75 kg ha^{-1}. Transplanting was done using thirty-day-old seedlings. Seedlings were uprooted and transplanted @ 2 seedlings $hill^{-1}$ about 2-3 cm deep in puddled soil at 20 x 15 cm spacing manually. In SRI (T_{10}) method, raised bed nursery was prepared and seeds were broadcasted. Seed rate adopted was 5 kg ha^{-1}. Twelve-day-old seedlings were transplanted manually at 25 x 25 cm in the puddled field. In MSRI (T_{11}) method, nursery was sown in plastic trays of 60 x 30 x 2.7 cm size, filled with well powdered soil. The soaked seeds were broadcasted in the trays and covered with soil. Water was sprinkled 3-4 times every day up to 6-7 days after sowing to keep the seed bed wet. From a week after sowing, water was applied through the water channel until transplanting. Machine transplanting was done using Kubota NSPU- 68C transplanter which planted 6 rows at one time with a spacing of 30 x 16 cm. Fifteen day old seedlings in mats were lifted from the plastic trays and placed directly in the trays of the transplanter. Seed rate adopted in MSRI was 25 kg ha^{-1}. The sowing/ transplanting in all the plots was done on 1^{st} August, 2015. The gross plot size in all the treatments was 9.3 x 4.5 m and net plot size was 8.7 x 3.5 m.

For control of weeds, pretilachlor was applied @ 7.5 ml in 150 gm soil per plot on 4 August, 2015. The left over weeds were removed by hand weeding at 15 days interval. Irrigation was applied as per requirement to the plots. No irrigation was applied on rainy days. It was withheld 15 days before harvesting of the crop. A fertilizer dose of 120, 60 and 40 kg N, P_2O_5 and K_2O ha^{-1} was applied. Phosphorus and potash were applied as basal dose in the form of SSP and MOP, respectively. Nitrogen was applied as 3 equal splits *viz*., as basal at the time of transplanting/sowing, maximum tillering and panicle initiation stage. Zinc was applied in the form of $ZnSO_4$ as foliar spray @ 2g lt^{-1} to all the plots at 30 DAS. Carbofuran 3G granules @ 25 kg ha^{-1} was applied at 27 DAS. Other plant protection measures were taken up as and when required. Harvesting in conventional transplanting and the rest of the methods was done on 144 DAS and 150DAS, respectively.

Data on the number of panicles in one m^2 area in net plot was counted and expressed as panicles m^{-2}. Ten panicles were selected at random from each plot to compute the number of spikelets $panicle^{-1}$, number of chaffy grains $panicle^{-1}$ and percentage of filled spikelets. For 1000-grain weight, five hand full of grain samples were collected at random from the net plot yield of each individual treatment. The grains were counted and weighed to arrive at test weight. The crop was harvested manually with the help of sickles when the grain almost matured and the straw had turned yellow and data on grain and straw yield was recorded (Kumar *et al*. 2017).

The hulling, milling and head rice recovery were also recorded as per Brar *et al*. (2007). Sample of one hundred grams of well dried paddy (12-14% moisture) from each treatment was dehulled in "Satake" dehuller and the weight of brown rice was recorded. Hulling percentage was computed using the following formula and expressed in percent.

Hulling (%)=(Weight of brown rice (g) X 100)/ (Weight of unhusked rice (g))

The brown rice obtained by dehulling was subjected to milling for 90 sec ***i.e***., 5 percent milling in "Satake" polisher (Type-TM 05) and the weight of polished rice was recorded.

Milling (%)=(Weight of polished grain (g) X 100)/{Weight of rough rice (g)}

The milled samples were sieved to separate whole grains from the broken ones. Small proportion of whole grains, which passed along with broken grains were separated by hand. Full rice and three-fourth grains were taken as whole rice for computation. Head rice recovery (HRR) was calculated in percentage as

Head rice recovery (%)=(Weight of head rice recovered (g) X 100)/{Weight of sample used for milling (g)}

The duration of the crop from sowing to harvest was calculated and expressed as days. The grain yield obtained was divided by the crop duration to get the productivity day^{-1}. It was expressed as kg ha^{-1} day^{-1}. The number of labourers required during the entire crop period in different treatments from sowing to harvesting was calculated and expressed as the number of man days. The energy consumption during the entire crop period from sowing to harvest, taking into account the energy consumed by human labour, number of litres of diesel and fertilizers was recorded according to Patel *et al*. (1994), expressed as MJ ha^{-1} and presented in Table 1.

Table 1. Equivalent energy of the inputs used in the study

Particular	Unit	Equivalent energy (MJ)
Inputs		
Adult man	Man (hr)	1.96
Woman	Woman (hr)	1.57
Bullock	Pair (hr)	14.05
Diesel	litre	56.31
Chemical fertilizers		
Nitrogen	kg	60.60
P_2O_5	kg	11.10
K_2O	kg	6.70
Other chemicals	kg	120

Gross returns ha^{-1} were calculated by multiplying the grain and straw yield with their respective prevailing market price. The net return ha^{-1} was calculated by deducting the cost of cultivation from the gross returns. The benefit:cost ratio was also worked out by dividing the net returns from the cost of cultivation.

All the data were subjected to analysis of variance (ANOVA) as per the standard procedures. The comparison of treatment means was made by critical difference (CD) at P=0.05.

RESULTS AND DISCUSSION

Yield attributes and yield of rice were influenced by different crop establishment methods (Table 2). Highest number of panicles m^{-2} were recorded in MSRI method (T_{11}) which was at par with SRI method (T_{10}) and dry andwet seeding with drum seeder at 30 cm row to row spacing (T_5 and T_6) and was superior to rest of the treatments. Significantly higher number of spikelets were found in MSRI method (T_{11}) compared to broadcasting (T_7 and T_8), drum seeding with dry and wet seed at 20 cm spacing (T_1 and T_2) or dry seed at 25 cm spacing (T_3) and transplanting method (T_9) and at par with other methods. MSRI method (T_{11}) registered highest percentage of filled spikelets which was superior to broadcasting (T_7 and T_8) and drum seeding at 20 cm spacing (T_1 and T_2) and at par with other method. The number of chaffy spikelet $panicle^{-1}$ was in the reverse order and it was lower in MSRI method (T_{11}) which was at par with SRI method (T_{10}) and drum seeding with wet or dry seed at 30 cm row spacing (T_6 and T_5) or wet seed at 25 cm spacing (T_4). There was no significant difference among the establishment methods with respect to test weight of the grains.

In general, the scanty rainfall coupled with high mean temperature, relative humidity and wind velocity especially from vegetative to panicle initiation stage resulted in realisation of lower yields in the region. However, the grain yield and straw yield of rice was higher in MSRI method (T_{11}) and significantly superior to transplanting method (T_9) (Table 3). It was at par with SRI method (T_{10}) and drum seeding at 30 cm row spacing (T_6 and T_5) or wet seeding at 25 cm spacing (T_4). The grain yield recorded in MSRI method (T_{11}) and SRI method (T_{10}) was 31.5 and 23.4% higher than that in conventional transplanting (T_9), respectively. It is attributed to planting of young seedlings *i.e.*, before third phyllochron at shallow depth of planting in wider spacing (25 x 25 cm), which leads to large root volume, profuse and strong tillers with large panicles, more and well filled spikelets with higher grain weight in SRI method (Satyanarayana and Babu 2004). Dass *et al*. (2015) in a review, concluded 50-100% increase in rice yield in India due to SRI method over conventional transplanting method. Pasha *et al.* (2014) and Ramana *et al*. (2015) also reported the superiority of MSRI or

Table 2. Yield attributes of rice as influenced by different crop establishment methods

Treatment	No. of panicles m^{-2}	No. of spikelets $panicle^{-1}$	% filled spikelets	No. of chaffy spikelets $panicle^{-1}$	Test weight (g)
T_1: Drum seeding (dry) at 20 cm row spacing	314	154	70.5	44	13.4
T_2: Drum seeding (wet) at 20 cm row spacing	327	174	75.7	41	13.5
T_3: Drum seeding (dry) at 25 cm row spacing	342	189	79.2	39	13.5
T_4: Drum seeding (wet) at 25 cm row spacing	351	196	82.0	34	13.6
T_5: Drum seeding (dry) at 30 cm row spacing	377	201	84.4	32	13.6
T_6: Drum seeding (wet) at 30 cm row spacing	394	208	85.2	30	13.6
T_7: Broadcasting dry seed	277	127	56.0	52	13.2
T_8: Broadcasting sprouted seed	317	164	71.3	44	13.2
T_9: Transplanting	332	179	76.8	39	13.3
T_{10}: SRI method	412	229	86.6	29	13.7
T_{11}: MSRI method	431	249	90.2	24	13.7
SEm $\pm$	34	28	6.6	6	0.2
CD (P=0.05)	71	59	13.8	13	NS

Table 3. Yield and quality parameters of rice as influenced by different crop establishment methods

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)	Hulling (%)	Milling (%)	Head rice recovery (%)
T_1: Drum seeding (dry) at 20 cm row spacing	4806	6268	43.4	82.6	71.7	61.7
T_2: Drum seeding (wet) at 20 cm row spacing	5108	6585	43.6	82.6	72.5	62.5
T_3: Drum seeding (dry) at 25 cm row spacing	5559	7032	44.1	83.1	73.1	62.9
T_4: Drum seeding (wet) at 25 cm row spacing	5771	7187	44.5	83.1	73.2	62.9
T_5: Drum seeding (dry) at 30 cm row spacing	6136	7527	44.9	83.1	73.4	63.2
T_6: Drum seeding (wet) at 30 cm row spacing	6358	7762	45.1	83.5	73.8	63.7
T_7: Broadcasting dry seed	4208	5705	42.4	80.4	70.4	61.4
T_8: Broadcasting sprouted seed	4888	6308	43.8	82.6	72.5	62.4
T_9: Transplanting	5207	6733	43.4	83.5	72.8	62.6
T_{10}: SRI method	6425	7871	45.0	84.0	74.0	64.1
T_{11}: MSRI method	6848	8313	45.0	87.1	77.5	67.0
SEm ±	563	595	2.2	2.6	1.7	1.6
CD (P=0.05)	1176	1243	NS	NS	NS	NS

SRI method over conventional transplanting method.

Drum seeding at 30 cm spacing with wet seed (T_6) and dry seed (T_5) also registered an increase of 22.1 and 17.8% in yield over conventional transplanting method, respectively. This can be attributed to more space, sunlight and nutrients available at wider spacing in drum seeding. Visalakshi and Sireesha (2014) evaluated drum seeder in farmers' fields and inferred that drum seeding was superior to conventional transplanting and broadcasting methods.

Harvest index remained unaffected by the different crop establishment methods. The hulling, milling and head rice recovery was also not influenced by different crop establishment methods. Similarly, physico-chemical, physical properties and nutrient status of the soil was unaltered by the crop establishment methods after the harvest of rice crop (Table 6 and 7). This is in contrast to Choudhury *et al*. (2007) and Mandal and Pramanik (2015) who found higher soil organic carbon, bulk density, available N, P, K with SRI method compared to conventional transplanting method.

The crop duration varied with different establishment methods (Table 4). Among them, the crop matured 10-15 days earlier in drum seeding treatments (T_1, T_2, T_3, T_4, T_5 and T_6) compared to transplanting method (T_9). MSRI method (T_{11}) and SRI method (T_{10}) also recorded less duration by 5-6 days compared to conventional transplanting method (T_9). The treatments under wet drum seeding (T_2, T_4 and T_6) had little less duration compared to the dry drum seeding treatments (T_1, T_3 and T_5). The duration of the crop was prolonged by 4-7 days in broadcasting method (T_7 and T_8) compared to drum seeding (T_1, T_2, T_3, T_4, T_5 and T_6). It might be due to competition among the plants. Conventional transplanting (T_9) recorded the longest

Table 4. Crop duration and productivity of rice as influenced by different crop establishment methods

Treatment	Crop duration	Productivity ha^{-1} day^{-1} (days)
T_1: Drum seeding (dry) at 20 cm row spacing	141	34.1
T_2: Drum seeding (wet) at 20 cm row spacing	138	37.0
T_3: Drum seeding (dry) at 25 cm row spacing	141	39.4
T_4: Drum seeding (wet) at 25 cm row spacing	139	41.5
T_5: Drum seeding (dry) at 30 cm row spacing	140	43.8
T_6: Drum seeding (wet) at 30 cm row spacing	138	46.1
T_7: Broadcasting dry seed	146	28.8
T_8: Broadcasting sprouted seed	143	34.2
T_9: Transplanting	155	33.6
T_{10}: SRI method	150	42.8
T_{11}: MSRI method	149	46.0
	SEm ±	3.9
	CD(P=0.05)	8.0

duration compared to all the other treatments. The reason attributed is the transplanting shock which might have prolonged the crop duration in this method. Gill *et al.* (2006) also reported that direct seeded rice matured 10 days earlier than transplanted crop.

Maximum productivity day^{-1} (Table 4) was observed in drum seeding with wet seed at 30 cm row spacing (T_6), which was closely followed by MSRI method (T_{11}). Both of them were at par with dry or wet seeding at 25 cm row spacing (T_3 and T_4), dry seeding at 30 cm spacing (T_5), SRI method (T_{10}) and significantly superior to rest of the methods including transplanting practice (T_9). Lowest productivity was recorded in broadcasting of dry seed in puddled soil (T_7). However, broadcasting either dry or sprouted seed (T_7 and T_8), drum seeding at 20 and 25 cm (T_1, T_2, T_3 and T_4) were found to be at par with transplanting method (T_9). Reduced duration with enhanced or at par yield might be responsible for increased daily production in the alternate establishment methods.

The labour requirement was found to be the highest in conventional transplanting (T_9) on account of nursery raising, puddling and transplanting (Table 5). Among the alternate methods, the number of labour days from sowing to harvesting was the highest in broadcasting of dry or sprouted seed in puddled soil (T_7 and T_8). MSRI method (T_{11}) registered the lower number of labour days over rest of the treatments.

Table 5. No. of man daysand energy consumption as influenced by different crop establishment methods in rice

Treatment	No. of man days	Energy consumption (MJ ha^{-1})
T_1: Drum seeding (dry) at 20 cm row spacing	154	14940
T_2: Drum seeding (wet) at 20 cm row spacing	155	14942
T_3: Drum seeding (dry) at 25 cm row spacing	154	14940
T_4: Drum seeding (wet) at 25 cm row spacing	155	14942
T_5: Drum seeding (dry) at 30 cm row spacing	154	14940
T_6: Drum seeding (wet) at 30 cm row spacing	155	14942
T_7: Broadcasting dry seed	202	15490
T_8: Broadcasting sprouted seed	203	15492
T_9: Transplanting	232	15043
T_{10}: SRI method	169	14945
T_{11}: MSRI method	149	15270

Table 6. Physical and physic-chemical properties of the soil after harvest as influenced by different crop establishment methods in rice

Treatment	pH	EC (d Sm^{-1})	OC (%)	Bulk density (g cc^{-1})
T_1: Drum seeding (dry) at 20 cm row spacing	7.63	0.87	43.4	1.32
T_2: Drum seeding (wet) at 20 cm row spacing	7.66	0.87	43.6	1.32
T_3: Drum seeding (dry) at 25 cm row spacing	7.68	0.88	44.1	1.33
T_4: Drum seeding (wet) at 25 cm row spacing	7.69	0.88	44.5	1.33
T_5: Drum seeding (dry) at 30 cm row spacing	7.70	0.88	44.9	1.33
T_6: Drum seeding (wet) at 30 cm row spacing	7.70	0.88	45.1	1.34
T_7: Broadcasting dry seed	7.60	0.87	42.4	1.32
T_8: Broadcasting sprouted seed	7.65	0.87	43.8	1.32
T_9: Transplanting	7.67	0.88	43.4	1.33
T_{10}: SRI method	7.70	0.89	45.0	1.34
T_{11}: MSRI method	7.70	0.89	45.0	1.34
SEm ±	0.05	0.01	2.2	0.01
CD (P=0.05)	NS	NS	NS	NS

Venkateswarlu *et al*. (2011) reported 50 percent reduction in labour requirement in nursery raising and transplanting in machine method compared to manual transplanting method. Compared to MSRI method (T_{11}), the labour requirement was higher in SRI method (T_{10}). Drum seeding also required considerably lesser labour compared to transplanting (T_9), broadcasting (T_7 and T_8) and SRI method (T_{10}).

The comparison of energy use pattern (Table 5) in different crop establishment methods in rice revealed that the highest input energy were consumed in broadcasting of dry seed in puddled soil (T_7) or sprouted seed in puddled soil (T_8) due to engagement of more labour on manual weeding. The lowest energy was consumed in drum seeding (T_1, T_2, T_3, T_4, T_5 and T_6) and SRI method (T_{10}) compared to other methods due to reduction in use of labour component. The energy consumed in MSRI method (T_{11}) was higher than SRI method (T_{10}) and transplanting method (T_9) due to consumption of diesel even though engagement of labour was reduced.

Significantly higher gross and net returns (Table 8) were realized in MSRI method (T_{11}) compared to transplanting (T_9), broadcasting (T_7 and T_8) and drum seeding at 20 and 25 cm row spacing (T_1, T_2, T_3 and T_4). It was at par with SRI method (T_{10}) and dry and

Table 7. Economics of rice as influenced by different crop establishment methods

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Benefit: Cost ratio
T_1: Drum seeding (dry) at 20 cm row spacing	51650	122960	71310	1.4
T_2: Drum seeding (wet) at 20 cm row spacing	51850	130039	78189	1.5
T_3: Drum seeding (dry) at 25 cm row spacing	51650	140380	88730	1.7
T_4: Drum seeding (wet) at 25 cm row spacing	51850	144767	92917	1.8
T_5: Drum seeding (dry) at 30 cm row spacing	51650	152944	101294	2.0
T_6: Drum seeding (wet) at 30 cm row spacing	51850	158554	106704	2.1
T_7: Broadcasting dry seed	60750	109504	48754	0.8
T_8: Broadcasting sprouted seed	60950	124497	63547	1.0
T_9: Transplanting	51750	132732	80982	1.6
T_{10}: SRI method	52150	159072	106922	2.1
T_{11}: MSRI method	51300	169957	118657	2.3
	SEm ±	11702	11702	0.2
	CD (P=0.05)	24458	24458	0.5

Price (kg^{-1}): Grain: 14.50 and Straw: 8.5

wet drum seeding at 30 cm row spacing (T_5 and T_6). Lowest gross and net returns were realized in broadcasting of dry followed by sprouted seed (T_7 and T_8). Venkateswarulu *et al*. (2011) found an additional net income of Rs. 13837/- ha^{-1} with machine planting which was 29% higher over transplanting in rice. However, gross and net returns obtained in drum seeding at 20 (T_1 and T_2) and 25 cm (T_3 and T_4) and 30 cm (dry seed) (T_5) and broadcasting methods (T_7 and T_8) were at par with transplanting method (T_9).

Similar to gross and net returns, highest benefit:cost ratio was recorded in MSRI method (T_{11}), followed by SRI (T_{10}) and drum seeding at 30 (T_5 and T_6) and 25 cm (T_3 and T_4) spacing which were superior to farmers' method of transplanting (T_9). The other methods were inferior to transplanting method. Higher returns and B:C ratio with MSRI (T_{11}), SRI (T_{10}) and drum seeding method (T_3, T_4, T_5 and T_6) was due to reduction in cost of cultivation on account of reduced labour requirement for planting and weeding coupled with realization of higher yields.

From this study it can be concluded that Mechanised SRI (MSRI) and SRI methods were found to be superior to conventional transplanting method in yield and profit but drum seeding emerged as an alternate method of rice establishment with higher daily productivity and less energy consumption with reduced duration.

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