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PERFORMANCE AND PROFITABILITY OF RICE ESTABLISHMENT METHODS UNDER PUDDLED CONDITIONS IN TELANGANA, INDIA: A THREE-YEAR ON-FARM EVALUATION

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ABSTRACT
On-farm trial entitled "performance and profitability of rice establishment methods under puddled conditions in telangana : a three-year on-farm evaluation" was conducted during three consecutive rabi seasons (2018–19 to 2020–21) at 15 farmers' locations in the adopted villages of Krishi Vigyan Kendra, Garimellapadu, Bhadradri Kothagudem district, Telangana, to compare machine transplanting, direct wet seeding in puddled soil (DSR) and manual transplanting, and to document the performance of RNR 15048 and HMT Sona. Based on the supplied pooled records, machine transplanting produced the highest mean grain yield (6498 kg ha^{-1}), followed by puddled DSR (6150 kg ha^{-1}) and manual transplanting (5802 kg ha^{-1}). Machine transplanting increased yield by 12.0% over manual transplanting and by 5.7% over DSR. Mean net returns were ₹63,961 ha^{-1} under machine transplanting, ₹55,118 ha^{-1} under DSR and ₹44,950 ha^{-1} under manual transplanting; corresponding benefit:cost ratios were 2.2, 1.9 and 1.7. RNR 15048 out-yielded HMT Sona under all three establishment methods, with pooled yields of 6498, 6150 and 5802 kg ha^{-1} under machine, DSR and manual establishment, respectively, compared with 6075, 5913 and 5625 kg ha^{-1} for HMT Sona. The observations indicate that machine transplanting was the most productive and profitable option in these on-farm comparisons, whereas puddled DSR also performed better than manual transplanting in yield and reported net returns.

KEYWORDS: *Oryza sativa;* machine transplanting; direct seeding; manual transplanting; yield; farm economics

INTRODUCTION

Rice (Oryza sativa L.) production systems are under increasing pressure to sustain grain output while managing labour availability, water resources and rising cultivation costs. Crop establishment is a major component of rice production because it determines early crop stand, spatial arrangement, weed competition and the timing and cost of field operations. In many irrigated rice areas, puddled transplanting remains common, but the labour-intensive nature of manual transplanting has encouraged the evaluation of mechanical transplanting and direct-seeding alternatives.

Mechanical transplanting can improve the regularity of plant placement and reduce dependence on manual labour when suitable mat type nurseries, well levelled puddled fields and properly adjusted transplanters are available. Its performance, however, depends on nursery quality, seedling age, field preparation, machine settings and the timeliness of operation (Haripriya *et al.,* 2025; Kumar *et al.,* 2026). Recent work from Indian rice-growing regions has reported economic and productivity benefits from small-scale mechanical transplanters, although the magnitude of the response varies with production environment and implementation conditions (Kiran Kumar *et al.,* 2024; Vijay *et al.,* 2024).

Direct seeded rice (DSR) avoids the separate nursery raising and transplanting operations and can reduce labour demand. Nevertheless, crop establishment under DSR is sensitive to seed placement, weed pressure, water management and early season nutrient availability (Padma *et al.,* 2023; Chowdhury *et al.,* 2025). Evidence from India shows that the yield and income effects of DSR are not uniform across locations, reinforcing the need to evaluate the technology under local agroecological and management conditions (Dey *et al.,* 2024; Dey *et al.,* 2025). A recent studies of rice mechanization in India similarly emphasizes that machinery performance must be considered alongside field conditions, operational constraints and the capacity of farmers to manage the associated production system (Guru *et al.,* 2025).

In Telangana, farmers require locally generated comparisons of alternative establishment methods under their prevailing puddled rice production conditions. On farm evaluations across multiple farmers' fields can provide

practical evidence on the performance of establishment options beyond that obtained from a single site research study. The present study therefore compared machine transplanting, direct wet seeding in puddled soil and manual transplanting over three rabi seasons at 15 locations in Bhadradri Kothagudem district. The evaluation also documented the performance of two rice varieties, RNR 15048 and HMT Sona, under each establishment method, with emphasis on grain yield, selected crop stand attributes and farm economics.

MATERIAL AND METHODS

Study location and seasons

The on-farm evaluation was conducted during the rabi seasons of 2018–19, 2019–20 and 2020–21 at 15 farmers' field locations in the adopted villages of Krishi Vigyan Kendra (KVK), Garimellapadu, Bhadradri Kothagudem district, Telangana, India. The study area is located between North Latitude 17°29'31.1" and East Longitude 81°07'28.8" and encompasses the central Telangana zone, specifically focusing on the oil palm growing soils in the area. This region experiences a semi-arid monsoon climate characterized by distinct rainy, winter, and summer seasons. The average annual precipitation is 1191 mm, with approximately 74 percent of this rainfall occurring during the peak southwest monsoon period, which extends from mid-June to mid-September. Temperature extremes in the research area range from as high as 39.3°C to as low as 18.3°C. Main irrigation sources of rice cultivationg areas were bore wells and ponds. The most significant soil groups of the region are: red loamy soils (Alfisols), black cotton soils (Vertisols) and alluvial soils (Entisols/Inceptisols).

Treatments and crop establishment

Three establishment methods were compared: (T_1) machine transplanting; (T_2) direct seeding of rice in puddled soil (puddled DSR); and (T_3) manual transplanting. The source dataset reports a machine transplanted spacing of 30 × 12 cm, a DSR spacing of approximately 20 × 5–8 cm and variable spacing under manual transplanting. The recorded number of plants per hill was five under machine transplanting, 2–3 under DSR (variable) and 1–3 under manual transplanting (variable). The variety wise dataset included RNR 15048 and HMT Sona.

Data collection and economic analysis

The annual grain yields and net returns for RNR 15048, pooled mean yield attributes for the three establishment methods, an operation-wise cost summary, and year-wise and pooled yield and economic observations for RNR 15048 and HMT Sona were recorded. Grain yield is expressed in kg ha^{-1} and economic values in Indian rupees per hectare (₹ ha^{-1}). Benefit:cost ratios are reproduced as reported in the source. The percentage yield advantage of a treatment over manual transplanting was calculated as [(treatment yield − manual-transplanting yield)/manual-transplanting yield] × 100.

RESULTS

Grain yield across establishment methods

Machine transplanting recorded the highest pooled grain yield of 6498 kg ha^{-1}, followed by puddled DSR (6150 kg ha^{-1}) and manual transplanting (5802 kg ha^{-1}) (Table 1; Figure 1). Relative to manual transplanting, machine transplanting produced an additional 696 kg ha^{-1}, equivalent to a 12.0% increase. Puddled DSR produced 348 kg ha^{-1} more grain than manual transplanting, a 6.0% increase. Machine transplanting also exceeded puddled DSR by 348 kg ha−1 (5.7%).

Table 1. Year wise grain yield of RNR 15048 under different rice establishment methods.

Season	Machine transplanting (Kg ha^{-1})	Puddled DSR (Kg ha^{-1})	Manual transplanting (Kg ha^{-1})
2018–19	6,750	6,375	5,802
2019–20	6,930	6,440	6,180
2020–21	5,815	5,636	5,424
Three year mean	6,498	6,150	5,802

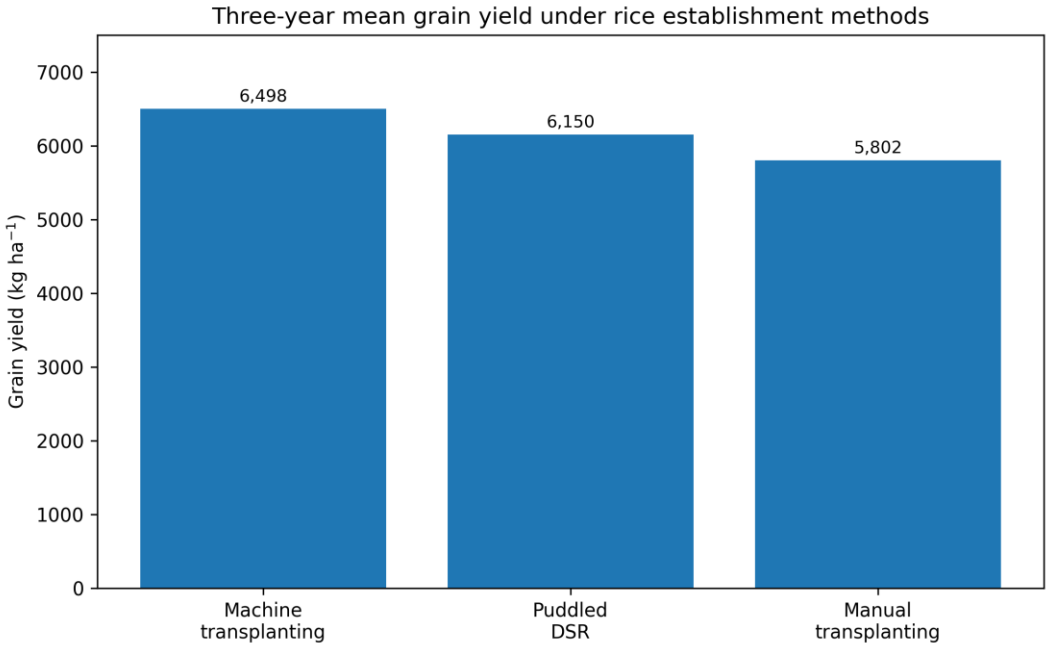

Figure 1. Three-year mean grain yield of RNR 15048 under machine transplanting, puddled direct seeding and manual transplanting.

The year-wise data showed that machine transplanting ranked first in each of the three seasons. Yields under machine transplanting were 6750, 6930 and 5815 kg ha^{-1} in 2018–19, 2019–20 and 2020–21, respectively. Corresponding yields under puddled DSR were 6375, 6440 and 5636 kg ha^{-1}, while manual transplanting recorded 5802, 6180 and 5424 kg ha^{-1} (Figure 3). The relative ranking of establishment methods was therefore consistent across the reported seasons, although yields were lower in 2020–21 than in the preceding two seasons.

Yield attributes and crop geometry

The recorded observations showed 32 tillers hill−1 under machine transplanting, compared with 24 under puddled DSR and 18 under manual transplanting. In contrast, the number of hills m^{-2} was highest under DSR (31), followed by machine transplanting (28) and manual transplanting (22) (Table 2). The greater tiller count per hill under machine transplanting should be interpreted alongside the different hill densities and plant numbers per hill. Because productive tillers, panicle number per unit area and grain number per panicle were not reported, the contribution of individual yield components to final grain yield cannot be resolved from these data.

Table 2. Reported crop geometry and yield attributes under the three establishment methods.

Parameter	Machine transplanting	Puddled DSR	Manual transplanting
Tillers hill^{-1}	32	24	18
Hills m^{-2}	28	31	22
Spacing	30 × 12 cm	20 × 5–8 cm	Variable
Plants hill^{-1}	5	2–3 (variable)	1–3 (variable)

Cost of cultivation and profitability

The operation-wise cost summary reported total cultivation costs of ₹53,978 ha^{-1} for machine transplanting, ₹57,505 ha^{-1} for puddled DSR and ₹59,486 ha^{-1} for manual transplanting (Table 3). Machine transplanting therefore had the lowest reported total cost, despite the recorded expenditure on nursery and transplanting operations. The pooled net returns were ₹63,961 ha^{-1} under machine transplanting, ₹55,118 ha^{-1} under puddled DSR and ₹44,950 ha^{-1} under manual transplanting. The respective benefit:cost ratios were 2.2, 1.9 and 1.7 (Figure 2).The three-season mean of annual DSR net returns value ₹55,118 ha^{-1} and a gross return of ₹111,623 ha$^{-1.}$

Table 3. Operation-wise cost of cultivation and reported economic indicators (₹ ha^{-1}).

Cost component / indicator	Machine transplanting	Puddled DSR	Manual transplanting
Seed and nursery	2,350	750	1,350
Field preparation	12,500	15,500	13,500
Transplanting / seeding	8,750	2,750	8,750

Fertilizers	9,478	10,505	9,400
Weeding / herbicides	4,500	8,500	6,600
Pest and disease control	10,400	13,500	13,886
Harvesting	6,000	6,000	6,000
Total cost	53,978	57,505	59,486
Mean grain yield (kg ha−1)	6,498	6,150	5,802
Mean net returns	63,961	55,118	44,950
Benefit:cost ratio	2.2	1.9	1.7

Within the cost components, field preparation was ₹12,500, ₹15,500 and ₹13,500 ha^{-1} for machine transplanting, DSR and manual transplanting, respectively. Expenditure on weeding/herbicides was highest under DSR (₹8,500 ha^{-1}), compared with ₹4,500 ha^{-1} under machine transplanting and ₹6,600 ha^{-1} under manual transplanting. Pest and disease control costs were reported as ₹10,400, ₹13,500 and ₹13,886 ha^{-1}, respectively. These results showed that the overall economic advantage of machine transplanting was associated with the combination of higher yield and lower total cultivation cost (Tamilarasu *et al.,* 2026).

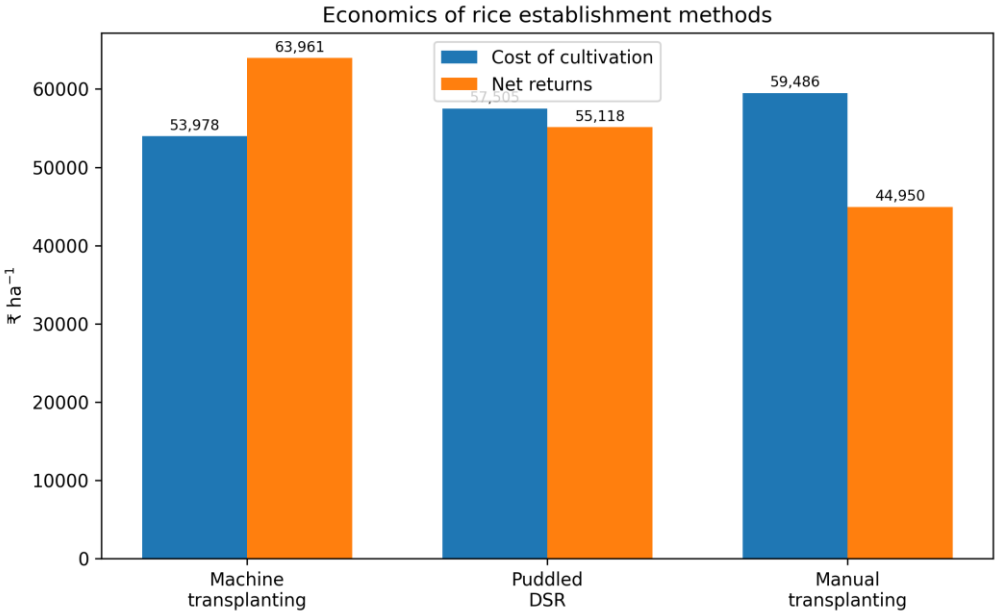

Figure 2. Cost of cultivation and pooled net returns under the three rice establishment methods.

Varietal performance under establishment methods

RNR 15048 out yielded HMT Sona under all three establishment methods in each season represented in the table 4. Pooled yields of RNR 15048 were 6498 kg ha^{-1} under machine transplanting, 6150 kg ha^{-1} under puddled DSR and 5802 kg ha^{-1} under manual transplanting. The corresponding yields of HMT Sona were 6075, 5913 and 5625 kg ha^{-1}. The yield advantage of RNR 15048 over HMT Sona was 423 kg ha^{-1} (7.0%) under machine transplanting, 237 kg ha^{-1} (4.0%) under DSR and 177 kg ha^{-1} (3.1%) under manual transplanting. The pooled net returns for HMT Sona were ₹56,822 ha^{-1} under machine transplanting, ₹52,761 ha^{-1} under DSR and ₹43,396 ha^{-1} under manual transplanting, compared with ₹63,961, ₹55,118 and ₹44,950 ha^{-1}, respectively, for RNR 15048. The reported benefit:cost ratios were 2.0, 1.8 and 1.6 for HMT Sona, and 2.2, 1.9 and 1.7 for RNR 15048. Thus, RNR 15048 maintained the higher reported yield and profitability across the three establishment methods.

Table 4. Grain yield and economics of RNR 15048 and HMT Sona under different establishment methods (three-year pooled values).

Establishment method	Variety	Yield (kg ha−1)	Net returns (₹ ha−1)	B:C ratio
Machine transplanting	RNR 15048	6,498	63,961	2.2
Machine transplanting	HMT Sona	6,075	56,822	2.0
Puddled DSR	RNR 15048	6,150	55,118	1.9
Puddled DSR	HMT Sona	5,913	52,761	1.8
Manual transplanting	RNR 15048	5,802	44,950	1.7
Manual transplanting	HMT Sona	5,625	43,396	1.6

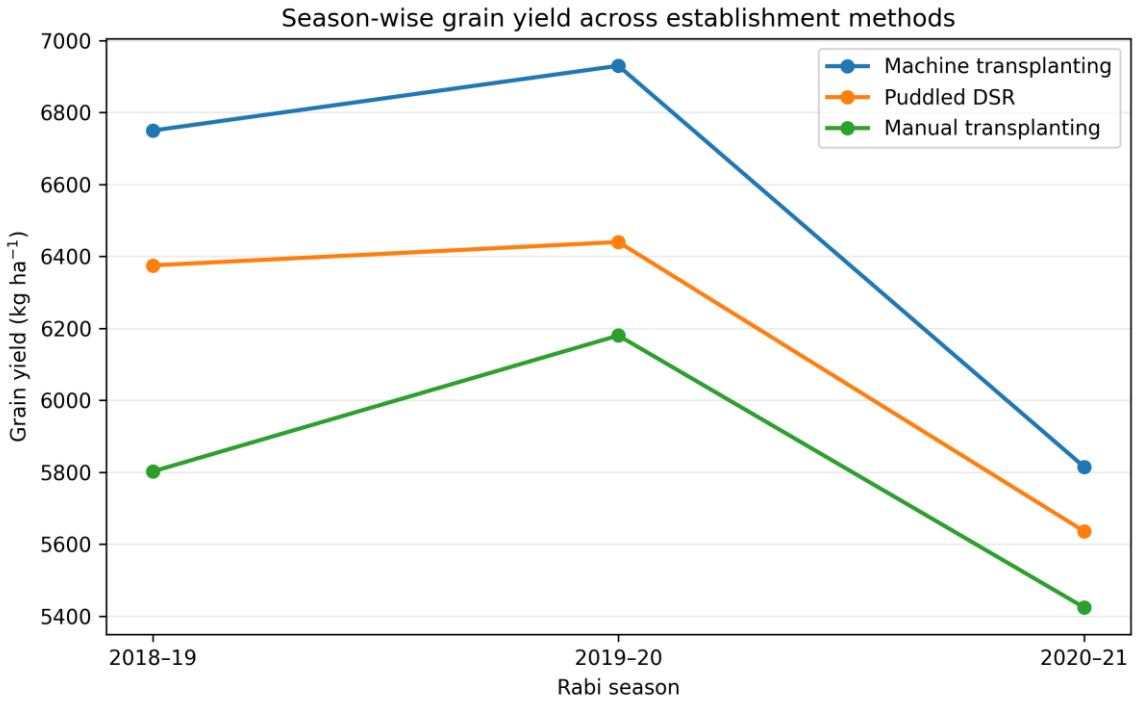

Figure 3. Season-wise grain yield of RNR 15048 under the three establishment methods during rabi 2018–19 to 2020–21.

DISCUSSION

The three season field records consistently favoured machine transplanting for grain yield, with a pooled advantage of 12.0% over manual transplanting. The higher yield under machine transplanting may be associated with more regular hill placement and a greater number of tillers per hill, as indicated by the available crop stand observations (Mondal *et al.,* 2024; Padma *et al.,* 2023). The higher number of hills per square metre under DSR did not translate into a yield greater than machine transplanting in the present comparison. This illustrates that plant density alone is insufficient to explain yield differences; uniform emergence, seedling survival, weed competition, tiller productivity and water management can influence the conversion of crop stand into grain yield. DSR performance differing among regions and management systems (Dey *et al.,* 2024; Dey *et al.,* 2025).

The economic comparison strengthens the case for machine transplanting under the different conditions rand methods. The reported cultivation cost was lower under machine transplanting than under either DSR or manual transplanting, while the higher yield was accompanied by the highest net return and benefit:cost ratio.

The findings are consistent in direction with recent Indian studies that have reported improved profitability or labour related advantages from mechanical transplanting rice (Kiran Kumar *et al.,* 2024; Vijay *et al.,* 2024). At the same time, adoption depends on access to transplanters, mat nursery skills, field levelling and timely operation. A recent synthesis of Indian rice mechanization has emphasized the importance of operational readiness and machinery suitability, rather than treating mechanization as a stand-alone intervention (Guru *et al.,* 2025).

RNR 15048 recorded higher pooled yield and net returns than HMT Sona across all establishment methods. The yield advantage was largest under machine transplanting (7.0%) and narrowed under DSR (4.0%) and manual transplanting (3.1%).

CONCLUSION

Across the three rabi seasons and 15 reported on-farm locations in Bhadradri Kothagudem district, machine transplanting recorded the highest pooled grain yield (6498 kg ha−1), net returns (₹63,961 ha−1) and benefit:cost ratio (2.2) among the three rice establishment methods. Puddled DSR was intermediate, while manual transplanting recorded the lowest pooled yield and profitability. RNR 15048 out yielded HMT Sona under all three establishment methods. These results identify machine transplanting as a promising option for the production conditions represented in this evaluation, provided suitable nursery and field-management arrangements are available.

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