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# Water Productivity, Economic Viability and Yield of Rice under Different Rice Establishment Methods

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## Abstract

A field experiment was conducted during the *kharif* (2013) at Tamil Nadu Rice Research Institute (TRRI), Aduthurai to evaluate the productivity and input usage of different rice establishment methods *viz*., wet direct seeding using drum seeder, dry direct seeding using tractor operated seed drill, and conventional transplanting. Data reveal that dry seeding using a tractor drawn seed drill utilized a lower seed rate of 30 kg/ha compared to wet seeding (37.5 kg/ha) and transplanted rice (60 kg/ha). The plant height and plant population did not exhibit significant variations across the different establishment methods. However, yield attributes like ear bearing tillers (396/m$^2$) and filled grains (137/panicle) were significantly higher in transplanted rice. Nonetheless, dry seeded rice recorded a grain yield of 6040 kg/ha which was only 5.5% lower than that of transplanted rice. Notably, dry seeding conserved 32.6% of irrigation water and reduced labour requirement by 48.9% compared to transplanted rice. Moreover, dry seeded rice exhibited higher water productivity (6.40 kg/ha/mm) and a higher benefit cost ratio (2.66) as compared to other establishment methods. Therefore, considering the existing water crisis and labour shortage, the adoption of dry seeding for rice cultivation holds promise as a viable solution for farmers. This method not only addresses the challenges posed by limited water availability and the scarcity of labour but also maintains satisfactory levels of productivity.

**Keywords:** Dry seeded rice, wet seeded rice, transplanted rice, productivity, input use, economics

## Introduction

The Cauvery delta region often referred to as the "Rice bowl of South India" is renowned for its extensive rice cultivation. However, rice production in this region faces several challenges, including water scarcity, labour shortage and rising labour costs (Surendran *et al.,* 2021). Furthermore, the impact of climate change exacerbates the water availability issues for irrigated agriculture, particularly in rice cultivation (Vijayakumar *et al*., 2021). In the Cauvery Delta Zone, the cultivation of *kharif* rice (May/June to September/October) heavily Threlies on irrigation from the Cauvery river water supplied by the Mettur Dam, groundwater sources, and supplemented by rainfall during South West monsoon. Unfortunately, there has been a rise in the occurrence of problems such as failure of monsoon rains in catchment areas, uncertainties surrounding the release of canal water and untimely water supply in the past decade. These prevailing challenges have led farmers in the region to seek alternate rice establishment methods that require less input and lower cultivation costs (Subramanian *et al*., 2021).

The alternate rice establishment methods are crucial to address various challenges and enhance the efficiency of rice cultivation. Transplanting rice is known to be labour-intensive, and the scarcity of skilled laborers represents a significant constraint (Vijayakumar *et al*., 2018). By embracing alternate approaches such as drip irrigation, direct seeding or dry seeding, the reliance on manual labour can be reduced significantly (Subramanian *et al*., 2023). Moreover, these methods offer advantages such as time savings, cost reduction, and enhanced water management, thereby promoting the economic viability and environmental sustainability of rice production (Vijayakumar *et al*., 2022). Furthermore, alternate establishment methods provide the flexibility to adapt to evolving climate conditions and help overcome the limitations associated with traditional transplanting practices. Consequently, their implementation is deemed essential for augmenting the overall productivity and resilience of rice production systems (Mallareddy *et al*., 2023).

Dry seeded rice (DSR) has emerged as an attractive option for farmers to mitigate water scarcity and eliminate the labour-intensive processes such as nursery preparation and maintenance, pulling out and transport of seedlings to main field, and transplanting (Yadav *et al*., 2014). DSR, with its lower water requirement for crop establishment due to absence of puddling, offers a potential solution. Direct seeding of rice during the *kharif* season in the Cauvery Delta Zone holds promise in ensuring a timely harvest before the onset of the monsoon. This method allows rice to be advanced by 7-10 days, as it eliminates the transplanting methods. However, with the declining water availability for rice cultivation and the increasing demand for rice, it is crucial to thoroughly study the advantages and disadvantages of DSR and promote its adoption among rice growers (Vijayakumar *et al*., 2019). Therefore, this field experiment aims to critically evaluate various rice establishment methods in the Cauvery Delta Zone and propose new approaches to address these challenges effectively.

## Material and Methods

A field experiment was conducted during the *kharif* season (June-September) at Tamil Nadu Rice Research Institute (TRRI), Aduthurai, located in the Cauvery Delta Zone of Tamil Nadu, India. The geographical coordinates of the institute are 11$^{o}$ N and latitude 79.3$^{o}$ E longitude with an altitude of 19.4 m above MSL. The experimental field had alluvial clay soil with a pH of 7.7 and an electrical conductivity (EC) of 0.3 dS/m. The available nitrogen, phosphorus, and potassium contents of the soil were medium, high, and low, respectively. The experiment field was ploughed twice using a cultivator, followed by a rotovator to create a suitable seedbed for the rice crop. The experiment was laid out in a Randomized Block Design with seven replications. The treatments consisted of three rice establishment methods *viz.,* dry seeding, wet seeding and conventional transplanted rice. In the transplanted rice treatment, 22 days old seedlings were planted at a spacing of 20 x 10 cm in puddled and levelled field. The variety ADT 45 was used in this experiment.

A pre-emergence application of butachlor at a rate of 1 kg a.i/ha was applied three days after transplanting (DAT). For the dry seeding method, a tractor drawn seed drill was used to sow the seeds in well prepared dry soil. Irrigation was immediately provided after sowing, and a pre-emergence application of pendimethalin @ 1 kg a.i/ha was sprayed on the 3$^{rd}$day after sowing (DAS). In the wet seeding method, the field was first puddle and then levelled, followed by seeding using a drum seeder. A pre-emergence application of Pretilachlorat a rate of 0.45 kg a.i/ha was applied at 5 DAS. Irrigation was applied to a depth of 5 cm after the disappearance of ponded water. Gap filling and thinning was done on 20 DAS in both wet and dry direct seeding. A recommended dose of fertilizer at 150:50:50 kg NPK/ha was applied in all the establishment methods. Nitrogen at 150 kg/ha through urea and K through Muriate of potash were applied in 4 equal splits from basal, active tillering, panicle initiation and heading stages in the transplanted rice method. Whereas, in wet and dry direct seeded rice, the N and K was given in 4 splits from 14 DAS, active tillering, panicle initiation and heading stages.

Various observations were recorded, including plant population, plant height and yield parameters such as ear bearing tillers, filled grains per panicle, as well as grain and straw yield. Labour used for various operations *viz.,* land preparation, sowing, nursery management, thinning and gap filling, transplanting, irrigation and weeding were recorded for different production systems. Similarly, seed rate used for different cropping system is also noted. The quantity of irrigation water applied to each crop establishment method was recorded using a water meter installed at the delivery point of every plot. The rainfall received during the cropping season (459.6 mm) was measured using an automatic rain gauge installed near the experimental field. Water productivity was worked out by dividing the grain yield by the total water used for the crop. Economic analysis was worked out based on the prevailing market price and net return was calculated by deducting the costs of cultivation from the gross return. The benefit cost ratio (BCR) was worked out by dividing the gross returns (Rs/ha) by the cost of cultivation (Rs/ha).

To determine if there were significant differences between the treatments, the data obtained from the study were analyzed statistically using the procedures suggested by Gomez and Gomez (1984). Significant differences between treatments were determined using critical differences calculated at a five per cent probability level.

## Results and Discussion

### Growth and yield parameters

Plant height and plant population did not show significant variation among the different rice establishment methods. However, transplanted rice exhibited slightly higher values compared to other methods. The better distribution of rainfall, amounting 459.6 mm, throughout the cropping period may have contributed to the similar growth of rice under different establishment methods. On the other hand, transplanted rice demonstrated significantly higher yield attributes such as ear bearing tillers (396/$m^2$) and filled grains per panicle (137/panicle), in comparison to wet seeding (**Table 1**). While dry direct seeded rice recorded the lowest number of productive tillers (368/$m^2$) and filled grains (123 grains/panicle) and it remained statistically at par with wet direct seeding method. The practice of transplanting rice seedlings in puddled soil condition might have favoured better nutrient availability and uptake, leading to increased photosynthesis, improved source-sink relationship (Midya *et al.,* 2021) and ultimately higher yield attributes. Furthermore, flooding the rice fields after successful establishment can alleviate nutrient deficiencies such as Fe and Zn and control soil-borne diseases (ex. nematodes) and weeds, thereby promoting better performance of rice crop (Kumar and Ladha, 2011).

### Grain yield and water productivity

Transplanted rice exhibited significantly higher grain yield (6391 kg/ha) and straw yield (11100 kg/ha) compared to wet seeded rice, but it showed comparable yield with dry direct seeded rice (**Table 1**). The grain yield of dry seeded rice was 6040 kg/ha, which was 5.5% lower than that of transplanted rice. This reduction can be attributed to the reduced availability of soil nutrients, particularly N, Fe, and Zn in direct seeded rice (Kumar and Ladha, 2011). Similarly, wet seeded rice registered 8.2% less grain yield than transplanted rice. Contrary to our finding, Singh *et al*., (2005) reported that, in North India, direct seeded rice produced comparable grain yield and higher net profit compared to transplanted rice.

In terms of water productivity (WP), dry seeded rice exhibited the highest value (6.40 kg/ha/mm), followed by transplanted rice (5.42 kg/ha/mm) and wet seeded rice (5.39 kg/ha/mm). The higher water productivity of dry seeded rice can be attributed to its minimal water usage combined with higher grain yield. Research by Soriano *et al.,* (2018) also reported significantly higher WP in dry direct seeded rice compared to transplanted-flooded rice.

**Table 1: Growth and yield parameters and grain yield of rice under different rice establishment methods**

| Rice establishment methods | Plant height (cm) | Plant population (No./m²) | Productive tillers (No./m²) | Filled grains (No./Panicle) | Grain yield (kg/ha) | Straw yield (kg/ha) |
|---|---|---|---|---|---|---|
| **Transplanted rice** | 102.7 | 48.3 | 396 | 137 | 6391 | 11100 |
| **Wet seeded rice** | 99.7 | 46.6 | 356 | 126 | 5932 | 9560 |
| **Dry seeded rice** | 100.2 | 48.0 | 368 | 123 | 6040 | 10508 |
| **CD (P=0.05)** | NS | NS | 30.7 | 8.4 | 354.6 | 854 |

### Inputs saving

Among the different methods of rice cultivations, dry seeding demonstrated superiority in terms of input saving compared to other methods. The use of a tractor drawn seed drill in dry seeding allowed for a lower seed rate of 30 kg/ha, whereas wet seeding required 37.5 kg/ha and transplanted rice necessitated 60 kg/ha (**Table 2**). Dry seeded rice also required the minimum irrigation water, utilizing 485 mm, followed by wet seeding with 641 mm, and transplanted rice with 720 mm. In terms of total water usage, transplanted rice utilized the highest amount of water (1179.6 mm), followed by wet seeding (1100.6 mm) and dry seeding (944.6 mm). Dry seeded rice registered a significant irrigation water saving (32.6%) as compared to transplanted rice. With respect to labour requirements, it was found that dry seeding require less labour (60 man-days/ha), followed by wet seeding (90 man-days/ha) and transplanted rice (117.5 man-days/ha). Dry seeded rice resulted in a substantial labour saving (48.9%) compared to transplanted rice. Within the direct seeding methods, dry seeding showed superiority in terms of seed, water and labour saving over wet seeding. DSR has been shown to reduce total labour requirements by 11% to 66%, depending on the season, location, and type of DSR, when compared with transplanted rice. It also saved 35–57% water compared to continuously flooded rice (Sharma *et al*., 2002).

**Table 2: Seed rate, water use, water productivity, labour use and economics of rice under different rice establishment methods**

| Particulars | Transplanted rice | Wet seeded rice | Dry seeded rice |
|---|---|---|---|
| **Seed rate (kg/ha)** | 60 | 37.5 | 30 |
| **Irrigation quantity (mm)** | 720 | 641 | 485 |
| **Irrigation water saving (%)** | - | 11.0 | 32.6 |
| **Total water used (mm)** | 1179.6 | 1100.6 | 944.6 |
| **Water productivity (kg/ha/mm)** | 5.42 | 5.39 | 6.40 |
| **Labour use (man days/ha)** | 117.5 | 90 | 60 |
| **Labour saving (%)** | - | 23.4 | 48.9 |
| **Cost of cultivation (Rs./ha)** | 38000 | 35645 | 33485 |
| **Net returns (Rs./ha)** | 56183 | 51031 | 55543 |
| **Benefit cost ratio** | 2.48 | 2.43 | 2.66 |

**Note:** Rainfall during cropping period: 459.6 mm

**Economics**

Transplanted rice incurred a higher cost of cultivation (Rs. 38000 /ha) but also resulted in higher net returns (Rs. 56183/ha) compared to direct seeding method (**Table 2**). The increased cost of cultivation in transplanted rice was primarily due to higher input and labour usage. On the other hand, dry seeded rice exhibited a lower cost of cultivation (Rs. 33485/ha) and a higher benefit cost ratio (2.66) compared to the other methods. The use of fewer inputs and reduced labour under dry seeding contributed to the higher benefit cost ratio. Direct seeding of rice offers several advantages, including labour savings, ease of operation, reduced drudgery, early crop maturity (7–10 days), lower water requirements, higher tolerance to water deficit, higher yield, low production cost, increased profitability, improved soil physical conditions for subsequent crops and reduced methane emission (Kumar and Ladha, 2011).

## Conclusion

Based on the findings of this field experiment and taking into account the current challenges of water and labour scarcity in the Cauvery Delta Zone, it can be concluded that dry direct seeding of rice using a tractor drawn seed drill, can be considered as an alternative rice establishment method to replace the existing practice of transplanted rice during the *kharif* season. Dry seeding offers several advantages in terms of input savings, reduced water requirements, lower labour demands, and similar grain yield compared to transplanted rice. Implementing dry direct seeding as an alternative method can help farmers overcome the challenges posed by water and labour availability while maintaining productivity levels. It is important to provide proper training and extension services to farmers to ensure the successful adoption of this method.

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