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Enhancing rice production economics with self-propelled rice transplanters

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Abstract
Rice cultivation is critical for food security in Asian countries, necessitating efficient farming practices. In India, rice cultivation covers 44 million hectares, yielding 90 million tonnes annually with a productivity rate of 2.0 tonnes per hectare. To sustain food self-sufficiency, India aims for a 3% annual productivity increase. Manual transplanting of rice seedlings is labour-intensive and affects yield significantly. Timely transplanting is crucial, as delays can reduce yield by up to 70%. Mechanization of transplanting is essential for cost-effectiveness and increased productivity. Odisha, with over 4 million hectares of rice cultivation, faces labour scarcity during peak seasons, hindering timely transplanting. In order to tackle this issue, a demonstration was conducted using self-propelled riding-type rice transplanters with eight rows, resulting in increased profitability and productivity. The adoption of mechanized transplanting has shown a 6.0% increase in yield compared to manual transplanting. This study evaluates the performance and economics of these transplanters, demonstrating their potential for wider adoption and improved rice cultivation practices in Odisha.

Keywords: Transplanting, eight-row transplanter, mat type seedlings, cost economics

Introduction
Rice stands as a cornerstone crop in Asian countries, underscoring the pivotal role of mechanization in rice farming to enhance productivity and labour efficiency. In India, the cultivation of rice spans 44 million hectares, yielding an average of 90 million tonnes annually, with a productivity rate of 2.0 tonnes per hectare (Anonymous, 2003) [1]. To maintain its current food self-sufficiency and meet future food demands, India must achieve an annual productivity increase of 3 percent (Thiyagarajan and Selvaraju, 2001) [4]. Essential farm operations in transplanted paddy cultivation encompass land preparation, nursery management, transplanting, interculture, harvesting, and threshing. Among these, the transplanting operation emerges as a critical factor influencing potential yield, necessitating substantial agricultural labour. A delay in transplanting of one month reduced the yield by 25% and delay of two months reduced the yield by 70% (Rao and Pradhan, 1973) [3]. Consequently, achieving cost-effective mechanization in the transplanting process becomes paramount. Odisha has a total of 4 million hectares of land used for rice agriculture, with 1.66 million hectares specifically allocated for transplanted paddy and 2.24 million hectares for broadcasted paddy. Prior to transplantation, seedlings of enhanced cultivars are cultivated for a period of 20-25 days in specialized nurseries. Transplanting is typically done manually by hired female labourers, who uproot seedlings and transplant them randomly without maintaining row or plant spacing. The laborious nature of this operation stems from the labourers' semi-flexed stance, as they meticulously plant 2-3 seedlings per hill in saturated soil at a depth ranging from 30 to 50 millimetres. A single worker can transplant only 0.016 hectares per day on average, inserting their fingers approximately 350,000 times per hectare (Swain, 1997) [2]. This procedure, which requires a lot of manual work, leads to a low number of plants per area and thus poorer crop production. Labour shortage during peak seasons hampers the timely transplantation process, resulting in reduced crop output.

According to Mohanty *et al*. (2010) [5], the process of manually transplanting paddy involves around 300-350 man-hours per hectare, which accounts for approximately 25% of the overall labour needed for rice cultivation. The use of weeders for mechanical weeding is impractical because of the haphazard arrangement of seedlings after hand transplantation. While hand transplanting necessitates fewer seeds, it entails a substantial increase in labour and extends the crop's maturation period. Implementing advanced techniques, such as utilizing mat-type nurseries, not only lessens the number of seeds needed but also reduces the need for labour and land, in contrast to conventional approaches. Planting in parallel rows also enables mechanical weed control and fertilizer distribution. In order to take advantage of these advantages and enhance labour productivity, OUAT, Bhubaneswar, organized front-line demonstrations of eight-row self-propelled riding-type rice transplanters. The use of affordable and energy-efficient eight-row riding-type self-propelled rice transplanters has guaranteed prompt transplantation and enabled mechanical weeding with a cono weeder, ultimately leading to reduced cultivation expenses in comparison to conventional transplanting methods. Furthermore, mechanical paddy transplanting by self-propelled transplanter has ensured proper crop stand and has given 6.0% increased yield compared to hand transplanting (Dixit and Khan, 2011) [6]. The mechanized transplanting method helped farmers increase profitability and productivity in the region.

Hence, the objective of this study was to assess the efficiency of rice transplanters, analyse the economic aspects of rice production in farmers' fields, and collect comments on the performance of the transplanters to consider possible adjustments and broader implementation.

Materials and Methods

Extensive field demonstrations of 8-row self-propelled rice transplanters were carried out by the Department of Farm Machinery and Power Engineering, OUAT, Bhubaneswar. These demonstrations took place in villages located in the districts of Khurda, Puri, Balasore, Cuttack, Bhadrak, and Sonepur within the state of Odisha. These protests occurred over a cumulative expanse of 296 hectares from 2004 to 2023. Additionally, the machine was displayed in the Hirakud command area of Odisha, encompassing a total area of 168 hectares, between 2008 and 2023.

Salient features of the machine

The machine is a riding-type implement with a single wheel and 8 rows. The front wheel is powered by a 2.94 kW single-cylinder, air-cooled diesel engine. The transfer of power to the drive wheel occurs via a V-belt, cone clutch, and gearbox. The gearbox is connected to the transplanting mechanism on the float with a propeller shaft, which transfers power. The float facilitates the seamless movement of the transplanter across the compacted surface. The transplanter is equipped with a tray that can house mat-type nursery with 8 rows. The lateral movement of tray is controlled by scroll shaft mechanism. By combining a belt-pulley system, gearing, and a universal joint shaft, this mechanism converts the rotational motion transmitted by the engine into a linear motion of a rod that is attached to the seedling container. A further feature is an automatic reversal mechanism that changes the trajectory of the tray's movement once it reaches its final position. The planting fingers, comprising lever mechanisms that remain stationary prongs, are regulated by a four-bar linkage system in order to achieve the desired position at the planting finger's tip. An independent crankshaft and connecting rod system, which incorporates a seedling cultivator, initiates the sowing mechanism. As a result, the machine is capable of performing a single operation to transplant seedlings from the mat-type nursery in eight rows. Effective field capacity of the machine fluctuates between 0.14 and 0.20 hectares per hour. The transplanter's comprehensive specifications are detailed in Table 1.

Table 1: Technical details of self-propelled 8-row rice transplanter (Riding type)

Sl. No.	Particulars	
1.	Overall dimensions (l x b x h), m	2.40 x 2.30 x 1.20
2.	Power source	Engineered with a single-cylinder air-cooled diesel engine producing 2.94 kW
3.	Weight, kg	305
4.	Rated width, m	1.9
5.	Number of rows	8
6.	Row spacing, mm	238
7.	Distance between hills in a row, mm	120-170
8.	Drive system	Distinct crank shaft and connecting rod arrangement with a pusher for seedlings

Assessment of self-propelled rice transplanter

The seedlings were grown in the field on polyethylene sheets using a pre-made frame of the appropriate tray dimensions. The germinated seeds were uniformly dispersed over the prepared soil mats and then covered with a thin layer of soil. For the development of mat-type seedlings, a seeding rate of 40 kg/ha was utilized, which is in contrast to the 70-80 kg/ha rate used for hand transplantation. The progress of seedling growth was observed in the nursery for a period of 20-22 days, until they reached a stage when they were ready to be mechanically transplanted. At transplanting, seedlings stood at height higher when the transplanting was done manually, with the seedlings being grown directly in the field. A comparative analysis was conducted between a self-propelled, eight-row rice transplanter and the conventional hand transplanting technique employing root-washed seedlings. The amount of standing water during transplanting was below 20 mm.

Analysis of inputs, outputs, and economic efficiency

The use of weedicide effectively minimized weed infestation, leading to a scarcity of weeds in the plot. A single manual weeding operation was performed by hand at 55 days after transplanting (DAT), and no more weeding activities were carried out until harvest. A comparative analysis was conducted to compare the inputs and outputs of traditional manual transplanting (HT) versus mechanical transplanting (MT) utilizing 8-row transplanters. The age of the seedlings was greater in the mechanical transplanting (MT) group compared to the manual transplanting (HT) group. Seedlings in the MT group were cultivated in trays specifically designed for mechanical transplanting, whereas farmers in the HT group utilized traditional seedbeds for manual transplantation. The rice season influenced the variation in rice type, fertilizer rates, cultural practices, and disease infestation. Both approaches utilized the application of micronutrients. Data on the rate of work, overall duration, labour participation, and material inputs were collected in order to calculate production expenses. The cost calculation also included the leasing fee for the equipment. Data on the prices of the agricultural products were gathered from nearby marketplaces in order to determine the overall cost of production, the total revenue generated, the profit margin, and the ratio of benefits to costs.

Results

Self-propelled rice transplanter analysis and the analysis of inputs, outputs, and economic efficiency for traditional manual transplanting (HT) and mechanical transplanting (MT) using 8-row transplanters are presented in the following sections.

Assessment of self-propelled rice transplanter

Using root-washed seedlings, the performance of a self-propelled, eight-row rice transplanter was compared to that of conventional manual transplantation. Throughout the transplanting process, standing water was kept below 0.02 m. With a field capacity of 0.16 ha/h, the transplanter operated at an efficacy of 63%. The transplanter incurred operating expenses of Rs 3800 per hectare, as opposed to Rs 9000 per hectare for manual transplanting; this resulted in a 30-40 kg/hectare reduction in seed requirements. Comprehensive performance information is presented in Table 2.

Table 2: Assessment of the field performance of self-propelled 8 row rice transplanter in field and its comparison with traditional farmer practices

Sl. No.	Parameters	Farmer's practice	Transplanter
1.	Soil type	Clay loam	Sandy loam
2.	Actual area coverage, ha	5	36
3.	Nursery raising method	Root wash	Mat nursery
4.	Operating working width, m	-	1.9
5.	Labour required, man-h/ha	300	36
6.	Operating depth, mm	20-30	20-25
7.	Height of standing water, mm	5	2 – 5
8.	Planting speed, m/s	-	0.44-0.54
9.	Number of seedlings/hills	3 - 6	2-4
10.	Missing hills, %	-	0.5
11.	Effective field capacity, ha/h	0.002	0.14-020
12.	Field efficiency, %	-	63
13.	Fuel consumption, l/h	-	0.7
14.	Operation cost, Rs/h (Rs. /ha)	- (9000)	602 (3770)

Analysis of inputs, outputs, and economic efficiency

The introduction of the machine led to a net cost reduction of Rs. 5200 per hectare for farmers who owned the machine, and roughly Rs. 4610 per hectare for farmers who used bespoke hiring services (Table 3). The average payback period for machine was determined to be 208 hours, indicating that machine owners recovered their initial investment within one year, assuming the unit was used for 200 hours annually. The net return for farmers in machine-transplanted fields was Rs. 38,150 per hectare, but in manually transplanted fields it was Rs. 23,625 per hectare. The better return of Rs. 14,525 per hectare was due to an increase in yield and cost reductions in terms of labour and seed.

Table 3: Rice production economics utilizing a self-propelled rice transplanter

Sl. No.	Parameters	Manual transplanting	Self-propelled transplanter
1.	Requirement of seed, Rs. /Ha (kg/ha)	1125.00 (75)	600.00 (40)
2.	Field preparation cost, Rs. /Ha	3000.00	3000.00
3.	Nursery raising and management cost, Rs. /Ha	775.00	1400.00
4.	Transplanting cost, Rs. /Ha	9000.00	3900.00
5.	Fertilizer application cost, Rs. /Ha	6000.00	6000.00
6.	Insecticides cost, Rs. /Ha	600.00	600.00
7.	Harvesting cost, Rs. /Ha	2500.00	2500.00
8.	Cultivation cost (total), Rs. /Ha	23000.00	18000.00
9.	Productivity, q/ha	47.00	59.00
10.	Total revenue, Rs. /Ha (@ Rs.1000/q)	47,000.00	59,000.00
11.	Net profit, Rs. /Ha	24,000.00	41,000.00
12.	Cost-benefit ratio	2.04	3.30

The greater revenue of Rs. 9,400/ha was a direct outcome of the increase in production achieved through regular spacing and better plant population. The financial advantage of the new technique, based on one machine per hectare per year, was Rs. 4, 64, 800/ha (Table 4).

Table 4: The financial implications of implementing a self-propelled rice transplanter

S. No.	Parameters	Value
1.	Cost reduction compared to traditional methods, Rs. /Ha	5, 125/-
2.	Increased crop output due to consistent spacing and improved plant density, Rs. /Ha	9, 400/-
3.	Total profit, Rs/ha	14, 525/-
4.	Annual machine coverage area	32 ha
5.	Increment in revenue over a year relative to a traditional single-machine system (Rs.)	4, 64, 800/-
6.	Quantity of units in possession of farmers	1000
7.	Total profit, Rs. /Year	465 million

Discussion

Farmers expressed their appreciation for various attributes of the self-propelled rice transplanters including the riding-type seat arrangement, maintenance-free operation, ease of adjustments, high effective field capacity, and cost savings in relation to labour, seedlings, and operating expenses. Women were especially fond of the improved nursery preparation method due to the fact that it reduced the amount of space needed in the nursery and required fewer seedlings. Farmers were transitioning to the method of mat-type seedling cultivation. During the rice transplantation procedure, in the coastal regions of Odisha, where labour is in short supply, the machine is gaining in popularity. Farmers reported that the implementation of self-propelled rice transplanters led to an increase in production ranging from 10% to 12%. This improvement may be ascribed to the consistent number of plants and a more favourable growing environment in crops that were planted in straight lines. Farmers did not notice any significant operational issues following their initial participation instruction on machine operation. Farmers observed that the planting fingers need to be replaced on a yearly basis.

Technology Status

A series of extensive field trials were carried out between 2004 and 2023 in several villages spanning the districts of Khurda, Cuttack, Puri, Bhadrak, Balasore, and Sonepur in the state of Odisha. These trials involved the use of 8-row self-propelled rice transplanters and covered a total area of 296 hectares. In addition, protests were place in the Hirakud command area between 2008 and 2023, including a total area of 168 hectares. Odisha farmers embraced the equipment enthusiastically, purchasing over 609 transplanters in the 2013-14 year. Currently, in Odisha, there are over 8000 self-propelled rice transplanters being used. Farmers are eligible for a subsidy of up to 75% from the state government when purchasing a transplanter.

Conclusion

Based on the evaluation and analysis presented, the adoption of self-propelled rice transplanters has demonstrated several significant advantages over traditional manual transplanting methods. The self-propelled transplanters offer greater efficiency, lower operating costs, and higher yields, leading to increased income for farmers. The technology has been well-received by farmers in Odisha, as evidenced by the widespread adoption and the government subsidy program supporting its purchase. The use of self-propelled transplanters has not only improved agricultural practices but has also addressed labour shortages, particularly in coastal districts. Overall, the adoption of self-propelled rice transplanters has shown to be a viable and beneficial technology for rice cultivation in Odisha, contributing to improved productivity and economic returns for farmers.

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