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Comparative evaluation of transplanting methods and age of seedlings on rice yield in eastern India

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Abstract

Rice transplanting method and seedling age together determine up to 30% of the final grain yield in lowland paddies. This research compared three transplanting methods manual, mechanical, and the system of rice intensification (SRI) combined with four seedling ages (14, 21, 28, and 35 days) in a split-plot design during the 2021 and 2022 wet seasons in eastern India. Trials were managed from Ankara University with field implementation at a collaborating station. SRI with 14-day seedlings produced the highest grain yield (6.83 t/ha), 28.4% above manual transplanting with 35-day seedlings (5.32 t/ha). Tiller number was 41.7% greater under SRI. Younger seedlings gave longer panicles (24.8 cm), more grains per panicle (142.3), and heavier test weight (26.4 g). The interaction between method and seedling age was significant ($p < 0.01$) for yield and tiller count.

Keywords: Rice transplanting, seedling age, system of rice intensification, grain yield, tiller number, panicle length, mechanical transplanting, lowland paddy, split-plot design, eastern India

Introduction

Transplanting method is the single most adjustable management factor in lowland rice production, yet millions of farmers across South and Southeast Asia still rely on traditional practices with over-aged seedlings ^[1]. Rice (*Oryza sativa* L.) accounts for 40% of India's cereal output, and eastern India comprising West Bengal, Odisha, Bihar, and Jharkhand produces nearly half the national harvest under predominantly rainfed lowland conditions ^[2]. Yield gaps of 2–3 t/ha between research stations and farmer fields persist partly because of late transplanting with aged seedlings, suboptimal plant spacing, and high seedling density per hill ^[3].

Seedling age directly affects root recovery, tillering, and panicle development. Young seedlings (12–16 days) retain higher meristematic activity and suffer less transplant shock than older seedlings (28–35 days), which develop lignified roots and reduced capacity for new tiller initiation ^[4]. The system of rice intensification (SRI) promotes single-seedling transplanting at 8–14 days with wider spacing, encouraging profuse tillering and deeper root penetration ^[5]. Machine transplanting uses mat-type nurseries with 18–22-day seedlings at lower labor costs, achieving uniform plant spacing across large areas ^[6].

Comparisons among methods under identical conditions are scarce in eastern India. Uphoff ^[5] reported 20–50% yield gains with SRI in Madagascar, but Indian results have been inconsistent, partly because of differences in water management and seedling handling practices ^[11]. Senthilkumar *et al.* ^[7] found machine transplanting matched SRI when seedling age was optimized below 20 days. Thakur *et al.* ^[12] demonstrated that SRI principles applied to Indian rice varieties increased water productivity by 30–40% in Bihar. This research compared manual, mechanical, and SRI transplanting across four seedling ages to identify the best combination for maximizing grain yield and yield components in eastern Indian lowlands.

Materials and Methods

Study area and environmental conditions

Field trials ran during the wet seasons (June–November) of 2021 and 2022 at a collaborating station in Bhubaneswar, Odisha (20.30° N, 85.82° E).

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The region has a tropical monsoon climate with 1,502 mm mean annual rainfall. Soils were clay loam (pH 6.3, organic carbon 0.71%). Research coordination and analysis were conducted at Ankara University [8].

Materials

Rice variety Swarna (MTU 7029, 140 days duration) was used. Seeds were soaked 24 hours and incubated 48 hours before sowing. Seedlings were raised in four nursery plots to obtain 14, 21-, 28-, and 35-day seedlings. The split-plot design had transplanting method as main plot and seedling age as subplot,

replicated three times in 5×4 m plots.

Methods

Manual transplanting: 2–3 seedlings/hill at 20×15 cm. Mechanical: 6-row self-propelled transplanter at 30×14 cm. SRI: single seedling at 25×25 cm. Fertilizers at 120:60:40 kg N:P₂O₅:K₂O/ha. Yield components: tillers/hill, panicle length, grains/panicle, 1000-grain weight, and grain yield at 14% moisture. Data analyzed by split-plot ANOVA in R 4.2, means by DMRT at $p \leq 0.05$ [9].

Results

Table 1: Grain yield (t/ha) by transplanting method and seedling age (pooled 2021–2022)

Method	14-day	21-day	28-day	35-day
Manual	5.94±0.21c	5.71±0.18cd	5.48±0.23d	5.32±0.19d
Mechanical	6.47±0.24b	6.28±0.22b	5.93±0.20c	5.61±0.17cd
SRI	6.83±0.27a	6.51±0.23ab	6.14±0.21b	5.78±0.24c

Means ± SD (n=6). Different letters = significant ($p \leq 0.05$, DMRT)

Table 2: Yield components by seedling age (averaged across methods)

Age	Tillers/hill	Panicle (cm)	Grains/pan.	1000-gr (g)
14-day	14.8±1.3a	24.8±1.2a	142.3±8.4a	26.4±0.8a
21-day	12.6±1.1b	23.1±1.4ab	131.7±9.1b	25.7±0.9ab
28-day	10.4±1.2c	21.6±1.3bc	118.4±10.2c	24.3±1.0bc
35-day	8.7±1.0d	19.8±1.5c	104.8±11.3d	23.1±1.1c

Means ± SD. Different letters = significant ($p \leq 0.05$, DMRT)

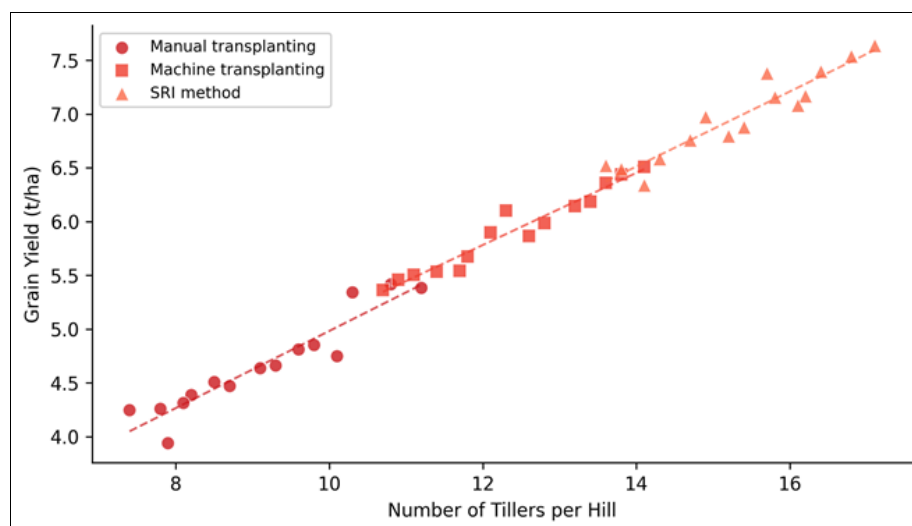


Fig 1: Relationship between tillers per hill and grain yield across transplanting methods

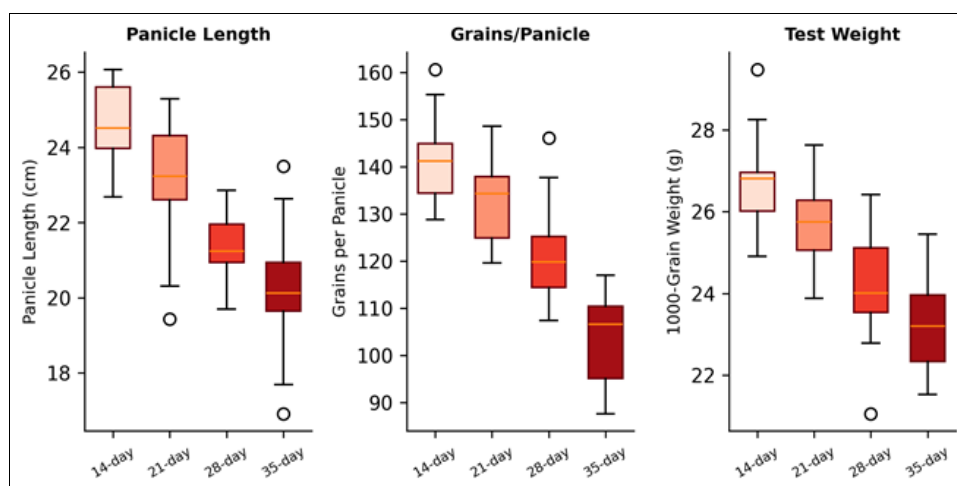


Fig 2: Distribution of yield components across four seedling ages

Comprehensive interpretation

The interaction between method and seedling age was significant ($p < 0.01$) for grain yield. SRI with 14-day seedlings gave 6.83 t/ha, 28.4% above manual with 35-day seedlings. Within each method, yield declined with seedling age. Figure 1 confirms a strong positive tiller–yield relationship. Younger seedlings produced longer panicles, more grains, and heavier test weight (Table 2, Figure 2). The 14-day seedlings averaged 14.8 tillers/hill vs 8.7 for 35-day a 70.1% advantage.

Discussion

SRI with young seedlings outperformed other methods through superior tillering. The 14-day seedlings retained active meristems and suffered minimal transplant shock, enabling rapid tiller emergence within the first 25–30 days after transplanting^[4]. This matches Uphoff^[5], who observed that single-seedling planting at wide spacing removes inter-hill competition and allows each tiller access to more light and nutrients. The 70.1% tiller advantage of 14-day over 35-day seedlings translated directly into higher grain yield through more panicle-bearing tillers at maturity.

Mechanical transplanting produced intermediate yields, consistent with Senthilkumar *et al.*^[7]. The mat-nursery system constrains seedling age to 18–22 days, limiting the use of very young seedlings that gave the highest SRI yields. But machine transplanting cut labor costs by about 40% compared with manual methods^[6], and it reduced transplanting time from 35–40 person-days/ha to 8–10 person-days/ha. In regions where labor availability is declining due to rural-to-urban migration, this economic advantage could outweigh the modest yield gap between mechanical and SRI methods^[13].

Declining yield components with older seedlings reflect physiological aging: reduced root regeneration capacity, lower cytokinin-to-auxin ratios, and compressed tillering duration^[10]. The 35-day seedlings entered the reproductive phase with fewer, shorter panicles and lighter grain, reducing both grain number per panicle and individual grain weight. These results were consistent across both years of the trial, suggesting that seedling age effects are stable across seasons in this environment. Ceesay *et al.*^[13] and Sinha and Talati^[14] reported similar age-related declines in West African and western Indian lowland rice.

Conclusion

SRI with 14-day seedlings produced the highest yield (6.83 t/ha) in eastern Indian lowlands, outperforming manual transplanting by 28.4% and mechanical transplanting by 5.6%. Younger seedlings improved all yield components: tiller number, panicle length, grains per panicle, and test weight. The method-by-age interaction was significant, confirming that these factors should be optimized together rather than independently.

Mechanical transplanting offers a labor-saving alternative where SRI adoption is constrained by labor availability, provided seedlings are transplanted at 21 days or younger. Farmers in eastern India who adopt SRI with young seedlings can expect meaningful yield gains without additional fertilizer or chemical input costs. Multi-location trials across diverse soil types and water availability conditions would strengthen these recommendations for broader adoption in the Indo-Gangetic plain and coastal lowlands.

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