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Evaluation of mechanical transplanting versus manual transplanting in puddled rice cultivation

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Abstract

This research compared mechanical and manual transplanting at different seedling densities in puddled rice at Nanjing, China, during kharif 2022. MT-2S (machine, 2 seedlings/hill) produced the highest grain yield (7.48 t/ha), 5.1 % above manual HT-2S (7.12 t/ha). Mechanical transplanting achieved 14.3-28.0 % more panicles/m² but fewer grains/panicle than manual methods. Labour requirement was 68-74 % lower with mechanical transplanting, reducing cost by 61-67 %.

Keywords: Mechanical transplanting, manual transplanting, puddled rice, seedling density, tiller dynamics, grain yield, labour efficiency, panicle density, transplanting cost, rice cultivation

Introduction

Rice transplanting by hand has shaped Asian agriculture for millennia, yet labour shortages now threaten this practice ^[1]. In China's Yangtze River Delta, rural-to-urban migration has reduced the agricultural workforce by over 30% since 2005 ^[2]. Mechanical transplanters establish rice quickly and uniformly in puddled fields ^[3, 4]. Machine-transplanted rice typically starts with shallower placement, affecting tillering dynamics and yield formation ^[5, 6]. Some trials report comparable or higher yields from mechanical transplanting ^[7, 8], while others note a slight penalty ^[9]. The number of seedlings per hill can shift the balance between panicle number and individual panicle weight ^[10]. This research evaluated three mechanical and two manual transplanting configurations to determine which maximizes grain yield and minimizes labour input under Nanjing's puddled rice conditions.

Material and Methods

Research area and seasonal conditions

The trial was conducted at Nanjing Agricultural University's Pukou Experimental Farm (32.1147°N, 118.6267°E) during the kharif rice season of June to October 2022. Soil was a gleyed paddy soil with pH 6.1, organic matter 2.34 %, and available N 174 mg/kg ^[11]. Total rainfall was 712 mm. Mean reproductive-phase temperature ranged from 26.3 to 31.7 °C.

Material

Rice variety Nanjing 9108 (japonica, medium-duration) was used. Mechanical seedlings were raised on mat-type nursery trays at 120 g dry seed/tray; manual seedlings on wet-bed nursery at 40 g/m² ^[12]. A Kubota SPW-48C transplanter was used. Fertilizer: 225 kg N/ha, 60 kg P₂O₅/ha, 90 kg K₂O/ha in splits.

Methods

Five treatments in RCBD with four replications: MT-2S, MT-3S, MT-4S (machine, 2/3/4 seedlings/hill at 30 × 14 cm), HT-2S, HT-3S (hand, 2/3 seedlings at 20 × 15 cm). Plot size: 10 m × 5 m. Tillers were counted at 15-day intervals from 15-90 DAT on 10 hills/plot. Yield Components were measured from 5 m² crop cuts at harvest. Labour was recorded as person-hours/ha. Data were analysed by ANOVA in SAS 9.4 with Tukey HSD at P = 0.05 ^[13].

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Results

Table 1: Growth and yield parameters of rice under mechanical and manual transplanting

Treatment	Plant ht (cm)	Tillers/ hill	Panicles/ m ²	Grains/ panicle	Filled grain (%)	1000-grain wt (g)	Yield (t/ha)
MT-2S	94.7	17.6	287	118	87.3	24.8	7.48
MT-3S	92.3	16.8	314	112	85.6	24.3	7.31
MT-4S	89.6	15.4	338	106	83.1	23.7	7.04
HT-2S	96.1	15.4	264	121	88.7	25.1	7.12
HT-3S	93.8	14.7	291	114	86.4	24.6	6.89
SEm (±)	1.83	0.64	11.2	3.8	1.24	0.31	0.18
CD (5%)	5.62	1.97	34.4	11.7	3.81	0.95	0.55

MT = mechanical transplanting, HT = hand (manual) transplanting. 2S/3S/4S = seedlings per hill

Comprehensive interpretation

MT-2S achieved the highest yield at 7.48 t/ha, at par with MT-3S (7.31 t/ha) but above MT-4S (7.04 t/ha) and both manual treatments (Table 1). Machine transplanting produced 14.3-28.0

% more panicles/m² than manual. However, manual plots had 2.5-14.2 % more grains/panicle and higher filled grain %. The trade-off was most balanced in MT-2S, maintaining adequate panicle density (287/m²) with reasonable grains per panicle (118).

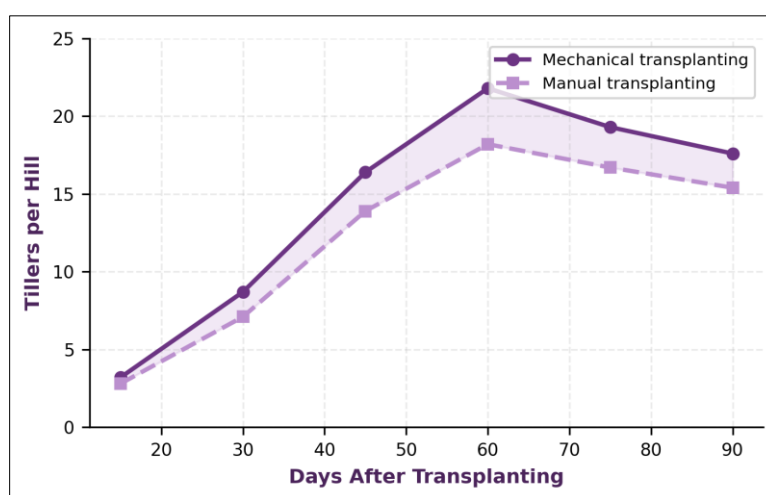


Fig 1: Tiller dynamics of rice under mechanical and manual transplanting from 15 to 90 DAT

Mechanical transplanting reached peak tillers earlier (60 DAT, 21.8/hill) than manual (18.2/hill) (Figure 1). Tiller mortality was

higher in MT (19.3 % vs 15.4 %), but final productive tillers remained greater in mechanically transplanted plots.

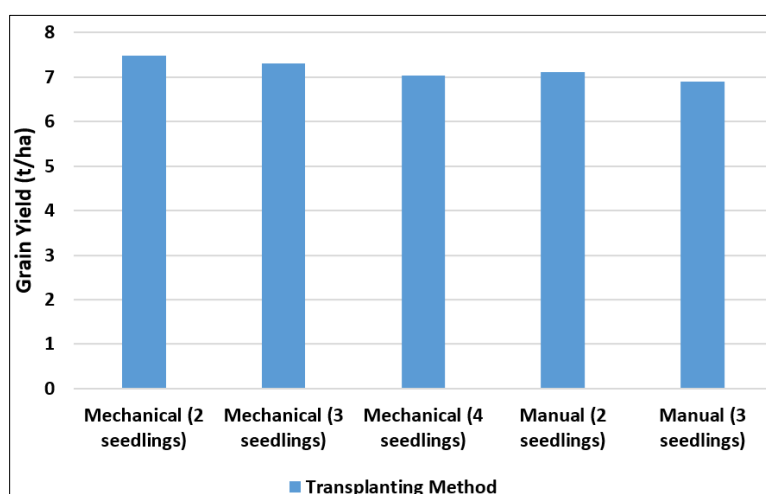


Fig 2: Grain yield of rice under different transplanting method and seedling density combinations

Yield declined as seedlings per hill increased within both transplanting methods (Figure 2). MT-2S yielded 6.3 % more than MT-4S; HT-2S outperformed HT-3S by 3.3 %, indicating that lower seedling density per hill allows better tiller development regardless of method.

Labour use was 186 person-hours/ha for MT versus 584-612 for

HT, a 68-70% reduction. Transplanting cost dropped from CNY 3,200-3,400/ha (manual) to CNY 1,100-1,250/ha (mechanical).

Discussion

The 5.1 % yield advantage of MT-2S over HT-2S aligns with reports showing 3-8 % gains from mechanical transplanting when

seedling density is well calibrated ^[7,8]. Faster early tillering in MT reflects shallower planting depth (2-3 cm vs 4-5 cm) promoting basal node emergence ^[5]. That yield declined with increasing seedlings per hill in both methods confirms the inverse relationship between hill density and tiller productivity ^[10]. The 68-74 % labour reduction is the most compelling argument for mechanization given ongoing rural labour shortages ^[2]. MT-4S, despite having the highest panicle count, suffered from inter-tiller shading and lower filled grain percentage, making it the least efficient mechanical option.

Conclusion

Mechanical transplanting with 2 seedlings per hill (MT-2S) produced the highest grain yield (7.48 t/ha) while reducing labour by 68-70 % and cost by 61-67 % versus manual methods. Yield declined as seedlings per hill increased in both systems. MT-2S is the recommended configuration for puddled rice in the Nanjing region, combining yield competitiveness with labour efficiency.

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