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Performance Evaluation of a Walking-Type Rice Transplanter under Different Seedling Media Thicknesses in Yogyakarta, Indonesia

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ABSTRACT

The performance of a walking-type rice transplanter is strongly affected by seedling quality, particularly the thickness of seedling media used in dapog nursery systems. This study aimed to evaluate the effect of seedling media thickness on field capacity, planting efficiency, and planting quality of a walking-type rice transplanter in accordance with SNI 7607:2020. Three levels of seedling media thickness were tested, namely 1.0 cm, 1.5 cm, and 2.0 cm. Field performance tests were conducted with three replications, while planting quality was assessed through field sampling based on standard quality parameters. The results showed that effective field capacities for seedling media thicknesses of 1.0, 1.5, and 2.0 cm were 0.17, 0.18, and 0.17 ha h^{-1}, respectively, while theoretical field capacities were 0.24, 0.22, and 0.21 ha h^{-1}. Planting efficiency increased with media thickness, reaching 72.42%, 81.82%, and 82.11%, whereas time-based efficiency values were 58.98%, 67.80%, and 67.28% for the respective treatments. Analysis of variance indicated no significant differences in efficiency parameters among treatments ($p > 0.05$). All treatments satisfied the planting quality requirements specified in SNI 7607:2020, including spacing uniformity, planting depth, number of seedlings per hill, and number of planting holes per meter. The lowest percentage of missing hills (1.16%) and lodged plants (12.54%) was observed at a seedling media thickness of 2.0 cm. A scoring analysis confirmed that 2.0 cm provided the best overall performance. These results indicate that optimizing seedling media thickness can improve the performance and planting quality of walking-type rice transplanters under field conditions.

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KEYWORDS: planting efficiency; planting quality; seedling media thickness; SNI 7607:2020; walking-type rice transplanter.

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1. INTRODUCTION

Rice is a staple food crop for a large proportion of the world's population, particularly in Asian countries where rice farming plays a central role in food security and rural livelihoods (Rajendran and Ranganathan, 2025). In Indonesia, rice production systems continue to face increasing challenges related to labor shortages, rising wages, and the declining interest of younger generations in agricultural work (Surya, 2013; Rikayanti, Arifin and Pata, 2021; Asmara *et al*, 2024). These conditions have encouraged the adoption of mechanization technologies to improve productivity, reduce labor dependency, and ensure timely field operations (Sabur and Ratmini, 2016; Lestari, - and Priyati, 2017; Singh *et al.*, 2023; Rajendran and Ranganathan, 2025).

Mechanical rice transplanting has been widely recognized as an effective solution to overcome labor constraints during the transplanting stage, which is traditionally labor-intensive and time-consuming (Saleh, 2018; Basir *et al.*, 2020; Kim *et al.*, 2023). Walking-type rice transplanters are commonly used in small to medium-scale paddy fields due to their relatively simple operation, lower investment cost, and adaptability to various field conditions (Singh *et al.*, 2023). However, the performance and planting quality of rice transplanters are not determined solely by machine specifications, but are also strongly influenced by seedling characteristics and nursery management practices (Lestari, - and Priyati, 2017).

One of the most critical factors affecting transplanting performance is the quality of rice seedlings prepared using the dapog nursery system. Seedling quality parameters such as age, density, root structure, and the thickness of the growing media play a significant role in determining seedling strength and uniformity during mechanical transplanting (Muharram and Supandji, 2022). Inappropriate seedling media thickness may lead to operational problems, including seedling breakage, floating seedlings, lodging, and increased rates of missing hills, which ultimately reduce planting quality and field performance (Choudhary and Machavaram, 2023; Kim *et al.*, 2023).

Several previous studies have reported that variations in seedling characteristics can influence the efficiency and effectiveness of rice transplanters(Ling *et al.*, no date; R. Asha, . and M. Ray, 2020; Choudhary and Machavaram, 2023; Wang *et al.*, 2024; Gan *et al.*, 2025; He *et al.*, 2025). However, most studies have focused on combined factors such as seedling age, variety, or planting density, while investigations that specifically examine the effect of seedling media thickness as an independent variable remain limited. In addition, comprehensive evaluations that integrate both transplanter performance parameters and planting quality indicators based on national or international standards are still scarce. In Indonesia, the performance and planting quality of rice transplanters are evaluated using the national standard **SNI 7607:2020**, which provides clear criteria for acceptable operational efficiency and planting quality. The application of this standard in experimental studies is essential to ensure that research findings are practically relevant and directly applicable to field conditions.

Therefore, this study aimed to evaluate the effect of different seedling media thicknesses (1.0 cm, 1.5 cm, and 2.0 cm) on the performance and planting quality of a walking-type rice transplanter under field conditions. The study assessed field capacity, planting efficiency, and planting quality parameters in accordance with SNI 7607:2020, and determined the optimal seedling media thickness using a scoring analysis approach. The results of this study are expected to contribute practical recommendations for improving mechanized rice transplanting performance through appropriate nursery management practices.

2. MATERIALS AND METHODS

2.1 Study Site and Experimental Period

The study was conducted in the Yogyakarta region, Indonesia, from January to April 2025. The experiment covered the stages of seedling preparation, machine adjustment, and field transplanting tests conducted during the same planting season to ensure uniform environmental conditions. Seedling preparation was carried out using the dapog nursery system, while transplanting operations were performed using a walking-type rice transplanter in previously prepared paddy fields. The seedling media preparation and field conditions for rice transplanting are shown in Figures 1 and 2.

Figure 1. Seedling media preparation

Figure 2. Paddy field

2.2 Rice Transplanter and Seedlings in dapog

A walking-type rice transplanter (Yanmar AP4) was used in this study. The machine is equipped with a mechanical transplanting mechanism suitable for dapog-grown seedlings. Rice seedlings of the variety *Inpari 47* were prepared using standard dapog trays. Seedlings were transplanted at the recommended age (18 days) for mechanical transplanting to ensure adequate strength and uniformity. Figures 3 and 4 show the walking-type rice transplanter and rice seedlings prepared using the dapog nursery system. The technical specifications of the walking-type rice transplanter are shown in Table 1.

Figure 3. The walking-type rice transplanter

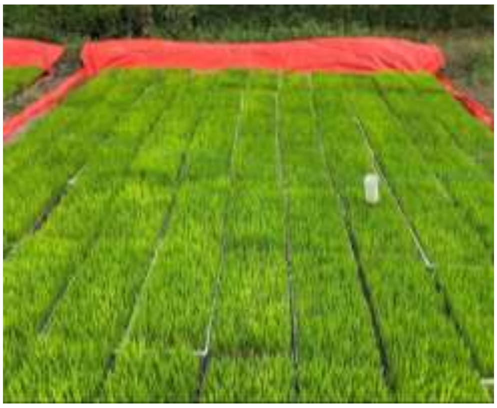

Figure 4. Rice seedling (dapog)

Table 1. Technical Specifications of The Walking-Type Rice Transplanter

Item	Specification
Model	AP4
Type	Walking-behind, 4-row, 2-wheel
Field capacity	5.51 h ha^{-1} (0.18 ha h^{-1})
Dimensions (L × W × H)	2190 × 1500 × 1020 mm
Weight	156.33 kg
Engine	
– Model	MZ175
– Type	Air-cooled, 4-stroke gasoline engine, OHV
– Displacement	171 cc
– Rated power	2.6 kW (3.5 hp) at 3000 rpm
– Maximum power	3.2 kW (4.3 hp) at 3000 rpm
– Fuel tank capacity	4 L
Transmission	
– Starting system	Manual (recoil starter)
– Wheel adjustment	Manual and automatic hydraulic height adjustment
– Number of wheels	2
– Wheel diameter	660 mm
– Gear selection	2 forward speeds, 1 reverse speed
– Average working speed	2.37 km h^{-1}
Planting unit	
– Travel speed (forward)	0.72–1.53 m s^{-1}
– Travel speed (reverse)	0.16–0.35 m s^{-1}
– Number of rows	4
– Row spacing	30 cm
– Intra-row spacing	12, 15, 17, 22 cm
– Number of hills per 3.3 m^2	90, 75, 65, 50
– Planting depth control	15–40 mm (6 levels)

2.3 Experimental Design

The experiment employed a single-factor design with seedling media thickness as the treatment variable. Three levels of seedling media thickness were evaluated: 1.0 cm, 1.5 cm, and 2.0 cm. Each treatment was replicated three times. Prior to field testing, the rice transplanter was adjusted according to the manufacturer's recommendations to ensure consistent operating conditions across all treatments.

The performance of the rice transplanter was evaluated using several operational parameters. Effective field capacity and theoretical field capacity were calculated based on working width, operating speed, and actual working time. Planting efficiency was determined as the ratio of effective field capacity to theoretical field capacity. Time loss efficiency was calculated by comparing productive working time with total operating time, including turning and adjustment periods.

The planting quality parameters was evaluated following the criteria specified in SNI 7607:2020. The measured parameters included row spacing, intra-row spacing, planting depth, number of seedlings per hill, number of planting holes per meter, percentage of missing hills, percentage of lodged plants, and plant upright angle. Measurements were carried out through systematic field sampling after transplanting to obtain representative data for each treatment.

2.4 Data Analysis

The data obtained from field measurements were processed using the following equations (Lestari, - and Priyati, 2017):

a. Effective Field Capacity

The effective field capacity was calculated using the following equation:

$$\text{EFC} = \frac{A}{T_p} \qquad \text{(1)}$$

where:

EFC = effective field capacity (ha h^{-1})

A = cultivated area (ha)

T_p = total operating time (h)

b. Theoretical Field Capacity

The theoretical field capacity was calculated using the following equation:

$$\text{TFC} = \frac{W_t \times V_t}{10} \qquad \text{(2)}$$

where:

TFC = theoretical field capacity (ha h^{-1})

W_t = theoretical working width (m)

V_t = theoretical operating speed (km h^{-1})

c. Planting Efficiency

Planting efficiency was calculated as follows:

$$\text{PE} = \frac{\text{EFC}}{\text{TFC}} \times 100 \qquad \text{(3)}$$

where:

PE = planting efficiency (%)

d. Planting Time Efficiency Analysis

In addition, planting efficiency can be evaluated by considering all sources of losses that affect the actual working width, actual operating speed, and effective operating time of the machine. Planting time efficiency based on time losses was calculated using the following equation:

$$E = (1 - L_1)(1 - L_2)(1 - L_3 - L_4) \times 100 \qquad \text{(4)}$$

where:

E = time-based planting efficiency (%)

e. Loss due to Overlapping of Planting Operation (L_1)

Loss caused by overlapping during planting was calculated using the following equation:

$$L_1 = \frac{W_1 - W_2}{W_1} \times 100 \qquad \text{(4.1)}$$

where:

L_1 = overlapping loss (%)

W_1 = theoretical working width (m)

W_2 = actual working width (m)

f. Loss due to Wheel Slip (L_2)

Wheel slip loss was calculated as follows:

$$S_r = \frac{L_1 - L_2}{L_1} \times 100 \qquad \text{(4.2)}$$

where:

S_r = wheel slip (%)

L_1 = distance traveled for *n* wheel revolutions when the transplanter moves without slip (m)

L_2 = distance traveled for *n* wheel revolutions when the transplanter operates in the field (m)

g. Loss due to Turning at Field Ends (L_3)

Loss caused by turning at the field ends was calculated using the following equation:

$$L_3 = \frac{T_1}{T} \times 100 \qquad \text{(4.3)}$$

L_3 = turning loss (%)

T_1 = turning time during field operation (h)

T = total operating time (h)

h. Loss due to Adjustment, Clogging, Minor Repairs, Seedling Replacement, and Others (L_4)

Loss due to adjustment, clogging, minor repairs, seedling replacement, and other interruptions was calculated as:

$$L_4 = \frac{T_2}{T} \times 100 \qquad \text{(4.4)}$$

where:

L_4 = loss due to adjustment, clogging, minor repairs, seedling replacement, and others (%)

T_2 = total time spent on adjustment, clogging removal, minor repairs, seedling replacement, and other interruptions (h)

Data were analyzed using descriptive statistical methods to summarize transplanter performance and planting quality. A one-way analysis of variance (ANOVA) at a significance level of α = 0.05 was applied to evaluate the effect of seedling media thickness on performance parameters. In addition, a scoring analysis was conducted by integrating selected performance and planting quality indicators to determine the most optimal seedling media thickness.

3. RESULTS AND DISCUSSION

3.1 Initial Seedling Conditions

Rice seedlings prepared using dapog trays with different media thicknesses showed visually distinguishable characteristics. Seedlings grown on thinner media (1.0 cm) tended to have weaker root binding and lower structural rigidity, whereas thicker media (2.0 cm) produced seedlings with stronger root mats and better integrity during handling and transplanting. These differences affected the interaction between seedlings and the transplanting mechanism during field operation.

3.2 Rice Transplanter Performance

The performance of the walking-type rice transplanter under different seedling media thicknesses is summarized based on field capacity and efficiency parameters. The results of the walking-type rice transplanter performance tests are shown in Table 2.

Table 2. Operational Parameters of the Rice Transplanter under Different Seedling Media Thicknesses

Parameter	**Unit**	**Seedling Media Thicknesses**		
		1.0 cm	**1.5 cm**	**2.0 cm**
Actual operating speed	km h^{-1}	1.97	1.91	1.93
Theoretical operating speed	km h^{-1}	2.11	1.96	1.87
Actual working width	m	1.13	1.14	1.17
Theoretical working width	m	1.12	1.12	1.12
Wheel slip	%	18.40	19.56	20.19
Fuel consumption	L h^{-1}	0.55	0.82	1.05
Theoretical field capacity	ha h^{-1}	0.24	0.22	0.21
Effective field capacity	ha h^{-1}	0.17	0.18	0.17

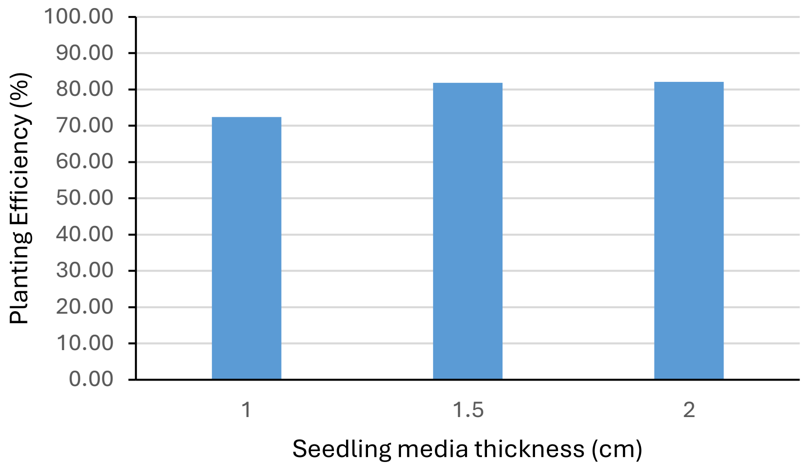

Figure 5. The planting efficiency of the rice transplanter under different seedling media thicknesses

Based on the field capacity data, planting efficiency was calculated as the ratio of actual field capacity to theoretical field capacity. The analysis presented in Figure 5 shows that the highest planting efficiency was achieved at a seedling media thickness of 2.0 cm (82.11%), followed by 1.5 cm (81.82%), while the lowest efficiency was observed at 1.0 cm (72.42%). These results indicate that increasing seedling media thickness tends to enhance planting efficiency. Differences in efficiency were associated with variations in total operating time and forward speed during transplanting, which influence both effective and theoretical field capacities. All treatments satisfied the minimum planting efficiency requirement of SNI 7607:2020, as the efficiency values exceeded 70%.

Statistical analysis using one-way ANOVA showed no significant differences among treatments for efficiency parameters ($p > 0.05$), suggesting that all media thicknesses allowed the machine to operate within an acceptable performance range.

Time efficiency represents the proportion of effective operating time relative to the total planned operating time, while non-productive periods are classified as time losses (Zakky, Prayoga and Indrayanti, 2021). In this study, time-based efficiency was evaluated by considering cumulative time losses resulting from planting overlap, wheel slip, headland turning, and time required for seedling replacement, minor repairs, and machine adjustment (Umar and Pangaribuan, 2017). The time-based efficiency of the walking-type rice transplanter is shown in Table 3.

Table 3. The time-based efficiency of the walking-type rice transplanter

Parameter	Unit	Seedling Media Thicknesses		
		1.0 cm	**1.5 cm**	**2.0 cm**
Planting overlap loss (L1)	%	-1.32	-1.57	1.12
Wheel slip loss (L2)	%	18.40	19.56	21.55
Headland turning loss (L3)	%	7.80	7.84	8.96
Loss due to adjustment, clogging, minor repairs, seedling replacement, and others (L4)	%	20.92	9.55	13.20
Time-based efficiency	%	58.98	67.80	60.39

As shown in Table 3, the highest time-based efficiency was obtained at a seedling media thickness of 1.5 cm (67.80%), followed closely by 2.0 cm (67.28%), whereas the lowest efficiency was recorded at 1.0 cm (58.98%). These differences were influenced by variations in individual time-loss components during transplanting operations.

Overlapping loss (L1) decreased with increasing seedling media thickness, as thicker media resulted in greater actual working width, thereby reducing overlap between planting passes. Conversely, wheel slip loss (L2) increased with media thickness, with the highest slip observed at 2.0 cm (20.19%). Thicker media produced more strongly bound root mats, increasing the pulling resistance on the transplanting forks and consequently the machine load.

Headland turning loss (L3) was highest at a media thickness of 2.0 cm (8.58%), followed by 1.5 cm (7.84%) and 1.0 cm (7.80%). The increased machine load associated with thicker seedling media contributed to wider turning paths and longer turning time. In contrast, losses due to seedling replacement, minor repairs, and machine adjustment (L4) were highest at 1.0 cm (20.92%), mainly because thinner media produced smaller and more fragile seedlings that were more prone to damage during operation.

One-way ANOVA indicated no statistically significant effect of seedling media thickness on time-based efficiency (Sig. = 0.357; $p > 0.05$). This result suggests that the observed differences among treatments were not sufficiently large to produce a significant statistical effect. Similar field dimensions, comparable turning times, and consistent operator skill levels contributed to relatively uniform time-loss components across treatments. Therefore, although numerical differences were observed, seedling media thickness did not significantly influence time-based efficiency under the tested conditions.

3.3 Planting Quality Evaluation

Planting quality parameters were evaluated in accordance with **SNI 7607:2020**. The result is shown in Table 4 indicated that row spacing, intra-row spacing, planting depth, number of seedlings per hill, and number of planting holes per meter for all treatments complied with the standard requirements. This confirms that the walking-type rice transplanter was capable of maintaining consistent planting geometry under varying seedling media thicknesses.

Table 4. Planting quality parameters under different seedling media thickness treatments

Parameter	Unit	1.0 cm	1.5 cm	2.0 cm
Row spacing	cm	29.07	28.88	29.10
Intra-row spacing	cm	17.72	17.83	16.92
Planting depth	cm	3.43	4.77	3.77
Number of seedlings per hill	stems	4.80	5.47	5.17
Number of planting holes per 1 m travel length	holes	22.43	22.73	24.30
Missing hills	%	9.26	6.83	1.16
Lodged plants	%	15.02	16.48	12.54
Plant upright angle	degrees	74.97	76.31	78.19

The percentage of missing hills decreased with increasing media thickness, from 9.26% at 1.0 cm to 6.83% at 1.5 cm and 1.16% at 2.0 cm. Thicker media provided stronger root cohesion, reducing seedling breakage and failure during transplanting. The percentage of lodged plants ranged from 12.54% to 16.48%, with the lowest value observed at a media thickness of 2.0 cm. These results indicate that thicker seedling media improved seedling stability after transplanting, particularly under wet field conditions.

3.4 Determination of Optimal Seedling Media Thickness

To integrate both performance and planting quality aspects, a scoring analysis was applied using selected key indicators. The scoring results for performance and planting quality parameters under different seedling media thickness treatments is shown in Table 5. The results showed that a seedling media thickness of 2.0 cm achieved the highest overall score, followed by 1.5 cm and 1.0 cm. Although statistical differences in efficiency were not significant, the consistently better planting quality indicators at 2.0 cm highlight its practical advantage for field application.

Table 5. Scoring results for performance and planting quality parameters under different seedling media thickness treatments

No.	Parameter	Evaluation criterion	1.0 cm	1.5 cm	2.0 cm
1	Theoretical field capacity	Higher is better	5	3	1
2	Effective field capacity	Higher is better	3	5	3
3	Planting efficiency	Higher is better	1	3	5
4	Time-based efficiency	Higher is better	1	5	3
5	Missing hills	Lower is better	1	3	5
6	Lodged plants	Lower is better	3	1	5
7	Plant upright angle	Higher is better	1	3	5
	Total score		15	23	27

Overall, the results demonstrate that seedling media thickness plays an important role in influencing the operational stability and planting quality of walking-type rice transplanters. Optimizing nursery practices, particularly media thickness, can therefore enhance the effectiveness of mechanized rice transplanting systems.

4. CONCLUSION

This study evaluated the effect of seedling media thickness on the performance and planting quality of a walking-type rice transplanter under field conditions in accordance with SNI 7607:2020. The results demonstrated that variations in seedling media thickness influenced planting efficiency and, more importantly, planting quality indicators such as missing hills and lodged plants. Although statistical analysis showed no significant differences in transplanter efficiency among the tested treatments, thicker seedling media consistently resulted in improved planting quality. A seedling media thickness of 2.0 cm produced the lowest percentage of missing hills and lodged plants while maintaining stable field capacity and operational efficiency. Based on the integrated scoring analysis, a media thickness of 2.0 cm was identified as the optimal condition for walking-type rice transplanter operation.

These findings indicate that appropriate management of seedling media thickness in dapog nursery systems plays a crucial role in enhancing the effectiveness of mechanized rice transplanting. The results of this study provide practical guidance for farmers, operators, and agricultural machinery practitioners to improve transplanting performance through simple adjustments in nursery practices, thereby supporting the wider adoption of mechanized rice production systems.

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