PRELIMINARY STUDY OF PERFORMANCE EVALUATION OF 6-ROWS AUTONOMOUS RICE TRANSPLANTER

Eddy Herman Sharu
Engineering Research Centre
Malaysian Agriculture Research and Development Institute (MARDI), 43400 Serdang, Selangor
Email: edherman@mardi.gov.my

Mohd Taufik Ahmad
Engineering Research Centre
Malaysian Agriculture Research and Development Institute (MARDI), 43400 Serdang, Selangor
Email: taufik@mardi.gov.my

Mohd. Khusairy Khadzir
Engineering Research Centre
Malaysian Agriculture Research and Development Institute (MARDI), 13200 Seberang Perai, Pulau Pinang
Email: khusairy@mardi.gov.my

Mohd Shahril Shah Mohd Ghazali
Engineering Research Centre,
Malaysian Agricultural Research and Development Institute MARDI 13200 Seberang Perai, Pulau Pinang
Email: shahril@mardi.gov.my.

ABSTRACT

Rice is the most widely consumed staple food in Asia, accounting for roughly 90% of global rice production. Malaysia has a total cultivated area of 730,016 hectares, with a total output of approximately 3.3 million metric tonnes in 2016. Rice is usually planted by manual sowing, transplanter, or direct sowing. This study explores the performance and operation of an autonomous rice transplanter machine compared to a conventional rice transplanter machine. Performance testing was conducted at the MARDI Seberang Perai, Penang rice study plot. The transplanter used in this study is a 6-row autonomous rice transplanter and a 6-row conventional rice transplanter. The settings for both transplanters are set at the same scene to ensure the same plant growth rate between them. According to the results of the autonomous rice transplanter's performance, it achieved 58 percent farm efficiency with a work rate of 3.49 hours/ha. The conventional rice transplanter recorded a work rate of 4 hours/ha with farm efficiency at 50 percent. The theoretical work rate for these two tractors is set at 2 hours/ha by maintaining the tractor's speed at the same rate of 2.75 km/hour. The study shows that an autonomous rice transplanter can accelerate rice planting up to 12.75 percent faster than a conventional rice transplanter. Results of rice cultivation with an autonomous rice transplanter also demonstrate straighter crops and uniformity when compared to a conventional rice transplanter. Using a weeding tool equipped with a fertilizer applicator, weeding and fertilizing tasks in the row are made simpler due to the plant's straightness.

Keywords: Paddy, performance, autonomous rice transplanter, conventional rice transplanter

Introduction

The world's population is expected to multiply, reaching 8 billion in 2025 and 9.15 billion in 2050. By 2025, it is predicted that this growth will be accompanied by a 60% increase in the food requirements of the present population (Arık, M. & Korkut, 2022). Agricultural productivity needs to be maximized to ensure that food production can grow at a rate that keeps up with population expansion (Aküzüm, T et al., 1999). The consumption of rice-based meals will increase dramatically with population growth, especially in developing countries (Godfray, H.C.J. and Garnett, T. 2014). Typically, paddy is cultivated through manual transplanting. Manual transplanting is not only time-consuming but also very expensive. Lack of labour is a big problem in sure of the paddy-producing regions of the country (Murumkar et al., 2014). A manual transplant requires 250–300 man-hours per ha or around 25% of the total labour needed for the crop (Murumkar et al., 2014). Therefore, using mechanization in rice cultivation is necessary to ensure that rice production can be improved in addition to reducing the labour force and thus guaranteeing sustainable food production.

Mechanical transplanting is the most viable technique because it decreases labour requirements to 50 man-hours per ha (Dixit A et al. 2007). Rice transplanters are specialized tools used to plant rice seedlings in paddy fields. It is outfitted with a transplanter mechanism, which commonly involves a reciprocating action (Prof. Shinde Jitendra G et al., 2018). Rice transplanter systems ensured timeliness in operation, accelerated transplanting, increased yield, and improved labour efficiency. With a rice transplanter, farmers can transplant rice seedlings quickly and effectively. The best seedlings for transplanting were found to be those that were 15-20 days old. The cost of transplantation is reduced by 45–50% using the manual and self-propelled transplanter. Compared to Japan's 6.58 t/ha and the global average of 3.91 t/ha, India's average rice yield is only 2.09 t/ha (Bala Ibrahim & Wan Ishak Wan Ismail, 2015). Typically, a 6-row transplanter can complete about 2-3 ha of work in a single day (highly efficient compared to the traditional method).

Autonomous rice transplanters have yet to be widely used in Malaysia. This technology has been used in rice production in most places in China, Japan, and Korea. Its use in Malaysia is still new and requires continuous testing to reach the best level compared to commonly used transplanters. In this study, the transplanter used is the same type: six rows. The only difference is autonomous and conventional. Therefore, this study was conducted to compare the efficiency of these two transplanters. The settings for both transplanters are set at the same scene to ensure the same plant growth rate between them.

MATERIALS AND METHOD

Study site

This study was done at MARDI Seberang Perai in Penang. An autonomous and conventional transplanter was used to plant the MR297 rice type in the rice field.

Machine description

As shown in **Figure 1**, the autonomous transplanter is powered by a 20.8 horsepower at 2,500 revolutions per minute, water-cooled, 4-stroke, 3-cylinder Diesel engine. This transplanting machine is compact, lightweight, self-propelled, and weighs only 850 kilograms. This machine's dimensions are 2960 mm x 2020 mm x 2140 mm (L x W x H). Figure 1 (b) depicts a conventional transplanter (**Figure 2**) with identical specifications to the autonomous transplanter. The operating width of the transplanters is 1,8 meters, and the distance between rows is 30 centimetres. The planting depth for both machines is 2 to 6 centimetres, and the hill spacing is 11 to 15 centimetres. This machine can be controlled by a single individual in the transplanting machine. Table 1 displays the specifications and technical details of the conventional and autonomous transplanter machines.

Figure 1. Autonomous transplanter

Figure 2. Conventional transplanter

Table 1 Technical specifications of Autonomous and conventional transplanter

	Autonomous transplanter	Conventional transplanter
No of row	6 rows planter	6 rows planter
distance	30 cm distance between row	30 cm distance between row
planting depth	Adjustable planting depth (at least 9 planting depth 2 to 6 cm)	Adjustable planting depth (at least 9 planting depth 2 to 6 cm)
Hill space	Hill space 11,12,12.5, 13, 14, and 15	Hill space 11,12,12.5, 13, 14, and 15
no of speed	No of speed 3 Forward + 3 Reverse	No of speed 3 Forward + 3 Reverse
Max. speed Working	6.55 km/hr	6.55 km/hr
Working width	180 cm	180 cm
Engine power	20.8 HP @ 2,500 rpm	20.8 HP @ 2,500 rpm
Prime mover integrated with smart system	Yes	No
RTK-GPS (human less) driving system prime mover	Yes	No

Performance Evaluation

The machine's theoretical and effective field capacities and field efficiency were evaluated. Multiple tests were conducted at the MARDI Seberang Perai study site. Using Equation 1, the time required to traverse the distance in the area during the process was recorded to determine the operation's speed.

$$S = \frac{d}{t} \ x\ 3.6 \qquad \textit{Equation 1}$$

Where:
S= Speed of operation (km/hr)
d = distance travelled (m)
t = time (s)

The theoretical field capacity was calculated without considering time disruptions that occur during operation (Equation 2).

$$TFC = \frac{\mathrm{W\ x\ S}}{10} \qquad \textit{Equation 2}$$

Where:
TFC = Theoretical field capacity,
W = The width between-row spacing (m),
S = The average forward speed (km/hr).

When calculating the effective field capacity, time losses during operation, such as turning at the end of rows, negligence, and implementing repair, were accounted for (Equation 3). EFC is also the machine's ability to function under real-world circumstances.

$$EFC = W \times S \times FE = TFC \times FE \qquad \textit{Equation 3}$$

Where:

EFC = Effective field capacity, which is the work rate attained across the entire plot based on the total amount of time spent working on the plot, is defined as follows:

FE = The efficiency of the implementation in the field under actual conditions.

The FE can be calculated by dividing the effective field capacity by the theoretical field capacity (Equation 3). Typically, field efficiency is expressed as a percentage.

$$FE = \frac{EFC}{TFC} x\ 100 \qquad \textit{Equation 4}$$

RESULT AND DISCUSSION

The autonomous and conventional transplanters have been evaluated at the MARDI Research Station in Seberang Perai, Penang. A paddy variety of MR 297 was planted in the test sites. Each plot measured one hectare. Observations and data about the implement's operability and speed have been collected.

The autonomous transplanter operates in rice fields successfully, as well as the conventional transplanter. The same settings have been set for both transplanters, such as adjusting the depth and spacing of the seedlings, as well as the planting speed. Before planting with an autonomous transplanter, the RTK is installed and then connected to the transplanter. Following a successful RTK transplanter connection, the operator manually drives around the plot to establish a border. After completing the border, planting can be initiated at any predetermined location, as indicated by the mobile remote. The autonomous transplanter will independently navigate the field and plant seedlings in the designated rows. The transplanter should monitor its progress to ensure that everything is going smoothly. This includes checking the seedling tray to ensure enough seedlings and monitoring the planting depth and spacing.

The tractor driving the implement moved forward at a maximum speed of 2.75 km/h. Based on the data, the appropriate mean spot work rate was calculated to be 2 hr/ha. The transplanter's field performance was evaluated, including different land sizes. The total time taken to work on each plot was measured, as well as the adequate working time, the time taken to turn the headland, and the seedlings loaded onto the seedling tray of the transplanter. The overall work rate, field efficiency, labor use, and comparison summary of field performance findings for autonomous and conventional transplanters are presented in Table 2. According to the results of the autonomous rice transplanter's performance, it achieved 58 percent farm efficiency with a work rate of 3.49 hours/ha. The conventional rice transplanter recorded a work rate of 4 hours/ha with farm efficiency at 50 percent.

Table 2: Performance Evaluation

	Speed (km/h)	Theoretical Field Capacity (TFC) (ha/h)	Effective Field Capacity (EFC) (ha/h)	Field efficiency (FE) (%)	Working capacity (Man-h/ha)	Time comparison (%)
Autonomous transplanter	2.75	2.0	3.49	58	0.29	**12.75**
Conventional transplanter	2.75	2.0	4.00	50	0.25	0

Compared to a conventional rice transplanter, the results of rice cultivation using an autonomous rice transplanter (**Figure 3**) show straighter crops (**Figure 4**). Due to the straightness of the plant, using a weeding tool with a fertilizer applicator makes it easier to fertilize and weed the row.

Figure 3. Planting using autonomous transplanter

Figure 4. Planting using conventional transplanter

Autonomous rice transplanters can increase precision and productivity. The transplanter may offer the cutting-edge technology needed to place seedlings apart at the proper depth and distance precisely. This may lead to larger yields and better crop quality than conventional transplanters. Also, compared to traditional transplanters, autonomous transplanters can plant seedlings more quickly. Farmers will be able to finish planting more rapidly, which might be crucial in regions with limited planting windows or unpredictable weather. Also, human operators are not required to work in potentially dangerous environments like muddy fields or unstable terrain, thanks to autonomous rice transplanters. This can increase security and lower the likelihood of accidents. It is possible to program autonomous transplanters to optimize planting patterns and use less water and fertilizer when planting. This can support more environmentally friendly agricultural techniques and lessen the adverse effects of rice farming.

The soil must be at its best to prevent seedlings from sinking too deeply in the too-wet ground or being planted too shallowly in too-dry soil, compromising the effectiveness of the autonomous transplanter. In addition, seedling quality must be at its highest level to prevent weak or damaged stems, which could make it challenging for the transplanter to plant them correctly. This may lead to unevenly spaced or crowded seedlings, which can lower yields. Incorrect planting depth or spacing can lead to uneven or improperly spaced seedlings, which can reduce yields; thus, the transplanter must be set up precisely to avoid this.

CONCLUSION

According to the study, adopting an autonomous rice transplanter can increase planting activities' efficiency by up to 12.75 percent more quickly than a conventional rice transplanter. Compared to a conventional rice transplanter, the results of rice cultivation with an autonomous rice transplanter show straighter crops and uniformity. Autonomous rice transplanters can provide more environmentally friendly farming methods. To guarantee optimum effectiveness, preparing the field carefully before planting, utilizing high-quality seedlings, and setting up and maintaining the transplanter is crucial. Using Autonomous transplanters will require regulations and standards to meet safety, performance, and quality standards. Policies must be implemented to ensure that autonomous transplanters are tested, certified, and approved for use in agriculture. Besides that, using autonomous transplanters may require farmers to invest in new technology and infrastructure. Policies must be implemented to ensure that small and medium-sized farmers have access to this technology and are included. This policy should benefit autonomous transplanters while minimizing any potential negative impacts.

ACKNOWLEDGMENTS

The authors acknowledge the research grant from the Ministry of Agriculture and Food Security (KPKM) - through the Malaysia Agriculture Research and Development (MARDI). The authors also acknowledge the technical support provided by the staff of the Engineering Research Centre (ER) Field mechanization program MARDI HQ, ER Field mechanization program MARDI Seberang Perai station.

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