Research article

Efficiency of Two-Row Chinese Rice Transplanter Experimented at Royal University of Agriculture

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Received 21 December 2015 Accepted 11 April 2016 (*Corresponding Author)

Abstract As a number of agricultural labors have shifted to urban industry, rice production is now experiencing labor shortages. Thus making transplanting is deeply unpopular. Despite producing higher yields, transplanting has dramatically been replaced by direct seeding. Therefore, this research paper aims to introduce the rice transplanter model TMRT 2 and to determine its working performance and efficiency by conducting an on-station experiment, starting from June to August, 2015, at the Royal University of Agriculture (RUA), Cambodia. The experiment was divided into 9 treatments with the size of 2 m x 7 m, and two main factors—plant age and water level—were studied and analyzed on different periods of 12 days, 18 days, and 25 days in age; an water depths of 2 cm, 5 cm, and 10 cm for water level. The findings indicate that in the treatment (25 days and + 2 cm), the hills contained a density of 4-5 plants and suffered low damage during planting operation. Though transplanted at various water depths, old rice seedlings tended to stand upright at the average of 650 to 750 degrees, whereas slow transplanting speed might greatly reduce seedling losses to 1-2 plants per hill. Additionally, hill-to-hill spacing varied from 21 to 23 cm when the rice seedlings age 18 and 25 days were mechanically transplanted. However, transplanting of younger seedlings produced many missing hills that ranged from 3 to 7 hills in the 2 m x 7 m plot, and this might substantially decrease the future yields. Planting depths varied from 4 to 5 cm when transplanting of seedlings age 18 and 25 days was performed at a water level of 2 cm. It might be concluded that rice seedlings, age 18 and 25 days, should be transplanted at 2 cm water level, in combination with slow enough operational speed, while transplanting of 12-day seedlings at varied water depths produced greater damage and losses.

Keywords rice transplanter, water level, root growth, hill spacing, operational speed

INTRODUCTION

Rice cultivation is known as traditional income-generating work practiced by 60% of rural Cambodian people and as a staple crop consumed in the country. Rice is also rich in vitamin B, which is important to keep the body running (MAFF, 2012). Recently, rice has been prioritized as a strategic crop to boost exports (FAO, 2014). Therefore, rice yields have increased, while workload has decreased. Despite its tremendous significance, rice cultivation is laborious and takes a long time to yield. In general, the cultivation time ranges from three to six months, depending upon the selected rice varieties and the seasons when crops are cultivated. Rice growth and yields are highly sensitive to variability of land preparation, climatic conditions, proper care, and water supplies. So, improper farming techniques may obviously lead to a waste of invested capital and low outcomes. Since rice cultivation requires a great deal of available labor, lack of man-power may lead to late farming or little care which signifies a pressing need for machine aid to boost crop production (ADB, 2014).

At the present time, mechanization has started to appear as a useful farming method that accelerates agricultural work and cut down unnecessary labor use, as well as increasing crop yields per year. After years of globalization, Cambodia has imported hundreds of power tillers to quicken land preparation proportionally in the wake of youth out-migration for work abroad. This really demonstrates a noticeable trend in the Cambodian agricultural evolution, while labor shortages pose a serious challenge towards the existence of agriculture (Lay, 2009). Seldom introduced into the Cambodian domestic market, hand-powered rice transplanters have been widely marketed and utilized in the Asian regions to compensate for labor shortages and facilitate farming work. Such rice transplanters are of great importance to the rural economies as fewer people are needed to transplant rice crops than ever, seedlings are uniformly transplanted for the purpose of better field irrigation and weeding at a later stage. Apart from that, seedling uniformity results in proper nutrient intakes from the ground and enough solar absorption between rows, which means higher yields. Therefore, this research aims to introduce the rice transplanter model TMRT 2 and to determine its working performance and efficiency.

METHODOLOGY

The experiments were carried out at the Royal University of Agriculture during the period of June-August to test the performance of a hand-operated rice transplanter by selecting the mini hand cranked rice transplanter (2 row, 20 cm width), which was imported from China. Moreover, understanding different water levels in rice fields before, during, and after transplanting is crucial for the firm stance and survival of newly transplanted seedlings. Adequate water presence in the field also contributes to the ability of seedlings to take in nutrient dissolved in water, absorb oxygen from the air, and consume sufficient amounts of water to promote growth. Thus, the study was performed by selecting plots with three water levels above the ground: 2 cm, 5 cm, and 10 cm, which are similar to the real water levels observed in rice paddy field in Cambodia.

As the time frame of the practical experiment was about three months, the short-duration rice variety Sen Pidoa was chosen. The rice was germinated at the nursery prepared at RUA campus, and planted for the experiment. The age of seedlings strongly affects proper growth leading to low losses of transplanted seedlings and higher yields at the harvest time. So, experimenting with different seedling age categories can prove a premium seedling age that can assure high yields for the benefit of farmers. The tested rice seedlings were categorized into three different ages: 12 days, 18 days recommended in system of rice intensification (GDA, 2013); and 25 days to meet the optimum rice age for the rice transplanter. Both water level and seedling age affect rice growth. The 9 treatments were created with the size of 2 m x 7 m. Root growth, number of plants per hill, missing hills, damaged hills, inter-row spacing and stem angle were measured and analyzed using ONE-WAY and TWO-WAY ANOVA from Minitab-17.0 software packages. Transplanting speed was measured whereas machine depreciation cost and labor efficiency were calculated.

The seed rate for one square meter nursery was about 250 grams. During seedling preparation, organic matter was one ox-card for 100 m^2 nursery to obtain firm seedling stems, additionally 0.5 kg of Urea fertilizer was diluted into water to make seedling healthy. Rice needs to be fertilized three times, 2-3, 15, and 50 days after seeding, and weeding is needed after transplanting at 15, 30 and 45 days to prevent grass growth (GDA, 2013).

RESULTS AND DISCUSSION

Optimal Transplanting Speed Operational in Each Treatment

The seedling age and water level were tested to find the optimum transplanting speed necessary to streamline a whole transplanting process with little damage to seedlings. The seedlings transplanted at the age of 12 days tend to be associated with higher operational speed, which significantly variant from 0.24 $m.s^{-1}$ in 10-cm depth to 0.36 $m.s^{-1}$ in 2-cm depth, while the transplanting of 18-day seedlings might retard the machine mobility estimated at around 0.25 $m.s^{-1}$ in depths of 2 and 5 cm and at 0.30 $m.s^{-1}$ in 10-cm depth. It is clear that young seedlings were easy to be picked up and dug into the soil, hastening the operational speed. With 25-day seedlings, the transplanter was operated at slow speed of 0.20 $m.s^{-1}$ in each water depth. This shows slowness of the machine. As a result, the operational speed varies in uniformity to subsequent seedling ages, but may fluctuate due to soil conditions and constant mechanical pulling force.

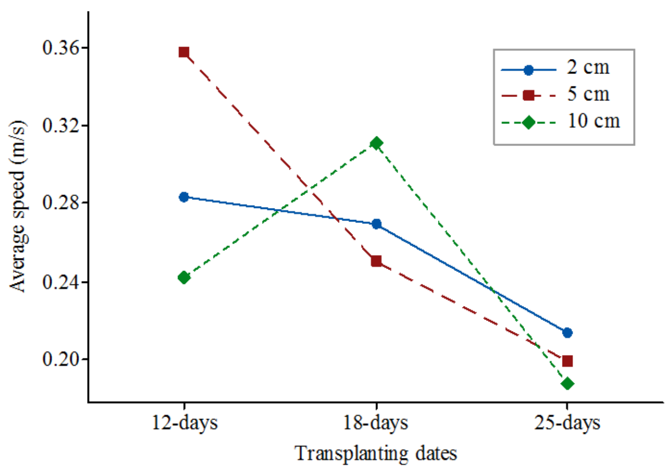

Fig. 1 Comparison in transplanting speeds operated in different seedling ages and water levels, with different speed means significant ($p < 0.001$) in transplanting date factor, non-significant ($p = 0.055$), and with significant interaction ($p = 0.019$)

Transplanting Speed Operational in Each Treatment

Missing hills and floating rates of transplanted seedlings were examined and counted in each treatment. This was to discover how significantly the age factor and the water-level factor affected the transplanter performance. As shown in Table 1, the difference in seedling damage in each hill is highly significant ($p < 0.001$), while the variation in an average floating rate of seedlings is also statistically significant ($p < 0.001$). As a result, the findings show that seedling damage in a density of 4 m^2 tend to be greater at high depth and young age, with the averages of 3 seedlings in the treatment (12 days + 5 cm), 4.5 seedlings in the treatment (18 days + 5 cm) and 7.5 seedlings in the treatment (18 days + 10 cm). The damage rate was non-significant in case older seedlings were transplanted, though at various depths. Water depth had a huge effect on a floating rate of seedlings in the vicinity of 4 m^2. High water level presented on the experimental plot signified a higher rate of seedlings afloat, and transplanting young seedlings was also influential in this rate. The seedlings age 25 days suffered a low floating rate at which very few drained seedlings were gathered in 4 m^2, which other treatments with younger seedlings had a floating rate of 4-7 seedlings.

Table 1 Effect of different depths and seedling ages on damage and floating rates

Treatment	Missing rate	Floating rate
12 days + 2 cm	1.70 b	4.50 abc
12 days + 5 cm	3.00 ab	4.00 abc
12 days + 10 cm	7.75 a	6.00 abc
18 days + 2 cm	2.00 b	-
18 days + 5 cm	4.50 ab	7.00 a
18 days + 10 cm	7.50 a	7.00 a
25 days + 2 cm	2.00 b	1.50 bc
25 days + 5 cm	-	0.75 bc
25 days + 10 cm	1.50 b	0.75 c
SE	2.164	2.050
F-test probabilities	< 0.001	< 0.001
CV (%)	19.65	18.18

Effects of Above-ground Water and Seedling Age on Root Depth

Seedling roots may penetrate as deep as into the ground depending upon the availability of water on the ground and the age of the seedlings, which is well illustrated in Fig. 2. The difference in average root depth penetrable into the soil is very significant. The roots of the seedlings transplanted at the age of 12 days shows obvious results as they had the lowest penetrability, but differed across different levels of above-ground water. In this seedling age category, the transplanter had the ability to dip the seedlings roots 3 cm into the soil at a water level of 2 cm, increasing the root depth by 1 cm at water levels of 5-10 cm. Deeper root penetrability occurred at higher level of water because the transplanter was manually adjusted to match the water level; otherwise, the seedlings were unable to be placed into the soil. Though transplanted at the same age categories, older seedlings tend to have deeper root penetrability, and the roots of the replanted seedlings age 18 days were averaged under 5 cm despite little depth variation across the water level. However, after replanting, the root depth of seedling age 25 days remained deeper than younger seedlings and was averaged 5 cm. This figure increased due to the rising level of water presented on the soil. The fact that older seedlings had higher penetrability could be explained by three reasons: the height of the seedlings, pulling mechanism, and periodic adjustment of the transplanter.

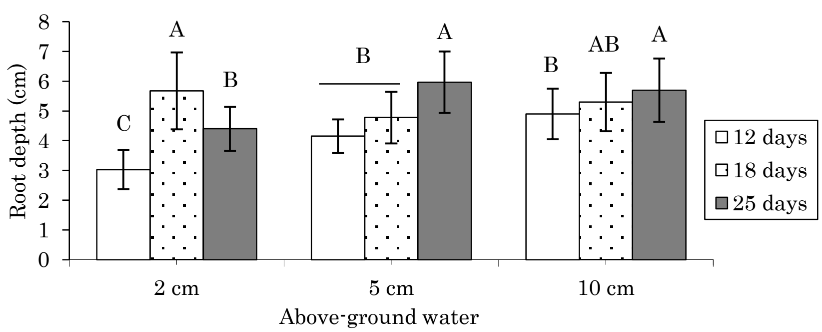

Fig. 2 Combined effects of seedling age and water level on seedling-root depth created during transplanting. The Mean ± SD of root depths are presented. Different used alphabets indicate measurement is significantly different *($p < 0.05$)* from each other

Effects of Above-ground Water and Seedling age

Numbers of seedlings per hill, crop spaces, standing angles of seedlings and seedling losses per hill were timely measured to identify effects that the transplanter had on rice seedlings (Table 2). Different age groups strongly affected the ability of the transplanter to pick up the seedlings, being highly significant ($p < 0.001$), while the water level might not have any significant effect ($p = 0.964$) on its capability in picking seedlings at a time during the transplanting process. Interaction between the water level and age group factors was also not significantly different ($p = 0.147$), showing that replanting at different levels of water, regardless of seedling ages, the number of seedlings transplanted at a single time was similar. As indicated above, the seedlings age 25 days were suitable enough for the transplanter to pick up 4 seedlings per hill, when operated at 2-cm water depth. As the water level was deeper, the number of picked-up seedlings also increased by one unit. As the interaction was not detected, the suitable seedlings for the utilization of the rice transplanter should exceed 20 days in age, so the machine is capable to firmly grab them. In addition, the water level should be considered to remain shallow to reduce excessive use of seedlings.

Table 2 Combined effects of seedling age and water level on seedlings transplanted at a time, inter-row spacing produced, stance of seedlings, and damage rate

Treatment		Number of seedlings (stems/hill)	Between-row spacing (cm)	Stem angle (^{0})	Damaged seedlings (stem/hill)
Age	Water level				
12 days	2 cm	9.25^{a}	19.65^{bcd}	62.75^{abc}	2.65^{a}
	5 cm	7.70^{ab}	18.75^{cd}	65.00^{abc}	0.20^{d}
	10 cm	7.25^{abc}	19.15^{cd}	72.50^{ab}	1.40^{b}
18 days	2 cm	4.60^{bcd}	16.30^{d}	73.40^{ab}	0.75^{bcd}
	5 cm	4.40^{cd}	18.45^{cd}	53.25^{c}	0.90^{bcd}
	10 cm	4.90^{bcd}	24.85^{a}	57.25^{bc}	1.35^{bc}
25 days	2 cm	3.90^{d}	21.50^{abc}	65.65^{abc}	0.80^{bcd}
	5 cm	5.20^{bcd}	22.10^{abc}	77.35^{a}	0.45^{bcd}
	10 cm	5.25^{bcd}	23.70^{ab}	78.60^{a}	0.40^{cd}
SE		1.72	2.04	16.68	0.97
F-test probabilities					
Seedling age (S)		< 0.001	< 0.001	< 0.001	< 0.001
Water level (W)		0.964	< 0.001	0.379	< 0.001
Interaction (SxP)		0.147	< 0.001	< 0.001	< 0.001

Spacing produced by the manual operation of the transplanter varied significantly at each water depths ($p < 0.001$) and at each age group ($p < 0.001$). This shows that the older the seedlings, the wider the spacing. The interaction effects of the water depths and age groups on crop spaces were detected ($p = 0.001$), showing that the transplanter tended to produce distinct spacing because the required traction force for the operation varied. Older seedlings required machine transplanting to spend slightly more time. This is obvious because deeper water levels tend to be difficult for the transplanting machine to pull out due to friction produced on the water surface, retarding the movement of the transplanter at water depths of 5 and 10 cm. This explanation is strongly linked to widened crop spacing. Of all the treatments, seedlings transplanted at the age of 25 days, though at varied water depths, remained highest and varied from 21 to 23 cm compared to others replanted at a younger age.

Plant ages were significantly influential in the ability of plants to stand after transplanting ($p = 0.001$), while different water depths had no effect on the standing ability ($p = 0.379$). This means stem heights affects plant verticality. However, the interaction between the age group and water level is statistically significant ($p = 0.001$), indicating that plant verticality tends to vary due to combination of plant age and water depths. Statistically, plants age 25 days were very suitable with the use of the transplanting machine as they slightly leaned at 80^0 on average when planted at water depths of 5 and 10 cm. Comparing to the replanting at a water depth of 2 cm, the seedlings of that age leaned to 65^0. High water levels seem to keep old and tall plants straight up. Younger rice plants age 12 and 18 days transplanted at high water levels caused the plants to stand less upright, while 18-day seedlings transplanted at a 2-cm water depth stood at 73^0.

Damage to plants per hill was measured in each treatment, while the seedling age and water level were both strongly influential in the degree at which plants might be broken ($p < 0.001$). These two factors interacted closely ($p < 0.001$) and might determine how much damage was done on seedlings transplanted when varying age groups and water levels were applied. Plants per hill were seen to suffer breakage at the age of 12 days more than older plants that were transplanted at different water levels. Rates of plant damage ranged from 1.40 to 2.50 plants per hill with too young seedlings. However, plants per hill suffered less damage when older seedlings were used. This damage was mainly caused by the way of operating the rice transplanter.

CONCLUSION

In short, it is deductible that the seedlings age 12 days are unsuitable for machine transplanting because substantial damage and seedling losses are frequently observed. Moreover, at higher water levels of 5 and 10 cm above the ground, machine transplanting may result in more floating and missing hills. Therefore, it is obvious that seedlings age 18 and 25 days should be considered for further experiments. Water depth of 2 cm is preferred as it leads to stronger seedling stance, low seedling density, easy machine operation, and marginal losses. Therefore, the rice transplanter should be considered as a good option to accelerate rice farming and reduce workload.

ACKNOWLEDGEMENTS

The author is grateful for constant technical support and advice from the Royal University of Agriculture, as well as the funding by Oxfam Cambodia. Moreover, it is also appreciative for the involvement of Ms. Kim Muy Leang, Ms. Sreng Ratana, Mr. Mao Thearith, Mr. Po Vengleang, Mr. Ty Savry, Mr. Sem Sopanha and Mr. Sith Sereypanha for their hard work in machine testing and data collection that provide productive research results and make this research possible.

REFERENCES

ADB (Asian Development Bank). 2014. Improving rice production and commercialization in Cambodia: Finding from a farm investment climate assessment. Mandaluyong City, Philippines.

FAO (Food and Agriculture Organization of the United Nations). 2014. Country fact sheet on food and agriculture policy trends; Socio-economic context and role of agriculture. Rome, Italy.

GDA. 2013. Rice production; Ten major rice varieties and rice exports. General Directorate of Agriculture. Phnom Penh, Cambodia.

Lay, C. 2009. Country report Cambodia; Agricultural mechanization and agricultural development strategies in Cambodia. Ethnical Committee of UNAPCAEM, Los Banos, Phlippines.

MAFF (Ministry of Agriculture, Forestry and Fisheries). 2012. Annual report of agriculture for 2011-2012. Phnom Penh, Cambodia.