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The transplanter tools for small paddy fields: System of Rice Intensification (SRI) compliance

M.S. Imran[1], M.S. Abdul Manan[2], A.N.M. Khalil[3], S. Hamat[4] ,R.N. Ahmad[5] and M.K. MdNaim[6]

[1,2,3,4,5]School of Manufacturing Engineering, Universiti Malaysia Perlis (UniMAP), Kampus Tetap Ulu Pauh, Jalan Arau-Changlun, 02600 Arau, Perlis, Malaysia
[6]Centre for Diploma Studies of the University Malaysia Perlis, Malaysia

E-mail: syediimran@unimap.edu.my

Abstract. The objectives of the research are to develop manual planting tools compliance with System of Rice Intensification cultivation guideline for small fields and improve SRI farmers working posture. Several problems were recognised to assist in developing design requirement. A current product called Planting Tools is identified as a base product to reverse engineering so it can plant a single young rice seedling in each planting point. Findings: a simple planting tool with smaller size compare to the current product is developed. It consists of several components that can be divided by four main functions which are the hopper, vertical tube, penetrator and handle. The hopper is where the rice seedling is placed. The seedling will fall by gravity through the vertical tube and positioned inside the penetrator. The operator needs to position the penetrator to a specific point. The seedlings will be planted less than 10mm from tops soil upon pressing the lever which connected to linkages. Therefore, a study of the penetrator strength in the static analysis was performed by using finite-element modelling technique.

1. Introduction

Since System of Rice Intensification (SRI) planting method is introduced in Malaysia, local farmers have been applied the technique and gain the good result of increasing in paddy yield. This method originated in Madagascar by French agronomist, Father Henri de Laulanié and spread to other countries worldwide including Malaysia. A case study conducted in privately owned paddy field known as SRI Lovely at Sik Kedah shows that local farmers have been practice the SRI method since 2010 and it proves to increase the paddy yield with minimum water usage and at minimum cost since no chemical fertiliser and pesticide being used. SRI transplanting method plays a significant role. Start from growing young seedling from the nursery, transplanting techniques which minimise possibilities of root injuries, wider spacing between plants, weeding process which also help to aerate the paddy fields soil and organic rice cultivation management. SRI technique will ensure good development for the overall growth of plants if all of the SRI technique is followed.[1] However, after more than 20 years since the SRI method been introduced, there is no fully automated paddy transplanter for SRI. There are some effort to develop those machine and some success in developing semi-auto machine [2]. It still not widely applied by SRI farmers in Malaysia due to few additions in SRI technique by farmers. During the interview session with local farmers, they tried to minimise heavy machinery allowed to enter their paddy field to maintain soil condition. This will add in design requirement to create simple, lightweight tool or machinery. The development of SRI transplanter tool is expected to fill the gap and hopefully drive others researcher to develop automated transplanter machine that fit with SRI technique. It also one of the mechanisms that studying for further development of fully automated SRI transplanter machine. The primary objective of this paper is to develop a manual planting tool that SRI compliance and also to improve the working posture of local farmers during the transplanting process.

2. Problem Identification

Base on observation in SRI Lovely paddy field located at Kedah. There are 6 techniques in practicing SRI method which is (i) the use of young seedling, (ii) planting it near the topsoil, (iii) plant young seedlings with 25 cm spacing, (iv) plough the field to create aerated soil, (v) minimum water level, (vi) organic fertilizer and organic pest control. However, there is no concrete method where some farmers will advance different technique to suit their field condition [1]. The innovation of SRI planting stick is to support the first three methods. Currently, farmers grow young seedling using nursery bed and transplant it afterwards by hand to the field. The problem with this method is the separation young seedling from it nursery soil may damage the root. It also will take a few minutes before the farmers plant it on topsoil. This will increase the risk of transplanting shock which will delay roots growth subsequently overall plant development [3]. Since there is no transplanter machine or tools available in the area, the transplanting process is done by the conventional way using a hand. Besides that, the farmers also need to plant the seedling close to the topsoil so the root can benefit the fertility of topsoil. It also observed that farmers need to bend their body repeatedly to complete the task as shown in figure 1. The farmers suffered discomfort in some of the body parts due to repetitive bending during the working process [4].

Figure 1. Transplanting process done by local farmers of SRI Lovely paddy field.

3. Product Requirement

Two significant requirements are developed base on problem identification which is: (i) A planting tool needs to be able to transplant a young seedling [5] (below 14 days old) near the topsoil (less than 10 mm of depth) without removing the nursery soil. There is an explanation for planting the young seedling along with the nursery soil which is to reduce the disturbance of seedlings root growth to a minimum so that the plants can adapt themselves to their new environment. Figure 2 shows the x value is target less than 10 mm. Just enough to make sure the seedling did not tilt and fixed in position after planted. (ii) The working posture for the user is standing to eliminate awkward working condition as shown previously in figure 2.

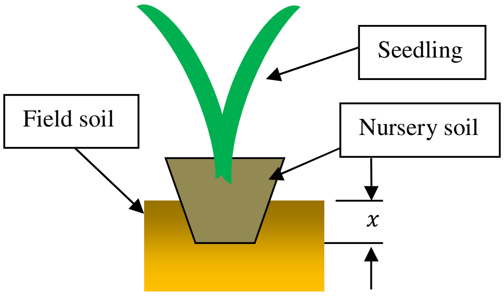

Figure 2. Target result.

A current Planting Tool is studied as shown in figure 3. The existing product is a tubular tool which inserts cylinder shapes crops seedlings into the ground when the lever is pressed. This Planting Tool is manufactured in China and made to plant crops such as vegetable or small plant. It can be bought at RM 200. The specifications of the tools are compared and analysed. Three areas are identified and measured so the redesign process will occur to meet SRI planting techniques.

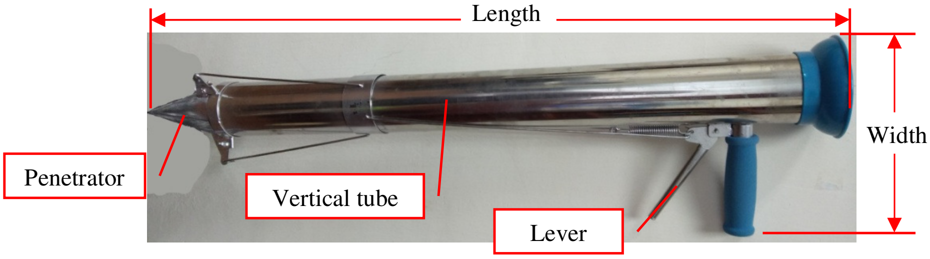

Figure 3. Current product

Table 1 shows the dimension and its relation to how the current product will function. The overall dimension will determine the working posture of the farmer. The shape and size of the vertical tube will determine the shape of seedling nursery soil and overall size allowable into the tube. While penetrator (refer Figure 3) depth will determine the maximum planting depth. Base on the measured dimension, it can be noticed that the vertical tube and penetrator is oversize to meet product requirement. The product weight is 1.62 kg.

Table 1. Current product dimension.

No	Item	Dimension (mm)	Design relation
1	Overall Dimension	930 (Length) × 240(Width)	The working posture of the operator
2	Vertical tube (Cylinder)	75 (Diameter)	Maximum seedlings size
3	Penetrator	140 (Depth)	Maximum planting depth

The current product is further analyzed, and the material is made from 90% stainless steel and others are made from plastic and soft foam (can be seen as blue colour in figure 3). It is noticed that almost all components are permanently joint by welding method (as shown in figure 4). This makes the product very sturdy but with disadvantage which is the component is difficult to maintain. For example, if any part needs to be replacing, another part that weld together will be broken or unusable in the disassembly process. As a result, the current product is not easy and costly to maintain.

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Figure 4. Close up view of the welded part.

4. New Product Development

In general, the SRI Planting Tools (as shown in Figure 5) consists of an aluminium square tube which is to insert a seedling along with nursery soil into the ground. The handle design is upgraded to improve the comfort level when holding the tool. The different shape of the vertical tube is to suit with nursery tray cavity shape which is square as shown in Figure 6. The process sequence is shown in a series of simulation picture shown in Figure 7.

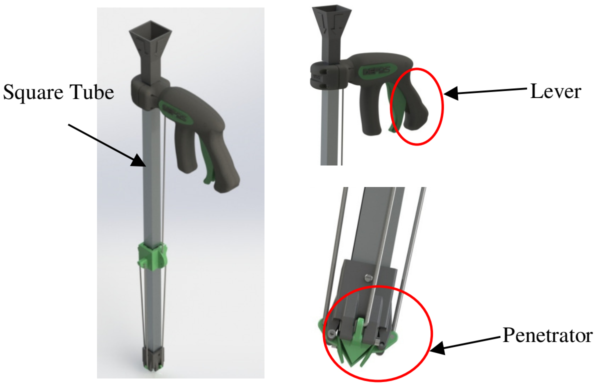

Figure 5. Assembly drawing.

Figure 6. Nursery tray.

Table 2 shows a dimension of newly designed planting tools. The overall dimension is similar to the previous dimension since the tool is used in a standing position. Since the shape and size of the vertical tube is change, almost all parts need to redesign to meet the new specification. The size of penetrator is significantly reduced, and the purpose is merely to scratch the topsoil so that the seedlings will securely be positioned. Possibility the scratched soil to concealed back is predicted since the field is moist. Thus, the penetrator dimension is designed above 10 mm of depth. There are few advantages come with the newly designed SRI Planting Tool which is:

i. All components are easily dismantled for maintenance or part replacement.
ii. The aluminium square tube is a standard part which is readily available in the local aluminium workshop. It can be cut or replaced to alter the length, so it ergonomically fit according to user preference.
iii. The total weight is 810 gram, a reduction by 50% compared to existing Planting Tool.
iv. All parts are from a non-corrosive material such as plastic, aluminium and stainless steel.

A full-scale working model is developed for future analysis and product testing. Plastic component is 3D printed (fused deposition modelling) using ABS (Acrylonitrile butadiene styrene) as a material.

Table 2. Improved product.

No	Item	Dimension (mm)	Design relation
1	Overall Dimension	900 (Length) × 278(Width)	The working posture of the operator
2	Vertical tube (Cylinder)	25.6 × 25.6 (Outer dimension)	Maximum seedlings size
3	Penetrator	15 (Depth)	Maximum planting depth

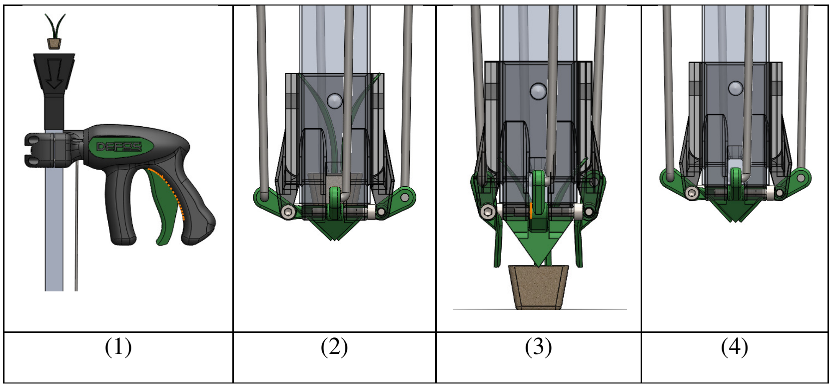

Figure 7. Assembly drawing. (1) The seedling is inserted inside the hopper 2) the seedling immediately felled by gravity into the bottom of the square tube. (3) The operator will press the lever which is a linkage that will open up the penetrator. 4) Seedling is planted to the ground and spring mechanism will retract and close the penetrator for next cycle.

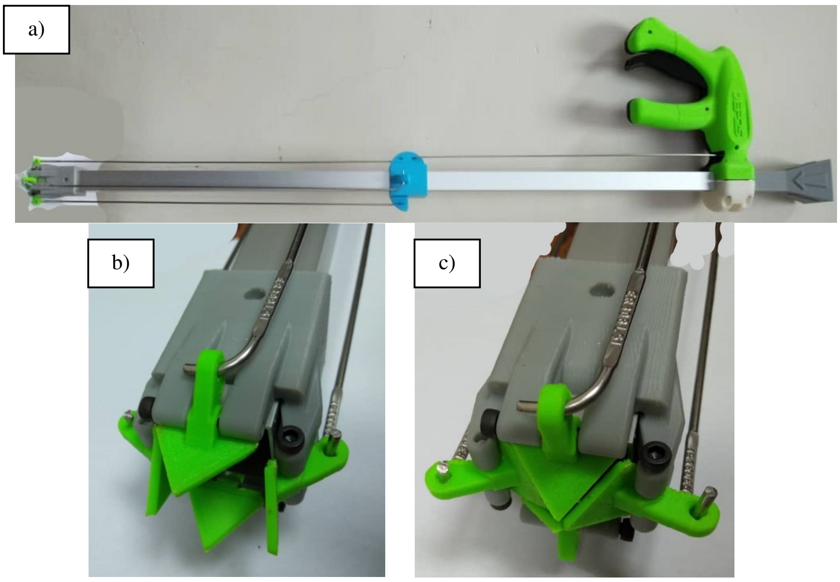

Figure 8. Working model of SRI Planting Tool. a) Assemble product. b) Open penetrator. c) close penetrator.

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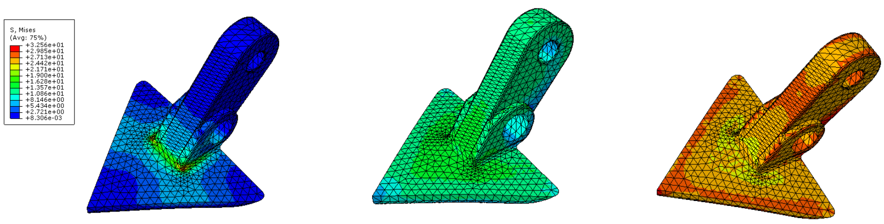
5. Finite Element Modelling

In this work, a study of the single penetrator strength using finite element modelling in the static analysis was performed in the commercial software Abaqus. An elastoplastic model was applied during analysis to simulate the behaviour and damage of the polymer type ABS in penetrator. The performance of the penetrator was analyzed in term of stress distribution, plastic strain, and failure of material where the failures are modelled with two damage initiation criteria: the ductile damage criterion and the shear damage criterion. To combine and visualize a damaging behaviour for the elastic-plastic model (isotropic elasticity and Von Mises plasticity), it requires the damage evolution law in displacement and energy type for both ductile damage criterion and shear damage. Thus, the damage evolution law is specified as the function strain failure and function fracture energy for ductile damage and shear damage [6] respectively in ABS property of penetrator besides isotropic elasticity and Von Mises plasticity.

In order to develop a material model for this polymer, a tensile test was performed with three specimens at 50 mm/min (equivalent strain rate of 0.0083 1/s) to obtain the engineering stress-strain data and then converted to a true stress-strain curve during the calibration process. In the material calibration process the elastic and plastic of ABS material data is auto calculated by Abaqus and recorded in material property library. After converting to a true stress-strain curve it shows that the average maximum yield stress is 43 MPa while the modulus of elasticity is 1350 MPa with 0.35 of Poisson's ratio. A second order tetrahedral elements (C3D10M) with an average element size of 1 mm were assigned to the penetrator region as the optimal parameters for an element type and mesh size in term of accuracy and simulation time. The penetrator was assigned a force of 50 N that respect to the perpendicular of the soil contact surface in penetrator during SRI planting process. The mass/inertia of the penetrator is neglected as the simulation is performed in static analysis. The simulation was performed in non-linear step mode with the starting incremental size of 0.1 is assigned and had a time length of 1 s. The boundary conditions were defined where all the movement and rotation towards any axis was fixed by using symmetry encastre at the two inner surface pin hole in penetrator. In post-analysis results visualisations presented on Figure 9(a) Von Mises, it shows that the maximum stress produced at critical region (joint area) of penetrator is 32.6 MPa lower than the yield stress of the ABS material. Hence, the equivalent plastic strain, PEEQ can be approximated as 0. The condition of material failure can be observed in damage initiation criteria which the ductile damage criterion defined as stress triaxiality, TRIAX and shear damage criterion as shear stress ratio, SHRRATIO that can be recalled as a field output in Abaqus. Figure 9(b) shows that stress triaxiality, TRIAX is 0.911 and for shear stress ratio, SHRRATIO in Figure 9(c) is 0.885 at the critical area of the penetrator. Thus, no failure occurred for both ductile and shear damage in penetrator as both value are below than 1 [7].



a) b) c)

Figure 9. Post-analysis of penetrator in FE-modelling. (a) Von Mises. (b) Ductile damage. (c) Shear damage

6. Conclusions

The designed tool is in the experimental stage, and the devices shown are more a 3D printed working model. Although few mechanical refinements may need for further development, the planting tool promises many advantages. It is hoped that further testing will facilitate with a new invention for large scale SRI compliance planting technique.

Acknowledgements
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