Design of transplanting mechanism for system of rice intensification (SRI) transplanter in Kedah, Malaysia

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Abstract. There is a demand to develop transplanter specifically for system of rice intensification (SRI) cultivation in Malaysia. This SRI transplanter is different from conventional transplanter as it is required special requirements for transplanting. The work focused on transplanting mechanism design which can be later attached to SRI transplanter. The mechanical design was established using linkage mechanism, having a wheel that act as timing wheel that will control the distance between transplanted seedlings. The linkage mechanism also control the opening of the flapper that allow the seedling together with its nursery soil to be dropped, and control the stopper to prevent next seedling from sliding down the tray. The use of simple mechanism will have low cost for fabrication. The design was analysed using motion analysis software. Results show the design is perfectly good and can be fabricated without any problem. The animation successfully shows the perfect movement of the mechanism and transplanting process.

1. Introduction

SRI (System of Rice Intensification) is a method synthesized in the early 1980s by Fr. Henri de Laulanie\textsuperscript{1} for comprehensively increase the yield of rice produced in irrigated farming [1] [2]. Principles included applying a minimum quantity of water for optimal effect on the growth of rice plants [3], instead of continuous flooding that can cuts off the oxygen supply to the roots [4], and the individual transplanting of very young seedlings in a similar square pattern to maintain the distance between seedlings (25 cm or more) [5]. The experiments and observations over the period revealed that there was significant reduction in the investments on external inputs. The productivity is usually more than the conventional rice cultivation [1]. Higher grain yield compared to traditional irrigated transplanted can reach up to 7 to 20 percent and it can be as high as 65 percent in certain place [2]

In 2008, SRI was first introduced in Malaysia by setting up research group on SRI paddy. This SRI was adopted in some areas in Malaysia i.e. Selangor, Tunjong Kelantan and Sik Kedah. Koperasi Agro Belantek at Kampong Lentang, Sik, Kedah has been practiced SRI method since 2010.

Transplanting SRI paddy is a real challenge as it uses young and soft seedlings (5-12 days old) [6] and almost transplanted on top of the surface of the soil. Conventional paddy transplanter uses matured seedlings and transplanting deep into the flood soil. It is also normally transplants more than one seedling. Currently SRI farmers in Malaysia transplant the SRI seedling manually. It is essential to develop transplanter for SRI cultivation to reduce load for farmers to manually transplant the
seedlings. The main challenge to develop the transplanter lies on how to design its transplanting mechanism. Therefore, this research focused on the design of transplanting mechanism that can meet SRI transplanting requirements.

2. Problem Statement
The research has studied SRI cultivation at Kampung Sri Belantek, Sik, Kedah in Malaysia to determine actual problem and design requirements of the transplanter. Most of the transplanter machine is designed for seedlings of age between 14 days to 20 days. Figure 1 shows an example of the existing transplanter machine for conventional rice cultivation. Figure 2 shows a problem that occurred when using current transplanter machine with depth of between 2 cm and 3 cm. The transplanter also used more than one seedling at each point whereas SRI method requires single seedling to be planted at each point.

Figure 1. An example of transplanter for conventional rice cultivation.

Figure 2. More than one seedlings are planted with depth of between 2 and 3 cm.

Farmers in this region have transplanted the young seedlings manually as shown in Figure 3. Firstly they use wooden marker as shown in Figure 4 to obtain constant square line. They then transplant the seedling at the intersection line manually as shown in Figure 5.

Figure 3. Single seedling manually planted at each point (SRI method).
Therefore, new transplanting mechanism for SRI transplanter is required specially for transplanting SRI rice seedlings. The mechanism that is suitable for SRI should have three major requirements; (1) Able to plant only a single rice seedling at constant distance. (2) The seedling root is planted almost on the top soil or less than 1cm of depth. (3) Use seedling of age between 8 and 14 days. Figure 6 shows the design process completed for SRI rice seedlings transplanting mechanism.

3. Design of Transplanting Mechanism

3.1. Seedlings Tray Preparation
Young seedlings that are used for SRI transplanting is very soft and weak as compared to conventional seedlings. Therefore it is almost impossible to design a mechanism that can directly grip the seedling during transplanting process.

The main idea is to transplant a seedling together with its nursery soil. Initially a high quality seed will be transplanted in slightly compacted soil in the tray as shown in figure 7. The seedlings should be ready to be transplanted in paddy field after 8 to 12 days.

3.2. SRI Transplanting Mechanism.
The design of the transplanting mechanism is shown in figure 8. The rice seedlings together with its soil from the nursery tray will be arranged on the seedlings container waiting for its turn to be transferred to the ground. The design uses timing wheel to control the opening of the flapper and hence maintain the same gap between transplanted seedlings. The design also applied linkage mechanism in order to organize the overall mechanical movement. Detail of the design is discussed in the following sections.
4. Detail Design

4.1. Timing Wheel Design
The main purpose of the timing wheel is to control the opening of the flapper so that the seedling together with its soil will be constantly dropped at the specific location. The dimension of the wheel was designed to meet the transplanting requirement of the SRI. Figure 9 shows the constraint and variables that involve for the timing wheel design. Minimum radius of the wheel $r_{min}$ can be calculated using:

$$r_{min} = \frac{l}{2\pi}$$  \hspace{1cm} (1)

Where $l$ is the distance between the two seedlings.

Since the value $r_{min}$ is based on rotation on the solid ground, it has to be added with submerged section of the wheel, $x$ during rotation on the paddy soil. Final equation can be written as:

$$r = r_{min} + x$$  \hspace{1cm} (2)

4.2. Transplanting Mechanism Design
Figure 10 shows the kinematic diagram of the transplanting mechanism. Containers that contain seedlings are placed on the track. With the help of gravity force, the seedlings will constantly drag to the end of the track. There is a flapper at the end of the track that is joined to the linkage mechanism.
that acts as a door to allow a seedling to be dropped. Detailed of the flapper kinematic diagram is shown in figure 11.

The flapper will open once a timing wheel (red) complete one complete rotation. At the same time a stopper plate which also linked to the mechanism will emerge to prevent sliding of the next seedling along the container. The flapper will close and the stopper return to initial position to allow the next seedling to slide down and ready to be dropped. This cycle will be repeated every time the timing wheel completes its rotation. Figure 12 shows the CAD drawing of the linkage mechanism when the flapper is open and close.

Figure 10. Transplanting kinematic diagram

Figure 11. Flapper kinematic diagram

Figure 12. CAD drawing when the flapper is (a) open and (b) close (shown in red circle).

4.3. Motion Analysis

The transplanting mechanism model was analysed using motion analysis integrated in Solidworks 2014 software [7] to observe its mechanical motion. Flawed design of some parts or assembly will show no mechanical movement in the analysis. Successful results of the motion analysis will ensure the successful of actual fabrication. The motion analysis result of the transplanting mechanism model shows the movement animation of the design is perfectly good. The motion of the transplanting mechanism shows no error in motion. The flapper timing which derived from the timing wheel had successfully working to transplant the seedlings. Three critical stages of the motion analysis are shown in figure 12 i.e. (i) the flapper is closed with one seedling ready to be dropped at the end of the tray, (ii) the flapper is opened to allow a seedling together with nursery soil to be dropped at the same time a stopper emerge to prevent next seedling from sliding down, and (iii) the flapper is closed while the stopper return to initial position to allow the next seedling to slide down the seedling container ready for the next drop. The cycle will be repeated once the timing wheel completes its rotation.
4.4. SRI Nursery Tray Design

Figure 13 shows detail drawing of the SRI nursery tray. It consists of two parts which are cubic partitions and bottom cover. The cover can be easily slide in order to remove the seedlings. Figure 14 shows the three-dimensional cross section view of the nursery tray.

5. Advantages of the transplanting mechanism design

The successful mechanism design can be fabricated and attached behind motorized chassis with small combustion engine as a puller. The use of timing wheel to control the drop distance of each seedling will eliminate manual line marking and thus reduce working time. This will also avoid farmers to bend forwards and down during manual transplanting.
Another advantage in using this design is the seedlings will be transplanted together with their nursery soils. Thus the potential to harm seedlings roots can be avoided. This method will improve the time taken for seedlings to reinstate with the new environment.

6. Additional Possible Work
The device currently has limitations on number of seedling that can be inserted in the seedlings container. It only can fit 30 seedlings at a time thus required farmer to refill frequently. Multiple containers with higher capacity of seedlings together with appropriate mechanism could be used to solve this problem.

7. Conclusion
The rice seedlings transplanting mechanism is designed specifically for SRI method of rice cultivation requirement. The use of this low cost and simple mechanism would promote cultivation of SRI method especially in Malaysia.

The transplanting mechanism was designed based on mechanical linkage mechanism and analysed using motion analysis tool. Results show it is perfectly fit and the mechanical movement of the design is perfectly good. The animation successfully shows the perfect movement of the linkage mechanism and transplanting process.

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