Design of Rice Transplanter

D.N.V. Chaitanya, Arunkumar S*, G. Bhanu Akhilesh, G. Saikiran Kumar, K.N.V.S. Avinash Babu*

*Department of Mechanical Engineering, Amrita School of Engineering, Amritapuri, Amrita Vishwa Vidyapeetham, Amritapuri, Kollam, Kerala - 690 525, India.

*Email address: arunkumars@am.amrita.edu

Abstract. Agriculture sector is the main source of food. This sector also forms country’s backbone and provides employment. With increasing population, it is necessary to produce food in a sustained manner. This can be accomplished by mechanizing the farming operations. Another advantage of mechanization is that it circumvents the problem of labor shortage when needed at the peak time of land preparation and harvesting. It also increases the crop yield through proper preparation of land, crop protection, efficient irrigation and minimizing the loss during the harvest. This paper focuses on the mechanization of rice planting. A review of the available rice planting methods, transplanting machines and their merits and limitations are elaborated. A new design has been proposed to overcome the problems in the existing design. With this design one can plant the seedling vertical to the ground at sufficient depth. This not only avoids the extrication of the seedlings but also ensures uniform ripening of the rice plants.

1. Introduction

Rice is an essential food for many people across the globe. It is largely grown in many countries and a major crop in India, China and other countries of South-East Asia. There are two methods of planting rice viz.: i) Direct seeding and ii) Transplanting. In direct seeding, the seeds are sown (either by row seeding or broadcasting of germinated or ungerminated seeds) in the field under dry or wet condition at the beginning of rainy season. This method of seeding requires minimum labour and well suited for upland farms. However, it suffers from few limitations. The rate of germination of all seeds is not uniform; heavy rains extricate the seeds from the soil; seeds are vulnerable for birds. Due to these inherent demerits of direct seeding, transplanting method is preferred. In this method, saplings are raised in nursery at least a month before planting. These saplings are then planted manually or mechanically in the puddled soil. The advantages of transplanting are: i) Saplings are planted at uniform spacing which aids in easy weed removal and intercultural operations ii) Requires minimum amount of seeds relative to direct seeding iii) Faster yields as the time dwell period of the crop in the land is reduced by 3-4 weeks iv) All the crops ripe nearly the same time. However, the process is laborious, expensive and requires highly skilled labour [1, 2]. The objective of this paper is to review the rice transplanting methods, existing machines for transplantation and their merits and demerits. Based on the observations from the review, a new design is proposed which overcomes the limitations of the existing designs.
2. Mechanization of Transplanting

The demand for rice transplanter is growing in the present scenario due to its inherent merits mentioned in the previous section. In addition, globalization and migration of rural people to urban areas has resulted in shortage of labour and high remuneration for the same. Hence, the timely planting of the seedlings during peak time is not possible. These factors necessitate the use of a mechanized transplanter. Mechanized transplanting as opposed to hand transplanting, is the process of planting the seedlings in the puddle soil using a machine incorporated with a planting mechanism driven by a prime mover. The source power could be animate (humans or animals) or engines. The benefits of using a transplanter are: i) Saving of labour cost, timeliness of transplanting and water saving ii) The seedlings are planted at uniform spacing and at sufficient depth iii) Increase in productivity compared to hand transplanting. Foreign-made transplanters though available, have few limitations, namely, i) they are expensive ii) repair and maintenance is not feasible in the local areas due to the complex in-built mechanism. In the light of these limitations, indigenous equipments are preferred as they are simple, low-cost and easy to maintain [3].

2.1 Types of Transplanter

Transplanters are classified based on the (a) type of nursery and (b) the source of power to drive it. There are two types of nursery [2]:

i) Washed root seedlings: The seedlings are removed from the nursery and have four to six leaves with 200-300 mm high. The roots are washed and clipped to assist in easy picking and planting. Then, these are arranged in the seeding boxes for planting. Thus this process of washing, clipping and uprooting is labor intensive and time consuming. The labor required for this process is 175 man-h/ha.

ii) Mat type or soil-bearing nursery: In this type, seedlings are raised in a soil bed prepared on a polythene sheet of thickness 150-200 mm. The soil is mixed with farmyard manure and fertilizer. Germinated seeds are then broadcasted over this soil bed. For these seeds to grow to the level of saplings a period of 20-25 days are required. These seedlings along with the soil bed are then placed on the transplanter for planting. This process requires less labor of 50 man-h/ha.

Based on the power source, paddy transplanters are classified as: i) Manually operated transplanter and ii) Self-propelled transplanter. Manually operated transplanters are driven by human beings or animals for planting the seedlings (Fig. 1). It is appropriate for planting mat type seedlings in puddled soil in rows. The number of rows may vary from two to ten. The transplanter comprises of a float, tray for holding seedling, tray indexing mechanism and picker arm for planting seedlings. As the machine is pulled by the operator, the picker draws a bunch of 2 or 3 seedlings and plants them in the soil. The distance between the rows is fixed in the mechanism, typically at 200 mm. With a six row transplanter, 0.04-0.05 ha/h can be covered with a labor of 40-50 man-h/ha and the yield increases approximately by 5-10%. The cost of this indigenous machine is Rs. 4,500 with an operating cost of Rs. 1250/ha as against Rs. 3750/ha with hand transplanting [7]. Similarly, for an eight row transplanter, the capacity is 0.15 ha/h and the cost of the machine and the human labor are higher than the 6-row transplanter.

The labors are susceptible for back pains and the machine encounters few problems in the long run. They are problems in the slacking of chain drive, high friction on the central and side of the tray, bending of picker arms [2]. These problems can be alleviated by using a self-propelled transplanter.
The self-propelled transplanter has two types: i) Walk-behind type and ii) Riding-type (Fig. 2). Both these type use mat type seedlings. The details of the traditional designs walkd-behind (Japaneese) and riding type (Chinese) can be found in Ref. [3]. Recently, a 4-row walk-behind type manufactucated by Mahindra Tractors consists of 4-stroke single cylinder gasoline engine, transmission system, planter planting the seedlings at 50 mm depth, with 300 mm distance between the seedlings with 160-210 mm planting pitch. The planting speed is ranges from 0.4 to 0.85 m/s. The total weight of the machine is 180 kg. The same company also manufactures 6-row riding type transplanter with the following features: distance between rows – 300 mm, planting pitch – 180 to 240 mm, planting depth – 20 to 50 mm, type of engine – gasoline or diesel, total weight of machine -830 kg [8]. Use tractor for transplantation is not generally preferred due to the large depressions and mud flow caused by the tractor wheels and missing of hills (nearly by 50%) [2].

3. Existing designs

The first rice transplanter was developed by Japan during industrialization and it was patented in 1898. The development was sluggish until 1955 as the focus was on commercializing the existing one. During the same time Korea mechanized the transplantation process by borrowing the technology from Japan. Further, two-wheel tractors or power tillers were developed in Japan. The first tractor was brought to India in 1914. In 1956, China fabricated a 6-row rice transplanter. This machine was used sparsely due to its inherent problems of planting seedlings unevenly and requiring considerable human effort to drive. China acquired four wheel tractors from Russia and constructed the tractor factory with the aid of Russia. In 1965, transplanters using washed-seedlings and soil-bearing nursery was first produced. From then, various transplanters were developed and marketed involving several modifications in the mechanism [4,5].

In the conventional rice transplanter, the planter or finger (Fig. 3a) is moved in such a way that it passes through the slot in the tray containing seedlings. During this motion, the finger traces circular path and picks the seedlings. During return, the finger executes elliptical path in order to avoid hitting the seedling tray. Generally a four bar linkage mechanism is used to accomplish this event. The manually operated 2-row transplanter shown in Fig. 3b, consists of ground wheel with fins in contact with the ground, sprokets for power transmission through chain, a four bar linkage mechanism to provide motion for the planting finger and a tray to hold the saplings. As the transplanter is pulled by the operator, the ground wheel moves in the mud smoothly due to the fins and drives the four bar mechanism. The ratio of the of driver to driven speed was mainted at 3:1 to reduce the effort of the operator. The planting finger picks the saplings during downward motion tracing a circular path and plants in the soil. The capacity of the transplanter is 0.2-0.3 ha/day and the cost of the machine is Rs. 6000/-. Similar rice transplanters developed by the other authors is shown in Fig. 3c and 3d. These designs were developed as an alternative to the designs of Ref [12], as they were built using complex mechanisms.
Some of the planting faults were observed in the existing mechanisms. They are: i) the seedlings are planted in an inclined direction and at insufficient depth because of the circular motion of the planter (Fig. 4). Hence, some part of the roots may be exposed to air and prevented from nutrient absorption from the soil. As a consequence they may not grow properly ii) The use of sharp pins in the planter damages the seedlings. To overcome these demerits a new planter mechanism is proposed which is shown in the Fig. 5 and Fig. 6. The basic construction of this transplanter is nearly similar to the designs described above with the exception of planting finger mechanism. The mechanism is built using six links and shape of the planter is “L”. To prevent the bending of the planter, it is provided with “C” shaped rib. The planter starts tracing a circular path and its trajectory becomes straight as it moves further. Then, it picks the seedling from the tray situated on a side and plants straightly in to the field at sufficient depth. During return it retraces the same trajectory without hitting the tray. Thus, the seedlings are planted vertically in the soil. In the next phase of this work, it is aimed to carry out

**Figure 3.** (a) Schematic of rice transplanting machine [9] (b) Isometric view of rice transplanter [10] (c) Rice planter machine [11] (d) Paddy transplanting machine [3]
numerical simulation of the proposed design which involves kinematic and dynamic analysis. The design is then optimized based on the numerical results and then ensued for fabrication.

![Trajectory of planting finger](image)

**Figure 4:** Circular trajectory of the finger resulting in oblique planting of the seedling with respect to the ground.

![Modified rice transplanter](image)

**Figure 5.** Modified rice transplanter

![Planter mechanism in the modified rice transplanter](image)

**Figure 6.** Planter mechanism in the modified rice transplanter

**Conclusions**

Design and development of low cost and efficient farm implement plays a vital role in sustaining the farmers holding small fields due to the sparse availability of laborers. Several designs though available in the market cannot be afforded by these farmers due to high initial investment and maintenance. Hence a simple and cost effective rice planter is the most promising in these circumstances. Nevertheless, there are few limitations with these transplanters as for the planting mechanism concerned. Due to the circular trajectory of the planter, the seedlings are planted in an inclined direction which is susceptible for extrication and improper growth. Hence, a new planter design is proposed in this work which overcomes this problem. With the proposed design, seedlings are planted vertically to the ground at sufficient depth by making the planter to travel in the straight path.
References

[1] www.nzdl.org
[2] A. Dixit, R Khurana, J. Singh, G. Singh, *Agric. Rev.*, 28 (2007) 262-269.
[3] S.V. Balbhudhe, D.H. Baghele, D.N. Shirke, M.C. Gaikwad, P.S. Bobde, U.G. Bisen, H.M. Bansod, *Int. J. Ana. Exp. FEA*, 3 (2016) 9-12.
[4] K.H. Ryu, *Proc. Int. Conf. Small Farm Equipment for Developing Countries: Past experiences and Future Priorities*, (1986) 237-254.
[5] Agriculture Mechanization and Testing of Agriculture Machinery in the Asia-Pacific Region, CSAM (2004).
[6] Operational Manual for Mechanical Transplanting of Rice, The Central Systems Initiative for South Asia, 2015.
[7] http://www.icar.org.in/en/node/9776.
[8] www.mahindratractor.com/tractor-mechanisation-solutions/implements/walk-behind-rice-transplanter.
[9] U. Kumar, E.V. Thomas, *Agri. Eng. Int.* 17 (2015) 30-43.
[10] S.Kumbhar, S.Khot, S.Mohite, S.V.Pandit, *Int. J. Innov. Res. Sci. Eng. Tech.* 6 (2017) 3699-3705.
[11] D.D. Patil, M.R. Phate, *Imp. J. Inter. Res.* 2 (2016) 1241-1246.
[12] M. Kumar, *Mfg. Process. Journal*, IIT Kanpur, India, (2015) 1-9.