



# Development of Manual (Pull-type) Two-row Paddy Transplanter for the Benefit of Small Farmers' Land Holdings

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## **Authors' contributions**

*This work was carried out in collaboration among all authors. Author KRA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author Padmashree managed the analyses of the study. Author BRMR managed the literature searches. All authors read and approved the final manuscript.*

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## **ABSTRACT**

Paddy (rice) is considered as the most important staple food-cereal crop in south-east Asian countries. It is the majorly consumed food in India. Transplanting of paddy is a highly labor-intensive operation and is still done manually. It takes around 182 to 250-man hours a day to manually transplant rice. Also, many a time due to shortage of labour, transplanting is delayed which causes a progressive decrease in yield. The scarcity of labour during the peak season of transplanting creates a problem to complete the transplanting operation in time. Manually operated paddy transplanter can be useful for small and marginal landholdings. Here we intended to develop equipment that should be of low cost, fabricated locally, versatile in utility, reducing drudgery by making transplanting possible without bending and useful for small farmers. The developed two row rice transplanter prototype can transplant 20 to 25-day old seedlings up to 5 cm depth with adjustable row spacing of about 15-20 cm. It requires two operators, one for filling the tray while walking behind and another for pulling the transplanter while walking in front of the machine. The actual filed capacity of 0.2 ha per day (eight hour working day) was achieved with the machine by considering a 5%- and 3%- time loss due to turning and filling tray respectively.

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## 1. INTRODUCTION

In Asia, transplanting of rice seedlings into puddled fields is widely practiced, mainly to enhance weed control. Transplanting requires less seed material, but much more amount of energy, and because of the transplant shock, the crop takes a bit longer time to mature. Rice is an annual semi-aquatic plant, the developing world's most important crop among all cereals [1-3]. Paddy (Rice) is grown in wetland with direct sowing method or transplanting depending on water availability, wetland conditions, etc.

In paddy production, India ranks second after China [4]. In India, paddy is grown on more than 43 Mha area with a production of about 112.91 million tonnes. This constitutes about 40 per cent of the country's major food grain production. West Bengal is the largest paddy producing state of the country with 15.09 million tonnes of production rate under 5.15 Mha area. The country's total production of paddy during 2017-18 was 112.91 million tones in comparison to 0.69 million tons during 1971 [5].

Roughly 90% of Asian countries cultivate and consume rice. Although Rice currently feeds over half of the world's population it is foreseen that it could not do this very well much longer because the demand is increasing just as the population is increasing although crop yields are topping out [6,7]. Throughout Asia, the big challenge is feeding another 650 million rice eaters by 2025. This raises the question of "how the current annual production rate of rice exceeds 700 million tons using less water and less land area". A study showed that most Asian countries would not be able to feed their potential populations without irreversibly destroying their land resources, even with high levels of supplies from management [8]. Seedlings are grown in the nurseries for different time frames before they are transplanted. Traditional varieties are transplanted 40 to 80 days while modified varieties are transplanted within 20 days after seeding respectively.

Manual transplanting of paddy is labor-intensive work. It may need 30 to 40 people in a day to plant one hectare of paddy, depending on the soil. Transplanting is usually extended by another 1 to 3 days after completing the final soil preparation work on loamy and clay soils due to the weakness of the soil in supporting the

seedlings [9-11]. In some sandy soils, transplanting is undertaken within hours of final harrowing or else the soil becomes too hard to manually implant the seedlings. In areas where there has been insufficient rain and the soil is hard, transplanting may also be done in non-flooded soils by using a stick to make a hole to implant the seedlings. In the random transplanting method, seedlings are transplanted without a definite distance or spacing between the plants. The straight-row transplanting method follows a uniform spacing between plants and the seedlings are transplanted in straight rows. The second method involves the standardized arrangement of planting guides in the form of twine, wire, and timber or wood to obtain desired uniform spacing. The wood marker is used to transplant in straight rows by means of marking the rows to the desired width with 20 to 25 cm spaced marker teeth. Planting in straight rows will make it easier for weeding and application of fertilizers, herbicides, insecticides and more importantly, to get the best plant spacing. Plant spacing is an important factor in rice transplanting. Proper spacing alone can increase the yield by 25 - 40% and also saves costs on inputs, labor, and materials.

### 1.1 Mechanical Transplanting of Paddy with the Machine (History, Origin and Development)

The rice transplanter was first developed during the 1960s in Japan by the Kubota corporation. These machines proliferated the whole of East and South Asia during the 1970s and 1980s. A rice transplanter is a machine specifically designed to aid in transplanting rice seedlings into paddy fields. Although rice is grown around the world, rice transplanters are mainly used in East, Southeast, and South Asian countries. Land needs to be well prepared for machine transplanting. The soil must be leveled enough to bear the machine weight that it carries and support the seedlings that are to be planted.

Complex transplanter machines are manufactured in Japan, South-Korea, China, Taiwan, and other countries. These machines range from walk-behind models (two rows) to ride-on models (eight rows). Most mechanical transplanters place seedlings in rows 30 cm apart with in-row spacing determined by forwarding speed. These machines generally help to produce larger yields with considerably

less time and labor than manual transplanting. Rice transplanters initially operated on basic principles before they became extremely high-tech machines. Farmers are required to drive the machine along a straight line to transplant the seedlings in straight rows, however, "driving a transplanter on an exact straight line is a delicate and difficult work even for a skilled operator". Continue from here.

A new system was developed in 2005 that plotted the position of seedlings on a virtual plane and fit probable line on it. The prototype system was attached to a Kubota rice transplanter for testing. It was equipped with motor sensors, computers, and two CCD color cameras. The system operated at a processing frequency of 10 hertz, with a maximum working velocity of 3.5 feet per second (1.1 m/s). The cameras captured RGB images and converted them to lab images, which are designed to approximate human vision. The computer software uses that image to extract seedling row location and calculate its angle and displacement. The rice transplanter motor then steers the machine according to the angle, displacement, and working velocity. Experiments showed that the angle of the rows gradually shifted, but the displacement was steady. Seedling trays were used in transplanter where seedlings are in mat type nurseries. The tray moves seedlings like a typewriter carriage as the pick-up forks bring seedlings out of the tray and place them on the soil surface. The pick-up forks act as human fingers by extracting the seedlings from the tray and driving them into the soil. There are both ride-on and walk-behind models of rice transplanters [12,13]. The components of the machine may vary depending on the manufacturer although many features are universal. Transplanting paddy is a very tedious job mainly performed by female workers during the Kharif season, and by 2020 there would be 50percent female workers versus 42 percent males. Manual hand transplanting consumes a lot of energy, time and full of fatigue, but the poor socio-economic condition of the farmers does not allow them to adopt power operated transplanter because about 70% of them have small and marginal landholdings [14]. Releasing of the workforce to sectors other than agriculture is important to develop the country because a large portion of the land in India is under the paddy rice cultivation. Mechanization will play an important role before the workforce could be released from the paddy production sector into another sector [15,16]. This is inevitable to

overcome the huge challenge of feeding the ever-growing population. The only alternative to this which is rice importation will lead to draining out the economy of the country. Undoubtedly, mechanization of the paddy sector will lead to higher productivity with the release of the critical mass of the workforce to other sectors in the country. The objective of this project was to develop a manually drawn (pull type) low-cost paddy rice seedling transplanter for resource-poor farmers with small landholdings in addition to its usefulness in the hilly areas because of its lightweight.

## 2. MATERIALS AND METHODS

The transplanter must be easy to operate, transport and be of low or reasonable cost. Hence material selection should match the desired outcome. Here, we decided to make our equipment lighter in weight, to make it easy to carry to the field as required. The developed machine has a simple construction with wooden planks, chain sprockets, Metal flats and shafts made of cast iron, bearings and bushes, alloy steel tray and fitting accessories. The schematic diagram of the developed transplanter and specifications for the machine elements are as shown in Fig. 1 and Table 1 respectively.

The working principle of the manual transplanter is such that a ground wheel that drives the entire system requires a single person to provide the required pulling force for the implement. The compound gear mechanism is powered by the ground wheels. The implement is provided with extra holes on the shaft for depth adjustments by changing the leverage distance. The Paddy rice seedlings are carefully arranged in the tray and allowed to flow down under gravity. The forks which are attached to the shaft pick up the horizontally placed seedlings from the tray and placed safely on the puddled paddy field. The motion of the shaft is provided by a compound gear mechanism using a chain and sprocket arrangement powered by a ground wheel (circumference of 100 cm).

Wood was used as the framing material to facilitate easy working, modification and easier machining. As per the purpose of the project, wood is low cost and locally available. Hence it gave us a strong background in material selection. The model schematic diagram consists of a rectangular base with 75 cm in length and 35 cm width and two right-hand triangles with 75 cm as a base and a height of 36 cm facing each

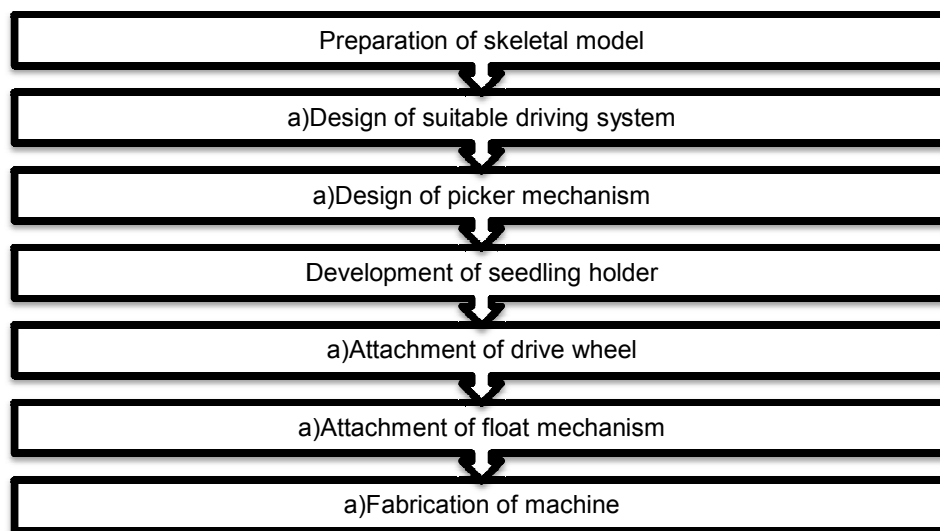
other on either side of the machine (Fig. 2). The two triangular portions act as support for other parts and the base holds the triangular portions in a proper position.

Designing a suitable driving system is an important step in any machine development. Given this, several factors were considered before selecting a particular type of driving system. Usually, for field operations, gears or

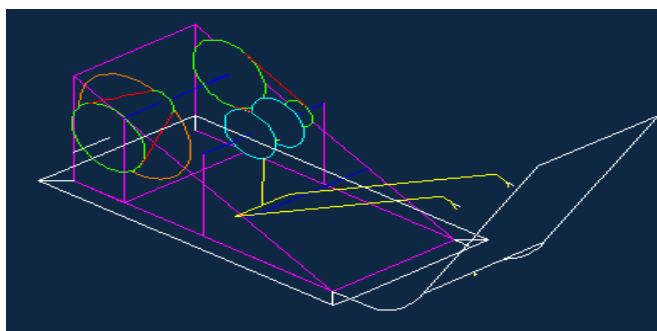
chains are preferred. In this case, the chain drive mechanism has been adopted so to reduce the cost because gear drive mechanisms are much more costly. The benefits of this adopted system of the drive are less slippage and versatility in its use under various operating conditions. To maintain the desired spacing, compound chain drive was introduced; based on availability and suitability two sprockets with 48 teeth and 18 teeth were selected (Fig. 3).

**Table 1. Specifications of the pull-type, two-row rice transplanter**

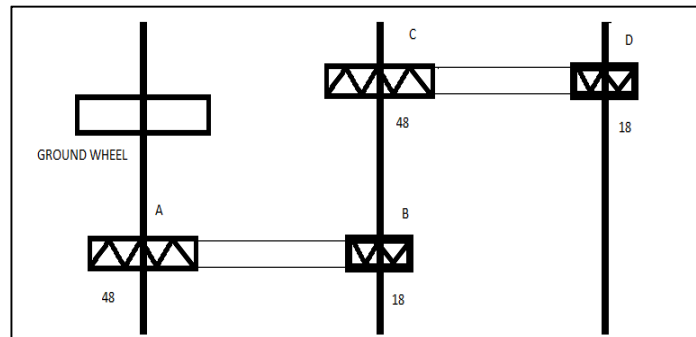
1. Length of model	100 cm
2. Width of the model	35 cm
3. Height of model	40 cm
4. Circumference of the ground wheel	100 cm
5. Power source	Ground wheel
6. Type of wheel	Peg type
7. Row spacing	15-20 cm
8. Depth of Planting	5 cm below the soil
9. Gear speed ratio	1:7.11



**Fig. 1. The workflow of the developed transplanter**



**Fig. 2. Schematic diagram of the paddy rice transplanter**



**Fig. 3. Mechanical power transmission system for the transplanter**

Although the recommended depth for placing paddy seedlings in current agronomic practice is 3 to 4 cm, the machine was designed to place the seedlings at a maximum possible depth of 5 cm.

Seedling holder development involves designing the height and inclination of the seedling holder. The height is a parameter of the area and inclination is a parameter related to the crop characteristics. The inclination must facilitate the flow of seedlings at the desired speed to maintain an equal population in the hills. It must not release all the seedlings at a time so that improper transplanting may occur. It is placed at a height of 15 cm from the ground to facilitate the easy placement of seedlings without any loss. The seedlings are to be placed horizontally and young seedlings of height approximately 20 days old are preferred to suit the operation.

The drive wheel or ground wheel is fixed on the front side for uniform weight distribution at the center of the machine and to facilitate easy movement of the machine. For every revolution of the ground wheel, there will be approximately 7 hills planted by the picker mechanism. The drive wheel is provided with lugs to facilitate movement and to avoid wheel slip which causes uneven planting (Fig. 4). The drive wheel is attached to the machine through a shaft made of cast iron with a diameter of 2 cm. The shaft is supported with a ball bearing enclosed in a housing attached to the machine. It facilitates easy movement of the wheel and hence requires less effort in operation.

Floating is very essential for the machine because it ensures that the machine does not sink deep inside the soil while operating in the wet field. The floating device is attached to the machine by screws at the bottom and it is rectangular in shape matching with base

dimensions of the machine. It is essentially of low weight material.



**Fig. 4. Drive wheel**

**Fabrication:** The basic components of the project which have been fabricated are the mainframe, lug wheel, tray, fingers, shaft, sprockets and chain, float and handle. The mainframe made of wooden logs is 3 cm thick. Wooden logs are cut according to required dimensions and joined using nuts and bolts. The length, height, and width of the frame are 1.0 m, 0.38 m and 0.30 m respectively (Fig. 5).



**Fig. 5. Mainframe**

The wheel Lugs are made from 2.0 cm width mild steel (MS) flat bars. The wheels are made from the same material with 1.0 m Length, bent with

the use of some tools like a hammer to form a circular shape. After getting the required shape the endpoints were then welded together. Thereafter, Lugs were welded onto the wheel external circumference (Fig. 4). The tray is made of MS sheet according to its dimensions and mounted in such a way that seedlings should freely fall based on the angle of repose. Fingers are used to pick up paddy rice seedlings from the tray and to keep it on the skid. There are two fingers, spaced at 20.0 cm apart attached to the shaft. The required motion for the fingers is provided by the compound gear mechanism. The total length of each finger is 40.0 cm each with extra holes drilled on them to allow for adjustments of their lengths to change the depth of transplanting.



**Fig. 6. Finger mechanism**

The shaft is a rotating element that transmits motion or power from the driving wheel to the machine functional elements. One shaft carries the fingers while another one carries the lever mechanism that carries the power transmitted from the lug wheel.

Shaft dimensions: Length = 30.0 cm; Diameter = 2.0 cm (Fig. 7).



**Fig. 7. Shaft**

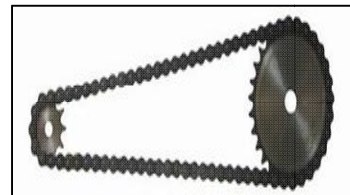
The Sprockets are used to multiply the number of rotations of the shaft to the level required to drive

the rotating fingers and lever mechanism (Fig. 8). The chains are used to transmit power from the lug wheel to the shaft to which the fingers are attached for their movement (Fig. 9).

The handle is used for pulling the implement. It is fabricated in such a way that it can easily be used to pull the implements without any bending or side thrust.



**Fig. 8. Sprockets**



**Fig. 9. Open chain drive**

### 3. RESULTS AND DISCUSSION

Field tests conducted at the testing field of the College of Agricultural Engineering, UAS-GKVK Bengaluru. Preliminary test results were used to modify some of the machine operating and geometric parameters such as tray height, planting depth, smooth driving mechanism, fingers sharpening and leverage distance adjustments. The total cost of transplanting was calculated as Rs. 5000/-, including machine and operator costs, transplanting costs and other required wages. The developed rice transplanter prototype can transplant 20 to 25-day old seedlings with 5.0 cm planting depth and adjustable row spacing of about 15-20 cm. It requires two persons to operate, one for tray filling and another for transplanting operation by walking behind the machine. The actual field capacity of 0.2 ha per day (eight hours of working) was achieved with the machine by considering a 5% loss of time in turning at the end land and a 3% loss in filling the transplanter tray. The developed prototype is suitable for semi-wetlands and small landholdings with costs as given in Table 2.

**Table 2. Cost outlay of the developed prototype**

Item name	Quantity	Total cost (In Rupees)
Wooden planks	4.77 m	235
Metal solid shaft (2.0 cm dia. and 35.0 cm length)	1 No.	250
Hollow shaft (1.5 cm dia. and 35.0 cm length)	1 No.	170
Metal solid shaft (1.0 cm dia. 35.0 cm length)	1 No.	150
Metal solid shaft (1.5 cm dia. and 35.0 cm length)	2 No.	400
Metal plate (7.5 cm dia.)	2 No.	160
Ball bearings with housing (2.0 cm dia.)	2 No.	500
Ball bearings (1.0 cm dia.)	2 No.	100
Sprockets (18 teeth)	2 No.	180
Sprockets (48 teeth)	2 No.	240
Roller chain	2 No.	140
MS flat	4.3 m	516
Metal tray (35 cm * 100 cm)	1 No.	350
Metal tray (35 cm * 50 cm)	1 No.	200
Fittings- Screws, bolts, etc.	-	350
Miscellaneous	-	300
<b>Total Cost</b>		<b>4,241</b>

#### 4. CONCLUSION

A survey conducted among the farmers shows that a huge amount of labor was required in growing nursery, transplanting and harvesting operations, all of which constitute a time-consuming process. Manually drawn paddy rice transplanter, as one of the most important cost-saving technologies by reducing the required seedlings quantity to a minimum, lesser manpower in paddy crop cultivation and can be adopted in the hilly regions. It is a low-cost implement. This can be a boon to forming a community lower in cost. The errors still prevailing has to be addressed. There are opportunities to improve like a plant to plant spacing, replacing wood with low weight metal with more modifications. It can be fabricated locally, versatile in utility, reducing drudgery by making transplanting possible without bending. It is useful for small & marginal farmers (in the hilly region we cannot carry bigger machines). Further study is required to modify the machine to improve its performance and to extend its use.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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