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Design and Fabrication of Manual Rice Transplanter

[1]Rajib Bhowmik, Assistant Professor, Girijananda Chowdhury Institute of Management and Technology, Guwahati, India, rajib_me@gimt-guwahati.ac.in

[2]Chitta Raktim Kakati, [3]Deepjyoti Dhar, Student, Girijananda Chowdhury Institute of Management and Technology, Guwahati, India, [2]chittarocktimkakati@gmail.com, [3]deepjyotidhar123@gmail.com

Abstract: **Agriculture is the most important sector of Indian economy. A major population of India is engaged in agriculture. Rice being the major crop cultivated in India, a huge amount of workforce is engaged in rice production. The common practice of rice cultivation is manual transplanting of seedlings in the puddled soil. Besides being costly, cumbersome and time consuming it is a very labour intensive task. To mechanize the transplanting system several attempts have been made to design and fabricate transplanting machines. Due to the high price of an automated rice transplanter it becomes impossible for a farmer to buy a non-subsidized automated rice transplanter. Thus an attempt has been made to fabricate a manual rice transplanter which is effective as well as low cost. Selection of an efficient power transmission system and a suitable mechanism to drive the planting claw is given due consideration in its design. The results obtained shows that the distance between two saplings is found to be 0.168m. It is seen that total time taken for the 20m ×20m is 3.13 hours. The field efficiency is calculated as 86.70%.**

Keywords* — *manual rice transplanter, design, fabricate, field efficiency, agriculture, mechanism.

I. INTRODUCTION

Rice (*Oryza sativa* L.) is a member of gramineae family. Around half of the world's population, mainly the Asian people considered rice as a major food crop [1], [2]. Around 90% of the total world's production and consumption is contributed by Asian countries [3]. Rice is the most important food crop of India covering about one-fourth of the total cropped area and providing food to about half of the Indian population. In India, 39.16 million hectares area is mostly occupied for rice cultivation. Out of these, 85.59 million tonnes of rice is produced with average yield 2.2 ton per hectares [4]. In India, around 106.19 million tonnes of rice is produced in the year 2013-2014 [Annual Report, 2013-2014]. Out of 10,000 varieties of rice available in the world, only 4000 types of rice are grown in India. This is the staple food of the people living in the eastern and the southern parts of the country, particularly in the areas having over 150cm annual rainfall. Rice production in India accounts for a significant contribution of nation's economy. Rice is grown under varying conditions in India from 8^0N to 25^0N latitude and from sea level to about 3000 m altitude. The average temperature required for rice cultivation ranges from 21^0C -37^0C [5].

North Eastern region of India mainly depends on rice. More than 80% of the total cultivated land is occupied by rice cultivation and in terms of total rice cultivation area in India, it occupies only 7.8%. However, the average rice productivity in North East region is estimated to be 1.57 tons per hectare [6]. The various method of establishment of rice depends on (i) age of the variety (ii) availability of moisture (iii) climatic conditions (iv) availability of inputs and labour. One of the most important methods of establishment of rice is the availability of inputs and labour. The rice production mainly involves the following three steps i.e., Pre-Planting, Post-production and Growth. There are four different methods of rice cultivation in India i.e. Broad casting method, Drilling method, Transplantation method, Japanese method.

In India, several attempts have been made to mechanize rice transplanting operation by introducing various transplanter and these researches is under progress to improve the cost of production with less fatigue. Therefore, study is conducted to compare the ergo-economical suitability of different transplanter with local hand transplanting procedure. Local transplanting requires frequent bending down and straightens up for transplanting process whereas mechanical transplanter requires energy for pulling the transplanter in puddle field. Hence an attempt has been made to fabricate a low cost manual rice transplanter that can reduce time and effort of the farmer.

II. METHODS AND MATERIALS

A. Methodology

Manual Rice transplanter consists of a finned ground wheel, tray for seeding, power transmission system, chain and sprocket, handle. When an effort is made to push the transplanter in forward direction, ground wheel shaft rotates. The driver sprocket attached with the ground wheel shaft will then rotate and hence transmit power to the driven sprocket attached to the driven shaft. The four bar mechanism attached to the driven shaft will in turn oscillate and pick the seedling from the tray by means of a planting

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fork attached to the tip of the four bar mechanism. A mild steel tray 400mm × 200mm × 30 mm is mounted at the top of the main frame of the manual rice transplanter. The tray can accommodate 15 seedlings at a time. The fabricated manual rice transplanter is shown in figure 2 below

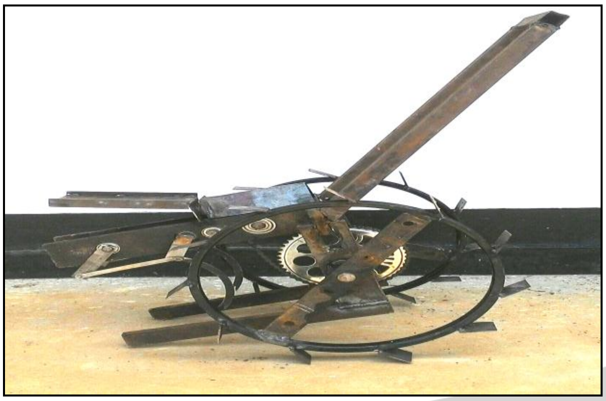

Fig. 1: Fabricated Manual Rice Transplanter

B. Working of four bar mechanism

The power transmitting mechanism of the transplanter is achieved by a simple four bar chain, also known as quadric cycle chain. A four bar chain has four links and four pairs which are turning in nature. The links are of different lengths. One of the rotating link is known as the crank or driver and the other link as follower or rocker. The member connecting the crank and the follower is known as connecting rod and fixed link is the frame. The crank is the shortest link and makes complete revolution. To obtain a mechanism from a chain, one of the links has to be fixed.

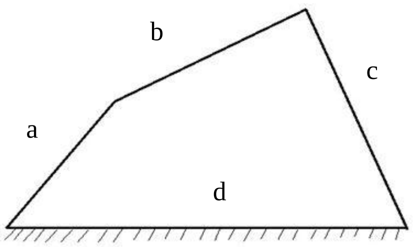

Fig.2: Four bar mechanism

Link length of a four bar mechanism can be calculated by the Freudensteins's Equation [7].

$$K_1 \cos\theta_4 - K_2 \cos\theta_2 + K_3 = \cos(\theta_2 - \theta_4)$$

where,

$$K_1 = d/a$$

$$K_2 = d/c$$

$$K_3 = \frac{a^2 - b^2 + c^2 + d^2}{2ac}$$

C. Design Methodology of rice transplanter

Speed of driving sprocket is calculated by

$$N_1 = \frac{(\omega \times 60)}{2\pi}$$

Spacing between successive saplings is determined by

$$D_s = \frac{C}{TR}$$

Linear distance travelled by the transplanter in one complete rotation of wheel or circumference of the wheel is determined by

$$C = \pi \times D_w$$

Overall velocity ratio is calculated by

$$TR = SR \times GR$$

Sprocket velocity ratio is calculated by

$$SR = \frac{S_1}{S_2}$$

Gear velocity ratio is calculated by

$$GR = \frac{Z_1}{Z_2}$$

Speed of driven shaft (N_2) is determined by

$$N_1 S_1 = N_2 S_2$$

Number of plantings per minute can be determined by the following relations

A. $N_c = N_1 \times TR$

D. Design of Gear Drive

In order to design the system, some starting point parameters have to be determined and fixed. From those initial design parameters, all the parameters can be calculated. Hence for designing a manual rice transplanter, the following parameters are to be considered [8].

(i) The power to be transmitted.
(ii) The speed of the driving gear.
(iii) The speed of the driven gear or the velocity ratio.
(iv) The center distance.

E. Spur Gear Design

Module of the gear is calculated by

$$m = \frac{D}{Z}$$

Gear ratio is determined by

$$GR = \frac{N_2}{N_3} = \frac{D_2}{D_1} = \frac{Z_2}{Z_1}$$

Circular pitch is determined by

$$P_c = \frac{\pi D}{z}$$

F. Force analysis on the gear

Tangential force is determined by

$$F_t = \frac{2M_t}{d}$$

Torque is determined by

$$M_t = \frac{10^6 P}{\omega}$$

Radial force is given by

$$F_r = F_t \tan\alpha$$

Normal component of force is calculated by

$$F_n = \frac{2M_t}{d \cos\alpha}$$

Maximum dynamic load is calculated by

$$F_d = F_t + \frac{k_3 v\,(C_b + F_t)}{k_3 v + \sqrt{C_b + F_t}}$$

Line velocity is estimated by

$$v = \frac{1000\,PC_s}{F_t}$$ for steady load C_s=1

Limiting load for wear is calculated by the following relation

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$F_w = d_1 Qbk$

Ratio factor is given by

$Q = \frac{2Z_2}{Z_1 + Z_2}$

Beam strength of the gear or the endurance strength of gear for steady loads is given by

$F_{en} = 1.25\, F_d$

Dynamic strength of gear is determined by

$F_s = \sigma_d bYm$

G. Selection of Chain drives

In order to ensure perfect velocity ratio, chain drive is used for transmission of motion and power from one shaft to another. The drive is selected from the data handbook. Total length of the chain can be calculated by

$$L = 2x + \pi r_1 + \pi r_2$$

Tension on the chain drive can be determined by the following procedure is given below

$T_1 = \frac{1000 \times P}{v}$

Velocity of the chain is calculated by

$v = \frac{s_1 p n_1}{60 \times 10^3}$

Torque transmitted is given by,

$$T = \frac{P \times 10^6}{\omega}$$

H. Design of Shaft

Shafts are machine component that support rotating parts of the transplanter. For the design aspect, the shaft subjected to combined twisting moment and bending moment with fluctuating load is considered. In actual practice, the shafts are subjected to fluctuating torque and bending moments. In order to design a shaft, the combined shock and fatigue factors must be taken into account for the computed maximum twisting moment (T) and maximum bending moment (M). The diameter of the shaft is calculated by the following equation

According to maximum shear stress theory or Guest's theory

$$d = \left[\frac{16}{\pi \tau_{max}}\left\{\sqrt{(K_m \times M)^2 + (K_t \times T)^2}\right\}\right]^{\frac{1}{3}}$$

According to maximum normal stress theory or Rankine's theory

$$\boldsymbol{d = \left[\frac{16}{\pi \sigma_{max}}\left\{\sqrt{(K_m \times M)^2 + (K_t \times T)^2}\right\}\right]^{\frac{1}{3}}}$$

III. Results and Discussion

Calculations are carried out based on the developed design. The detailed analysis and calculated values of the manual rice transplanter is shown step by step. The various calculations involving the working mechanism are done below.

A. Calculation of speed of driving sprocket

Table 1: Various parameters calculated for driving sprocket

Parameters	Units	Values
Angular velocity of the driving sprocket	rad/s	2.50
Speed of driving sprocket	rpm	24
Linear distance travelled in one rotation of wheel	m	1.26
Sprocket velocity ratio	--	3
Gear velocity ratio	--	2.50
Distance between two saplings	m	0.168
Speed of claw	rpm	180

B. Calculation of link lengths

Table 2: Output follower angle for corresponding input crank angle

Input Crank Angle, θ_2	30º	50º	80º
Output Follower Angle, θ_4	0º	30º	60º

Substituting the values of the input crank angle and output follower angle in the Freudenstein's equation, we get

$K_1 = 1.8321$

$K_2 = 1.4294$

$K_3 = 0.2718$

The following table gives the values of the link lengths, found by fixing the length of one of the links. Assuming the length of the fixed link (d) remains fixed

Table 3: Tabulation of link lengths

d (mm)	a (mm)	c (mm)	b (mm)
10	5.46	7.00	12.57
20	10.92	13.99	25.14
30	16.37	20.99	37.71
40	21.83	27.98	50.28
50	27.29	34.98	62.84
60	32.75	41.98	75.41
70	38.21	48.97	87.98
80	43.67	55.97	100.55
90	49.12	62.96	113.12
100	54.58	69.96	125.69
110	60.04	76.96	138.26
120	65.50	84.95	150.83
130	70.96	90.95	163.40

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Table 4: Length of the four links of the rice transplanter is calculated as follows

Link	Units	Values
a	*mm*	65
b	*mm*	150
c	*mm*	85
d	*mm*	120

C. Design of Gear

Table 5: Calculations of Standard tooth proportion of involute spur Gear

Gear Terms	Unit	Values
Addendum	*mm*	2
Dedendum	*mm*	2.5
Tooth thickness	*mm*	3.14
Working depth	*mm*	4
Pitch diameter	*mm*	100
Outside diameter	*mm*	104

Table 6: Various parameters calculated for selection of chain drive as shown below

Paramters	Units	Values
Length of the chain	*mm*	706.96
Velocity of the chain	m/s	0.18
Torque transmitted	$N-mm$	55624.65
Power transmitted	kW	0.057
Diameter of wheel shaft	*mm*	6
Diameter of Gear shaft	*mm*	6
Diameter of Idler and pinion shaft	*mm*	6

D.Field Experiment

In this paper, 20m ×20 m size field is considered for the experiment. The various factor considered to determine the time required to complete the transplanting of seedling. The sum of all the factors will give the exact time for transplantation process. The factors are time taken to cover the field, the time taken to turn the transplanter from one row to the next consecutive row, the time taken to fill the tray and also the time taken to for any repairing process made during the experiment.

Fig. 3: Testing of Manual Rice Transplanter

E. Performance Parameters during field experiment

The detailed performance analysis of the experiment carried out over a 20m ×20 m size field is shown below in table

Table 7: Performance Parameters

Parameters	Units	Values
Size of field	m × m	20×20
Linear distance travelled in one rotation of wheel	m	1.26
Time taken for transplanting the whole field	min	163
Time consumed for turing from one row to the other	min	7
Time consumed for filling seedling in the tray	min	8
Time taken for any type of repair during transplanting	min	10
Number of saplings transplanted per min	--	180
Field Efficiency	%	86.70
Time taken for transplanting per square metre of paddy field	sec	49
Total sapling planted in the field		29340
Number of saplings transplanted per m^2	--	147
Distance between two saplings	m	0.168

IV. Conclusion

The fabricated manual method of rice transplanting gives a quite satisfactory result. By incorporating mechanical means of transplanting seed reduces human effort in comparison to conventional transplanting. The results obtained from the experiment are that small amount of time is lost during turning of the transplanter in between the consecutive rows as well as time lost during any repairing. The distance between two saplings is found to be 0.168m. It is seen that total time taken for the 20m ×20m is 3.13 hours. The field efficiency is calculated as 86.70%.

Nomenclature

v_{avg}	average walking speed of man, m/s
r	radius of the wheel, mm
N_1	speed of the driving sprocket, rpm
N_2	speed of the driven sprocket, rpm
S_1	number of teeth on the driving sprocket
S_2	number of teeth on the driven sprocket
C	circumference of the wheel, mm
D_s	distance between two saplings, mm
D_w	diameter of the wheel, mm
SR	sprocket velocity ratio
GR	gear velocity ratio
TR	overall velocity ratio
N_c	speed of claw, rpm
Θ_2	input crank angle, degree
Θ_4	output follower angle, degree

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D	pitch circle diameter, mm
Z	number of teeth
N_3	speed of pinion, rpm
Z_1	number of teeth on driving gear
Z_2	number of teeth on driven gear
D_1	pitch circle diameter of driving gear, mm
D_2	pitch circle diameter of driven gear, mm
P_c	circular pitch, mm
F_t	tangential force, N
M_t	transmitted torque, N-mm
P	power transmitted, kW
α	pressure angle, degrees
v	line velocity, m/s
F_n	normal component of force, N
F_d	maximum dynamic load, N
F_w	limiting load for wear, N
Q	ratio factor
b	face width of the gear, mm
k	load stress factor
F_{en}	endurance strength of gear, N
σ_d	allowable static strength, N/mm^2

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