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Design and Analysis of Mechanism and Driving system for Manual Rice Transplantation Machine

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Abstract

Novel design and fabrication of manual rice transplantation machine based on linkage dimension from Thomas to suit the varying terrains of Nepal and to initiate mechanization from the small land holder's farmers are proposed in this study. The two row manual rice planter from Chandragiri Machinery Industry, Satungal was taken as reference to modify transplanting mechanisms and driving systems to ease the rice plantation process. The optimum adjustable spacing of the rice seedlings is 20 to 25 cm hill to hill spacing and 10 cm row to row spacing. The depth of penetration of rice seedlings is also adjustable in this design. The power transmission for the driving mechanism is achieved through the traction power of the rice planting wheel. The capacity of rice transplanter is 270 sq. meters per hour which is equivalent to 5 number of manual hand rice transplanter workers. By using the proposed rice transplanter machine the total cost of hand rice transplantation can be reduced by approximately 75%.

Keywords: Rice Transplantation Machine, Mechanisms, Driving Systems, Plant Spacing, Power Transmission

1. Introduction

Rice is the main source of food from agriculture and every year Asar 15 is celebrated as National Paddy Day in Nepal. The agriculture sector contributes to about 33.12 % to national GDP (MOF, 2015) and provides part and full time employment opportunities to 73.9 % of its population (NLFS, 2009). Small land area and continuous sharing of land in the family make it more difficult for Nepalese to look for expensive agriculture labor forces. The average size of agricultural land area in the country is 0.7 hectares. A majority of the agricultural households depend on small farm size for cultivation. Of the total farmers about 53 % are "small" farmers (operating less than 0.5 ha of land) and other 4 % are "large" farmers (operating 2 ha and more land) (NLSS, 2011). Unemployment, subsistence agriculture, low investment capacity, lack of infrastructure, market opportunities and poor irrigation system, majority of farmers are following indigenous technology in their production system.

Rice is grown in 47.98 % of the total cultivated area and shares 52 % of the total food grain production which contributes around 21 % to national AGDP (Upreti, 2013). Rice farming is highly unpredictable due to rain pattern at monsoon and availability of labors. Monsoon dependent nature of rice farming compounded with other factors has limited the average productivity of rice in around 3 t/ha for several years and consistently

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lagging behind as compared to other Asian rice producing countries; India (3.4 t/ha), Bangladesh (4.3 t/ha), Vietnam (5.3 t/ha), Sri Lanka (4.1 t/ha) and China (6.5 t/ha) (FAO, 2012; NARC, 2013). In context of Nepal, possible ways to increase rice productivity are, first by increasing arable lands and second by introducing technology to reduce rice transplantation time. The first option is not viabledue to rapid urbanization throughout Nepal. For the second option appropriate rice transplanter can be introduced to improve and ease in rice transplantation for different terrain and geographic land area. For this by improving plantation technology or introducing the farmer friendly rice transplanter to produce more and to achieve less labor intensive operation to reduce cost and tedious working pattern is very essential.

2. Literature

Rice seedlings (Qiang, 1986) have been hand transplanted for more than 1,000 years. Hand transplanting is tedious, risky and less efficient in productivity. To solve these limitations of hand transplantation mechanization of paddy rice transplanting were introduced by Japan and China. Other countries followed their design as a reference to make new models. Complexity of machine and operation functions did not fit an ordinary farmer as such machine requires specific trainings and skills to operate and maintain. To address these sorts of complexity, International Rice Research Institute (IRRI) developed a manually operated rice transplanter for mat seedlings. The IRRI TR1 (Salazar, 1986) 5 row transplanter initial work concentrated on redesigning a Chinese type, 5-row machine with 20 cm row spacing, to make it less expensive and easier to operate. It focuses on the picking and planting mechanism. But the four motions of the transplanting arm like picker fingers, tray seedlings picker, seedlings penetration into the paddy field, and releasing the planted seedlings became complex and monotonous job to the rice transplanter operator. In 1982, the IRRI TR4 6-row transplanter having the features like increased field capacity, easier fabrication, less troublesome operation and versatility was introduced. In 1980, with association of IRRI prototype, Burma country introduced manual, 5-row machine through the IRRI-Burma project. Based on the IRRI prototype, Agricultural Mechanization Department (AMD) produced six transplanters for testing and evaluation. It aimed to use local materials and to simplify the mechanism (Thein, 1986).

Japan developed the first rice transplanter from the patent obtained in 1898 (Han, 1977). After 1960, commercial rice transplanter research activities were intensively carried out. In 1965, washed root type rice transplanter machined was introduced. In 1966, soil bearing seedlings was designed. Thereafter, various transplanters were developed (Hoshino, 1997). Japanese transplanters (RNAM 1983) can be classified according to types of seedlings used (Lantin, 1980). In 1967, the Agricultural Mechanization Institute (AMI) manufactured a model that consists of 5-rows transplanter for conventional root washed seedlings. AMI also introduced two Japanese transplanters prototypes MAMETORA UP-2 and SHIBAURA GE-135K. In the year 1967, a hand-push, one row transplanter (KANRYU) was designed (Imran, 2017) and Korean agriculture accepted this model due to simplicity in design and cost economic. In 1967, three transplanters engine-powered, two-row transplanter (YANMAR FP-2A, MITSUBISHI PA-202, DAIKIN TL-20N) were introduced in Japanese market and were evaluated at AMI (MOAF, 1982). The planting mechanism of MITSUBISHI PA- 202 was similar to the strip-type transplanter. DAIKIN TL-20N used free fall or gravity. In the year 1971, AMI went for engine-powered driven 2-rows transplanter SATOH PS-20, ISEKI PC-20 and KUBOTA SPS-28. In the Year 1975 to 1978, a 4-rows rice transplanter driven from a five horse power tiller was introduced by AMI. The main limitations of this model are difficulty in machine operation and higher turning radius requirement. In 1981, AMI designed two row hand push type rice transplanter using mat seedlings that was almost similar to mat type rice transplanter. In 1982, experiment and fabrication of 12 prototypes of the rice transplanter were performed by farmers but operation of the machine was arduous (RYU, 1986).

Recently, the single row single mechanism rice transplanter was tested in Kedha, Malaysia (Imran, 2017). Solar and battery powered transplanter are recent demanded transplanter in India (Meena, 2025). Design and stress analysis of rice transplanting machine is important from its strength aspects (Tarek, 2023). Transplanting mechanism based on non-circular gears (Yang, 2024) are presented but these types of mechanism is complex and need advanced maintenance facility which will be not appropriate in context of Nepal. Tractor operated rice transplanter was massively used for plain area because of its productivity (Neeraj, 2023).

Not much information has been obtained regarding the practices of rice transplanters in Nepal. However, the record shows that some practices were made in the past years to ease the operation of transplanting. In Rupandehi, farmers with holdings of all sizes were experiencing labor shortages in the paddy season, especially during Jestha and Asar Nepali months. Then IRRI developed 6-row rice transplanter with mat-type rice seedlings used in puddled soil for rice transplanting. This model was modified at Agricultural Implement Research Center (AIRC), Ranighat, Birgunj (NAARC, 2007; AEC-FNCCI, 2070) and was tested for its performance at farms in Parsa and Bara Districts in 1997/98. Modified mechanism of rice transplanter developed by IOE, Central Campus Pulchowk in the year 2003 had 6-rows and it can be operated manually or using animal power. The transplanter is walk forward and double wheel type. The weight of the transplanter is approx. 35 kg and dimensions of 1428 mm × 1416 mm × 797 mm. The planting width, planting spacing and planting depth are 27 cm, 19 cm and 30 mm respectively. The power required for driving the mechanism is supplied by the two rolling wheels at field (Acharya, 2003).

Finally, the self-powered Manual Rice Transplantation Machine that can be designed to suit different terrain of Nepal by adjusting the optimum planting space and depth suitable for rice seedlings is the prime requirement in present situation. The two-row manual rice transplanter provided by Chandragiri Machinery Industry (P). Ltd., located at Satungal-16, Kathmandu has served as base/reference design for our machine. Based on their expertise and need assessment many of the machine parts to be used in this machine partially or wholly resemble the modification of reference machine to meet low cost and user friendly rice transplanting machine.

3. Design Method

The design methodology can be divided into five different phases as shown in Figure 1. First phase of the study, a framework is developed in the close co-ordination with the supervisor. Information and literature study, review of the literature and discussion for the suitable methodology and tools/models to be adopted, are performed in the first phase of the study. The information about the working principle and functional mechanisms of the existing rice transplanters are reviewed through secondary source of literatures available. The purpose of the second phase is to collect data and information necessary for the machine to work correctly in required pattern and spacing based on the comments of the farmers and agricultural specialists. The optimum spacing of the rice seedlings to be adopted in our rice transplanter is 20-25 cm (adjustable) hill to hill spacing and 10 cm row to row spacing. Also, an attempt has been made for the adjustable planting depth.

Phase I :	Collection and study of literatures and model defining
Phase II :	Collection of data, field work and preliminary analysis
Phase III :	Design of machine parts and simulation
Phase IV :	Fabrication of machine parts and assembly
Phase V :	Documentation (Report / Research paper writing)

Figure 1. Design phases of rice transplantation machine

In third phase, several machine parts are to be designed precisely for the proper function. The CAD/CAM software following standard design procedures are utilized to achieve this work. This part covers transplanter mechanism, traction wheel, seedling tray and floating tray. These are described in following sub sections. In fourth phase fabrication and assembly of machine parts are described. The short description for the fourth phase is provided in section 4.3. Then the rice trasplanter machine is tested in the field to observe its effectiveness in seed separating, seed feeding and seed plucking. Finally in fifth phase report writing and research paper writing will be carried out to transfer knowledge on design and fabrication of rice transplanter machine.

3.1 Transplanting Mechanism

Two different techniques were used for the evaluation of the various mechanisms to be used in the machine, they are analytical and simulation. Analytical techniques are used for the kinematic analysis of Cam-Follower mechanisms and Linkage Mechanisms followed by verification of the obtained results using simulation software.

A planar four-bar linkage with coupler extension (Uicker, 2009) and all revolute pairs is chosen, as this is very simple. The input motion is applied to the crank. The coupler trajectory follows a desirable path to meet the requirements of the rice transplanter. With one degree of freedom mechanism the planting finger is attached at the coupler point. The position of couple is represented as

$$x_F = L_1 \cos\theta + L_F \cos(\psi + \emptyset_1) \quad \text{(Equation 1)}$$

$$y_F = L_1 \sin\theta + L_F \sin(\psi + \emptyset_1)$$

where x_F and y_F represents the co-ordinates of the coupler point, L_F is the length of coupler extension, $L_1$is the length of crank, θ is the crank angle, ϕ_1 is the angle of coupler and ψ is the included angle between coupler and the coupler extension.

The dimensions of four links in the four bar loop, orientation of fixed link, length of coupler extension and angle of the coupler extension are determined based on the data obtained from Thomas (Thomas, 2002). The path of motion of the coupler extension (or finger point) is generated using GIM software and the solid model of the links for the transplanting mechanism is designed using CATIA V5 R20. The finalized kinematic dimensions of links for transplanting mechanism are given below in table 1.

Table 1. Finalized dimensions of the transplanting mechanism

Particulars	**Symbols**	**Dimensions**
Crank length, mm	L_1	50
Coupler length, mm	L_2	70
Follower length, mm	L_3	80
Fixedlink, mm	L_4	90
Couplerextension, mm	LF	218
Couplerextension and coupler link, degree	Ψ	-75
Fixedlink and the horizontal, degree	β	-30

The motion path is generated neglecting the effect of forward motion speed of the rice transplanting machine as it is small speed in comparison to the speed of the coupler point. The linkage transplanting mechanism with generated motion path is shown below in figure 2.

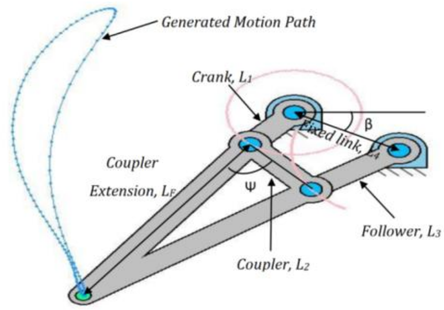

Figure 2. Transplanting mechanism linkage with generated motion path using GIM Software

3.2 Seed Separating, Seed-Feeding and Seed Plucking Mechanisms

The seed separating principle (Datta, 1981) is used for separating the rice seedlings from the seedling masses. The seed-feeding mechanism feed the separated rice seedlings to the seed plucking mechanism. The seed-plucking mechanism (Oberg, 2008) directly grip the seedlings that are fed to it by the seed-feeding mechanism and make it available to the transplanting mechanism at correct timing so as to ensure that the seedlings are transplanted with no defects. With these mechanisms involved, the transplanter will be able to separate seedlings from the seedling mass. It also grips layer by layer. This ensures seedling-separating quality for the seedling-separating efficiency. The seed separating and seed plucking mechanism in the rice transplanter are made ease with the aid of three different cam follower mechanisms having swinging roller follower's system. In this type of cam follower system, when the cam rotates, it imparts a swinging motion to the roller follower. All these cam follower mechanism schematics are presented in figure 3. The kinematic equations for the parabolic motion of cam are given by

For $0 \leq t \leq T/2$ and $0 \leq \phi \leq \beta/2$ (Equation 2)

$$y = 2h(t/T)^2 = 2h(\emptyset/\beta)^2$$

$$v = 4ht/T^2 = 4hw\emptyset/\beta^2$$

$$a = 4h/T^2 = 4h(w/\beta)^2$$

and

For T/2 ≤ t ≤ T and 0 β/2≤ ϕ ≤ β (Equation 3)

$$y = h\left[1 - 2\left(1 - \frac{t}{T}\right)^2\right] = h\left[1 - 2\left(1 - \frac{\emptyset}{\beta}\right)^2\right]$$

$$v = \frac{4h}{T}\left(1 - \frac{t}{T}\right) = \left(\frac{4hw}{\beta}\right)\left(1 - \frac{\emptyset}{\beta}\right)$$

$$a = -\frac{4h}{T^2} = -4h\left(\frac{w}{\beta}\right)^2$$

where,

h = maximum displacement of follower, m

t = time for cam to rotate through angle ϕ, sec

T = time for cam to rotate through angle β, sec

ϕ = cam angle rotation for follower displacement y, degrees

β = cam angle rotation for total rise h, degrees

v = velocity of follower, m/sec

a = follower acceleration, m/sec^2

N = cam speed, rpm and

ω = angular velocity of cam, degrees/sec

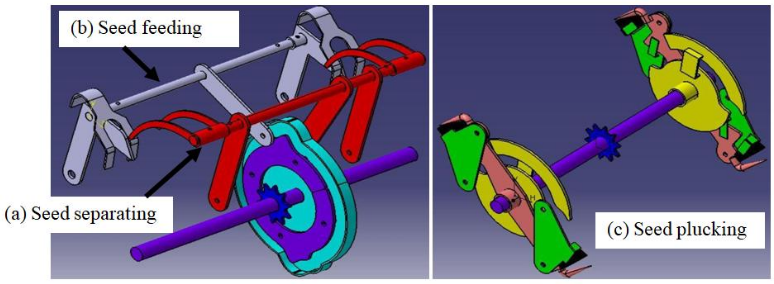

Figure 3. Cam follower mechanism (a) seed separating (b) seed feeding (c) seed plucking

3.3 Driving Mechanism

The driving mechanisms of the transplanter are shown in figure 4. The hand cranked driving mechanism of the provided machine has been replaced by the wheel driving mechanism. A pair of wheel is attached to the main driving shaft which due to the traction force of soil will rotate. The motion of the main driving shaft is then transferred to the intermediate shaft via chain and sprocket drive system in the ratio 4:1. The cam follower mechanism for seed-separating, seed-feeding and seed-plucking of the transplanter is attached to the intermediate shaft and works accordingly. Again, the motion of the intermediate shaft is further increased by the ratio 2:1 on reaching the rear shaft where transplanting mechanisms are fitted for operation.

3.4 Traction Wheel

The traction type wheel has been used in the rice transplanter for the ease of operation. A pair of wheel has been attached to the main driving shaft. The tractive force generated by the wheels with soil provides necessary torque to drive the whole mechanism while pulling the machine forward. The wheel has been designed with the literature review through secondary sources and inspection of commonly used mud wheel in other rice transplanter as shown in figure 5 (a). After inspection, a wheel prototype has been fabricated in the workshop and tested. To great extent, the wheel seems to be workable and the wheel has been fabricated using the following stated dimensions to synchronize with the gear ratio used in the driving mechanisms. The effective radius of wheel is 210 mm, forward movement of the machine is 1320 mm, shaft to rear shaft gear ratios is 1:8 and planting distance of 165 mm.

3.5 Seedling Tray with Frame

The washed root seedlings are loaded on the machine for transplantation by putting on two sheet metal trays of 50 cm length, provided above the machine, as shown in figure 5 (b). The trays are held nearly vertical on the frame by extended rods and screws and can hold seedlings for about 60 plantings. Frame is designed to accommodate and support components of the machine to maintain their relative positions and is main supporting structure of the machine.

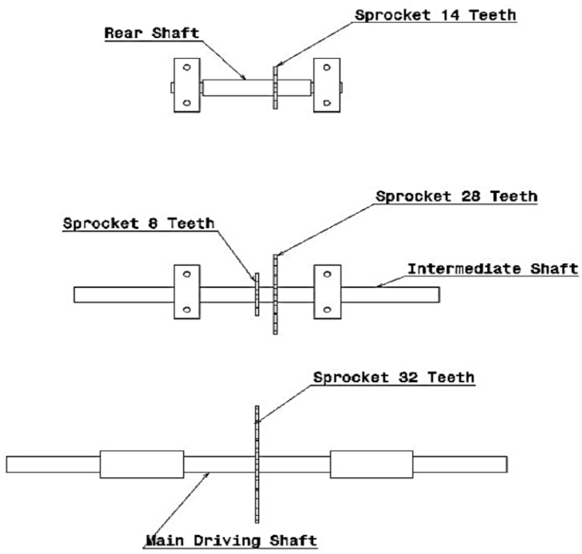

Figure 4. Schematic of driving mechanism of rice transplanting machine

3.6 Floating Tray

Overall weight of the RTM is about 20 kg which needs to be stable and should float on the water layer on prepared field for rice transplantation and is one of the necessary component of the machine. For the design of float, we approximate the size and shape suitable for the placement of the machine and mechanisms so that the weight is supported on the wooden float, as shown in figure 5 (c). Approximate dimension of the float is 800 mm × 480 mm × 85mm.

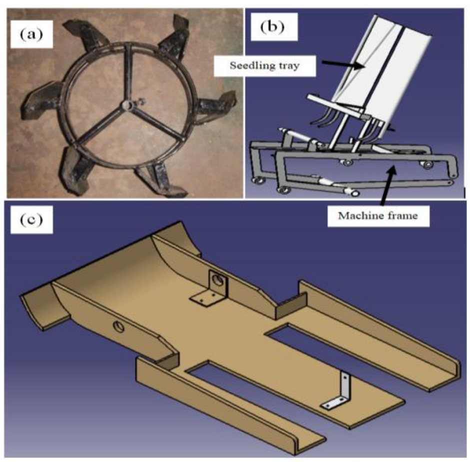

Figure 5. (a) Traction wheel, (b) seedling tray with frame and (c) wooden floating tray for rice transplanter

4. Results and Discussion

With the literature and design as described and with data collection and rearrangements in the proper format, the results are obtained. Also, the simulation using CAD/CAM/CAE software, helps to obtain various graphs relating the kinematic analysis of the mechanism used in the transplanter. The performance analysis of the machine was carried out by testing it in the real field. The data relating the machine performance were obtained and presented in the suitable format.

4.1 Kinematic Analysis of Transplanting Mechanism

Kinematic result of rice transplanting mechanism is presented in this section. Figure 6 shows the positions (in x-y coordinates system) of the transplanting finger used in transplanting mechanism when the crank makes one complete rotation, about origin O of the given reference system. The direction of the motion of transplanting finger is represented by arrow provided on the graph. The downward motion is through the left side of the path and the return motion is via the right loop of this path. It leaves behind the seedlings that had been planted at the right. Such action is required as the seedlings will not be disturbed after plantation. There is a distinct way of return motion of finger from the point of rice planting to point of picking up. The rice transplanting finger moves up to in a required depth in the soil. It promptly retraces to the position at an angle of 180^o sharply.

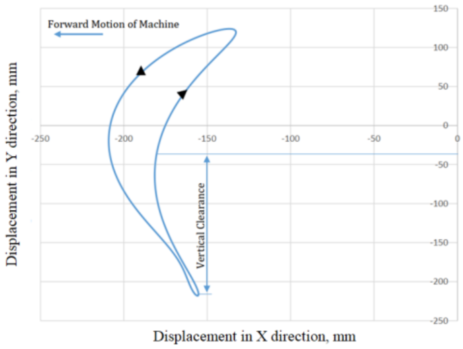

Figure 6. Motion point of coupler with vertical clearance

Figure 7 shows the variation in the velocity of the transplanting finger with the crank angle (anticlockwise direction positive). During downward motion, the velocity of the transplanting finger is relatively smaller than that of return motion. At the point of rice seedling pickup, the velocity is relatively constant for small instant of time so that the seedlings are picked up precisely. Also at the point of transplanting of rice seedlings, the velocity is relatively smaller than any other crank position to ensure that the rice seedlings are transplanted to the necessary depth. After the transplantation of rice seedlings to the soil, the transplanting finger return quickly upward so that no disturbance are made on to the transplanted rice seedlings.

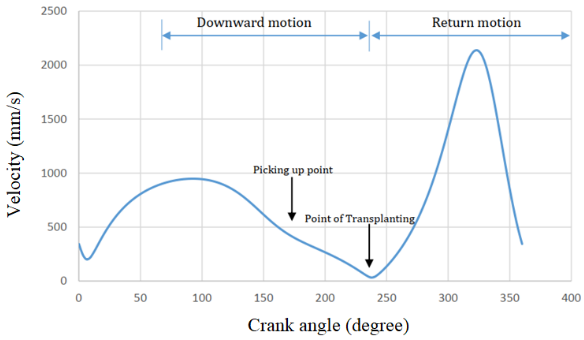

Figure 7. Velocity of the coupler at different crank angle

4.2 Kinematic Analysis of Seed-Plucking Mechanism

A cam mechanism with swinging follower system has been used in the seed-plucking mechanism. A rise, dwell and fall period of the follower has been properly assigned for the proper operation of the mechanism. The roller-type of follower has been used in the system. The period of rise, dwell and fall of the follower is given in table 2.

Table 2. Rise, Dwell and Fall period of Cam used in the seed plucking mechanism

Rise	Dwell	Fall	Dwell
10^0	180^0	10^0	160^0

A rise of 10 degree ensure that the oscillating follower quickly pluck the rice seedlings fed by the follower of the seed-feeding mechanism separated by seed-separating mechanism from the seedlings mass on the tray. The gripping of the seedling occurs for the period of 180 degree until the rice seedling is made available to the transplanting finger of the transplanting mechanism. At that point, again the rice seedlings is quickly released by the swinging follower of the seed plucking mechanism. The synchronization of the timings has been established between the release from the swinging follower and the transplantation by transplanting finger. For the rest of the period, the follower is dwell and the process continues. In one complete rotation of the cam, the process of the gripping of the rice seedlings and making it available to the transplanting finger occurs twice with the aid of two follower (swinging type) used in the seed-plucking mechanism. The transplanting finger is also made available twice to transplant the rice seedlings as the gear ratio of 1:2 has been set up between intermediate shaft and the rear shaft. Appropriate dimensions were specified for the cam-follower system to enhance the proper operation of the seed. The finalized dimensions used for the cam follower system were base circle 40 mm, roller diameter 12 mm and prime circle 46 mm. The follower used in the system is made to oscillate at a distance of 80 mm from the point of the roller position, as shown in figure 8.

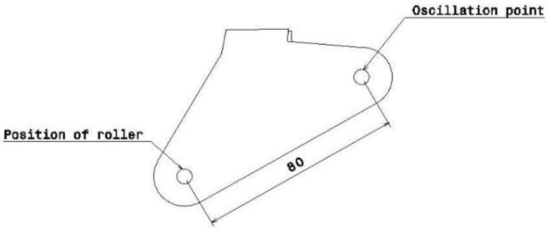

Figure 8. Schematic of swinging follower used in the seed plucking mechanism

A lift of 15 mm was achieved using this cam-follower system. As stated above, the motion used in the cam-follower system is parabolic type for both the rise and fall of the follower. So the data were obtained for the rise period of the cam-follower system as shown in figure 8, since the similarity on the motion exist on the rise period of the follower and the fall period for the same angle of rise and fall except in dwell period where the kinematic motion is almost same as it is at the end point of rise/fall.

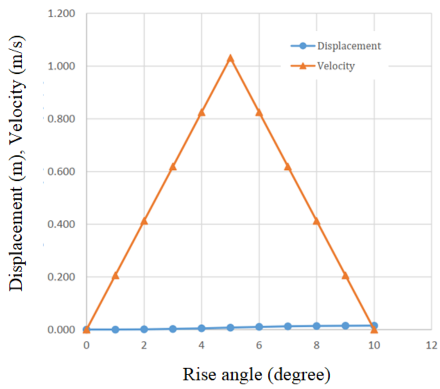

Figure 9. Kinematic analysis of the cam for rise period

Figure 9 shows the displacement and velocity of the follower for parabolic motion cam profile assuming the speed of the cam to be 1 rpm. Acceleration of the cam is calculated 70.9 m/s^2 from the data set. From that figure, it states that the velocity is zero at the initial point of rise of follower, when displacement is zero and acceleration has maximum positive value. Similarly, at the final point of rise i.e. at maximum lift, the velocity is again zero. Sudden changes in acceleration at the beginning, middle, and end of the stroke are observed. This may result in the production of shocks. The follower systems were tried to make rigid with less backlash and flexibility to ensure that the shocks produced at the beginning, middle and end of the stroke will be of less significant.

4.3 Fabrication of Rice Transplanting Machine

It consists of several components with various shapes, sizes and designed for specific performance. The material used for the fabrication of shaft, linkage, cam and follower is mild steel (Tarek 2023). Bearings, nuts, bolts, chains and sprockets are selected from Machinery's Handbook (Oberg 2008). Shafts are machined on lathe machine to produce design diameters and lengths. The bearing housings are made to support bearing on the frame which are attached by nuts and bolts at desired positions so that free rotation of shaft is obtained. The complex shape components like cams, sprocket, plucking and planting links are designed in CATIA V5 R20 and the outlines are printed on paper. These components are made by attaching the printed outline on the mild steel plates then followed by grinding, filling and drilling operations. Also the traction wheel has been fabricated to provide the necessary torque to drive the mechanism. All the mechanism are assembled together to complete the synchronization between the motion and its function. The final assembly of rice transplanting machine is shown in figure 10.

Figure 10. Assembly of Rice Tranplanter Machine

4.4 Field Rice transplanting

The machine has been tested on the field which was tilled by the use of Power tiller. The field has 0.3 m depth of tillage, 2 cm water level above the mud surface and average seedling height was 30 cm. The pulling of the machine was easy on the field but water on the field enter inside the wooden float during the plantation and disturbs the plantation as well as the floating tray efficiency. A total of 25 readings were recorded during the testing of the machine leaving the disturbances in between the several plantings as shown in Table 2.

During testing, the machine performs satisfactory during most of the testing time. However, the smoothness of the machine was lost for every forward movement of the machine because of the muddy soil. Sometimes, the machine was unable to grip the seedlings and sometimes the position of the transplantation links were displaced so that no accurate plantings were observed. It also depends on skill of using this machine. After practicing, the machine was able to pluck and plant the seedlings within the desired range. The range of the row to row spacing shall be 17 - 22 cm and that of planting spacing shall be 10 - 19 cm. As shown in Table 2, the row to row spacing and planting spacing are within in the desire range. The desired number of seedling to pick is 1 but in testing maximum of 4 seedlings is plucked.

Table 2. Seedlings transplantation in field

Test no	Row to Row Spacing (cm)	Planting Spacing (cm)	Number of seedlings	
			First Row	Second Row
1	18	-	2	3
2	18	12	3	4
3	19	15	4	4
4	18	18	2	1
5	18	14	1	1
6	20	12	1	1
7	19	19	3	1
8	20	15	2	2
9	20	18	2	1
10	20	13	1	1
11	20	12	4	2

12	20	17	3	4
13	21	14	1	3
14	20	17	2	3
15	20	17	2	2
16	19	18	4	3
17	19	17	2	2
18	20	12	1	3
19	19	15	1	3
20	19	12	4	1
21	18	13	3	1
22	19	13	3	2
23	20	17	2	1
24	20	18	1	1
25	18	14	1	1

4.5 Capacity of Machine

The rice transplanting machine cost can be categorized into three parts materials, labor and machining. The material cost, labor cost and machining cost were Rs 18360, Rs 12000 and Rs 8000 respectively. Thus the total cost of manufacturing rice transplanting machine is Rs 38360. The design cost is not included in manufacturing cost. The fabricated two rows rice transplanter as shown in figure 9 has planting width, planting spacing, planting frequency and planting speed as provided in Table 3.

Table 3. capacity of rice transplanter machine

Planting width Cm	Planting spacing cm	Planting frequency Rpm	Planting speed of machine m/s	Area transplanted per second m^2
20 – 25	15	120	0.3	0.075

With these specifications the rice transplanter can pluck paddy field of 0.075 sq. meters per second. Therefore, in one hour this machine can cover 270 sq. meters with the help of single machine operator. Now it can be compared with the conventional labor based rice transplanting. According to Gami, 25 workers are required to transplant 1 hectare (10000 sq. meters) in a single working day (Gami, 1998). Here single working day represents 8 hours of working. It indicates that one man can transplant 50 sq. meters of paddy field by following conventional technique. From this calculation it is transparent that with the application of rice transplanter machine the cost of five workers can be saved in one hour that is 270/50 = 5.4 ≅ 5 labor.

5. Conclusion

In this study, design of planar four bar linkage with coupler extension revolute pairs based transplanting mechanism and driving system was conceptualized, modeled, analyzed and fabricated. Solid modeling works were carried out using CATIA whereas path motion of the coupler extension was generated using GIM. The rice seedling pick up and transplantation of rice seedlings were achieved at lower velocity of crank to prevent production of hock during transplantation. The return of transplanting finger was able to design quick upward movement without disturbance for optimization of time. This machine was designed and fabricated by considering stepped terrains of Nepal. The design capacity of machine is 270 sq. meter per hour which is equivalent to 5 number of workers. The cost of rice transplantation can be reduced by approximately 75%, if the machine is used compared to traditional transplanting process, which is more tedious and labor intensive. The scarcity of manpower at peak season in many parts of Nepal can be compensated and transplanting can be completed at right period for the seedlings. To greater extent, the machine will serve as the initiation to the mechanization in agricultural field from small land holder farmers.

6. Recommendations

The Rice Transplantation Machine designed and fabricated for substitution of traditional practice of rice transplanting in Nepal, being economical and easy for the operation, there are some research and modification factors which could make the machine more efficient and lighter in weight. Some recommendations for the further improvement in efficiency of the Rice Transplantation Machine are described below:

- Main driving component of the whole mechanism i.e., the tested wheels are not thoroughly designed and analyzed for its optimum size. The existing type of wheels of suitable size is used instead of performing the tractive force analysis on dependent parameters like blade no., blade size and blade angle on the wheel rim. So, by detailed design of the wheel weight of the machine can be reduced with increase in tractive force.
- Wooden Float, another main component of the machine was designed at approximate shape and size rather than evaluating the buoyant force on the float by calculating surface area, to make the machine more stable and easier while in operation.
- The machine has many components and mechanisms with special shapes like cams, transplanting linkages etc. These components are not accurate as required due to some machining errors which resulted little faults in the machine performance. To eliminate these types of errors precise machining operation could be used.
- We have fabricated the RTM for testing purpose only rather than make it precise, accurate in operation and good looking. There are some factors to be considered in enhancing them.
- The number of rows, which is now two, can be increased in the machine with the aid of electric motor or small petrol engine to drive the mechanisms instead of wheels.

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