Automated Paddy Transplanter

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Abstract— *Rice is the main staple food in Sri Lanka therefore paddy cultivation plays a major role in the Sri Lankan economy. There are two main methods of paddy cultivation which are sowing and planting. Sowing is the current trend. Paddy is sowed due to lack of labour and increased labour cost for planting paddy though planting paddy gives a better harvest. Planting can be done using mechanized or mechanically operated paddy transplanters. These paddy transplanters are not very popular among Sri Lankan farmers due to its initial and operational costs being high and the unavailability of the proper knowledge to operate it. These paddy transplanters are imported form countries like China and India where the working conditions are different comparatively to the working conditions of wet zone paddy fields in Sri Lanka. As a result, these existing paddy transplanters tends to get stuck on mud. This study is done to minimize the limitations of the existing paddy transplanting methods and to incorporate a new design which is more suitable for wet zone paddy fields. The design includes a mechanical arm, a planting tray and a carrier that has the capability to absorb the load of both the planting tray and the mechanical arm. The design is done in order to minimize the environmental pollution and also opening many new areas of study.*

Keywords— **Automation, Paddy, Transplanter**

I. INTRODUCTION

Paddy cultivation is done on two main seasons "Yala" and "Maha" targeting the monsoons. In the wet zone paddy fields are muddier and comparatively small to the agricultural lands in the dry zone due to the land area being densely populated.

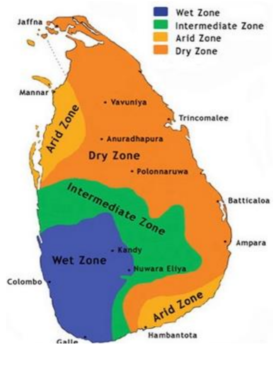

Figure 1: Sri Lankan Climatic Zones

A rice transplanter is a specialized machine to plant paddy. It consists of transplanter mechanism that usually consists of some reciprocating arm driven by the power from the live axle, in order to plant seedlings onto the paddy field. The main objective to do this research was to overcome the difficulties the farmers face when planting paddy. Almost 90% of Sri Lankans take rice as their main meal.

There are two main methods of paddy planting. Namely seeding and planting.

I. Seeding

Seeding is the common practice that is used in the Sri Lankan scenario. When seeding the farmers sow seeds.

a. Disadvantages

The main disadvantage of sowing is that it needs approximately 3 times the actual number of seeds that are needed to be planted. There are some other disadvantages such as there is a high tendency for seeds to get washed away or to be picked by birds. Also the tendency of the plant to survive the first day is very low.

II. Planting

The method of planting paddy is done in order to overcome the above disadvantages. Here the plants from nurseries are taken. When planting in nurseries seeds are sowed on a wet rug and allowed to plant as a bunch. Since it is as a bunch the probability of being planted successfully is very high and it is frequently watered to make the seeds grow. When the plants gain its maturity age they are removed from the rug and sold to the farmers. This age of maturity differs from plant type to plant type. Usually at least 15 to 18 people are needed to plant acre within a day. The cost of labour usually is around Rs.1000 with 3 meals per person per day. Also the method of planting is not ergonomic since these people has to bend over for long hours. Typically planting of paddy is mostly done by women. Nowadays there is a lack of human resources as there are job opportunities with higher pay and less strenuous. Therefore, farmers use the method of seeding.

By this study it is mainly focused on a way to minimize the use of human activities when planting paddy. Objective of the study is to plant more paddy plants with less time and with the least amount of man hours spent.

III. Methodology

Before designing the Automated Paddy Transplanter (APT) model a representative from the agriculture department was interviewed. According to him the tractor used in transplanting paddy was only suitable to be used in the dry areas such as Anuradhapura, Polonnaruwa. The main reason for it to fail in the wet zone is that the machine getting stuck on mud due to its weight. Since the designed APT does not travel on mud comparatively to the tractors, there is no disadvantage of the designed APT getting stuck on mud since this designed APT travels on the footpaths.

Furthermore, the method of transplanting paddy was the use of the manual transplanter where a person had to pull the transplanter along the field. The energy expenditure rate of a person who operates the above stated manual paddy transplanter is higher comparatively to the person who plant paddy with the automated transplanter [Rajivir Yadav et al. (2007)]. When considering the manually operated paddy transplanter it need more than one person to load and unload the mechanism and also load paddy to the tray.

Some remedies for the limitations of the existing paddy transplanter is discussed in this sections.

This study was divided into three parts these sections are discussed in detail in the section below.

1. Developing of the Planting Arm

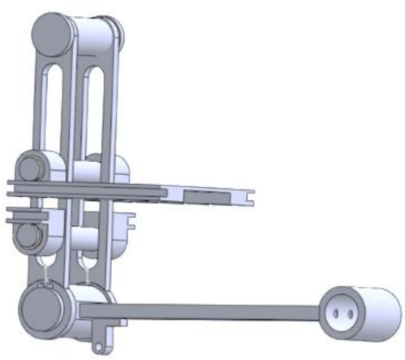

Figure 2. Planting Arm

This arm is designed to pick the rice plants from the feeding tray and plant them on mud of the paddy field automatically. The requirement is to pick the plants by a gripper instead of the hook used in other existing paddy transplanting machines. The planting distances between paddy plants differs from one type to another. Furthermore, the height of the foot path of the paddy field cannot be evenly prepared all over the field so the total depth of mud will be change. The planting arm should have an ability to change working depths of the arm keeping the planting depths of plants constant. Also this mechanism needs to withstand wet working conditions of the paddy field and also hard and rough use of the machine since these machines are mainly used by farmers with lack of knowledge on the working principles of the machines. The immature rice plants get damaged due to impacts that occurs on the plants as a result of the rotational movement of the hook that is placed in the existing designs. Therefore, a gentler grip is needed to be designed to ensure the safety of the plants and also to have proper grip without missing any plants. For actuators DC electrical motors were selected due to the easiness for controlling, and this can give a linear output than pneumatic or hydraulic actuators. Also DC electrical motors have an advantage over mechanical linkages because of the reliability. Furthermore, due to the complex moment involved in the mechanical planting arm linkages, they can be very complicated. This complexity can be reduced by using DC motors and which are also easy to control. Actuation of the gripper is done using a DC servo motor. The DC servo motor used because of its higher reliability and ease of control. Since this machine is continuously working with the wet conditions. Especially the lower arm section is continuously in contact with mud. Therefore, the material used to manufacture this arm needs properties which are resistive to corrosion. Hence a material such as Aluminum is selected. For rotating and sliding sections the material Teflon is used as it has higher load carrying capacity and also higher wear resistivity. This mechanical arm is consisting of main three parts.

- upper arm
- Lower arm and gripper.
- Mechanical linkage.

The prototype of the Planting Arm is made using Nylon. Furthermore, programming part is done using Arduino.

1.1 Upper Arm

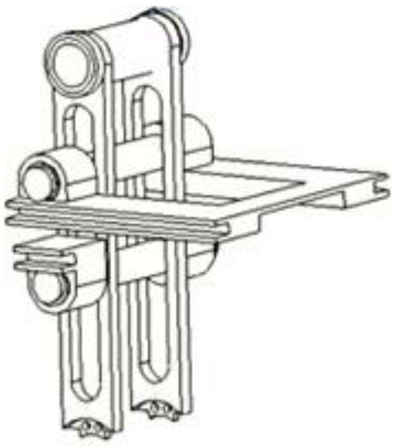

Figure 3. Upper Arm

Upper arm is consisted of a sliding mechanism that has two slotted arms and rack and pinion gear system that mounted on to one slotted arm. The slotted arms are manufactured using aluminum and for fabrication milling machine was used. In between the slots there are two cylinders which are made from Teflon. These two cylinders connected to the mounting brackets at each side. These brackets hold the Upper arm to the platform. Also the linkage is permanently mounted on to the bottom cylinder.

1.2 Lower Arm and Gripper

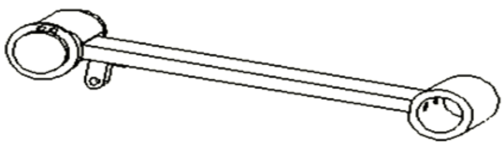

Figure 4. Lower Arm

Lower arm consists of the one square connecting bar that fixed in between the gripper and the mid joint, two cylinder which is connected at the both ends of the square connecting bar. It holds the gripper and lower arm components together. Also the rest of the linkage are fixed on to this connecting square bar. This square connecting bar is manufactured using aluminium and the cylinder components which are fixed at both ends also made from aluminium.

A pin is used to pivot the lower and upper arm together and the pin is inserted into one cylinder. The pin is made from Teflon material because this joint is continuously subjected to the rotary motion also Teflon material has a higher resistance to wear.

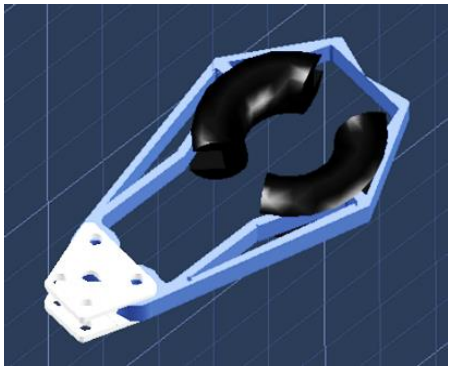

Figure 5. Gripper

The gripper is fabricated using plastic. Plastic has highest resistivity to corrosion. The gripper is the component that repeatedly interacts with mud. Therefore, it should have a high resistivity to corrosion and also the gripper is fixed at the far end of the lower arm where the weight affects the power requirement of the motors. This can be fabricated with the use of a plastic mold and the gripper jaws are actuated using a servo motor that is controlled by a Programmable Integrated Circuit (PIC).

The gripper especially designed to minimize the damage that affects the rice plants when picking from the feeding tray and planting them in the mud. To achieve that requirement, the griping section is cushioned using soft rubber and also the pointed edge of the gripper jaw is inverted inside so that it will increase the ability to separate the rice plant. Furthermore, the gripper is designed to minimize the distortion of the mud when planting the rice plants. In order to plant paddy without distorting mud, masses were removed in the gripper.

1.3 Linkage System

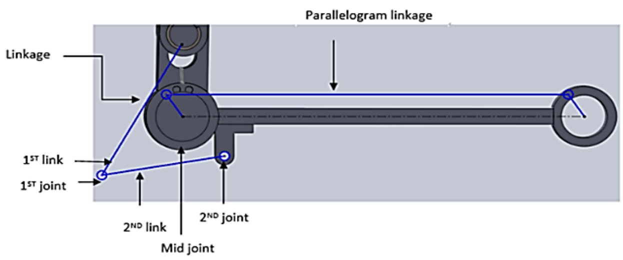

Figure 6. Linkage

The role of transmitting power from the upper arm to rotate the lower arm around the mid pivot joint is done by this Mechanical linkage used in this system. And also always this linkage is needed to be parallel to the ground. To achieve this another linkage is used called parallelogram linkage. It will maintain the gripper position always parallel to the ground. The first linkage is permanently fixed to the lower cylinder that is connected to the two lower brackets which holds the upper arm to the platform. The angle of the first link to the vertical is 29.05 degrees. The first and the second joints are pivots that can rotate freely around their own rotary axes. The sliding moment of the slotted arm (upward or downward) will vary the distance from the lower Teflon cylinder center to the middle joint center. This will exert a force around joint one. This exerted force will cause a moment around joint one. As a result of this moment it will rotate the lower arm around the mid joint.

1.4 Working Principle

The DC motor is mounted on the platform and the pinion gear is coupled to the motor shaft. It is meshed with the rack which was mounted on one of the slotted arms. Rotation of the pinion moves the rack vertically up and down. According to that moment the distance between the lower Teflon cylinder center and the mid joint center will vary. When the slotted arm moving up the variation of distance the second link exert a force on the first joint in vertical direction (upwards). But the first link cannot change the position. Therefore, the second link is rotated around the first joint. This produces the up and down movement of the mechanical planting arm.

In order for the motor to move the arm vertically up and down the driving direction should be reversed. For reversing polarity of the motor should be changed. This reversing is done through 'Relays'.

2. The Planting Tray

The purpose of the planting tray is to supply a constant feed of paddy plants to the planting arm and also to separate the rice plants according to the planting requirement. Also the amount of plants that needed to be fed into the mechanical arm each time has to be varied according to the type of rice plant. Consequently, when the machine is operated this tray has to be rotated around its main body in order to provide a constant feed of plants. Since this planting tray interacts with the paddy plants and is also continuously in contact with moisture and wet conditions, the material of this tray has to have high resistivity to corrosion plus the plants bearing material needs to have slippery surface texture in according to provide smooth plants move across the tray. For the manufacturing purpose of the planting tray Gauge 12, 2mm thickness Aluminum sheets were chosen.

This tray consists of four separate aluminum ring. Two rings having 0.54m outer radius and 0.24m of inner radius and two other rings of outer radius of 0.54m and inner radius of 0.5146m. Two wider rings were fit on the top and bottom of one of the inner ring and six screws were fixed at a radius of 0.527m. The height of the other thinner ring can be adjusted using these screws by two nuts which can be moved along the screws. Then the conical shaped fabric which is water resistive is fixed on to top of the thinner ring and the inner ring of the fabric is fixed to the inner edge of the bottom wider ring. The total volume capacity of the tray is $0.73m^3$. This whole planting tray is rested on another aluminum ring which is called as rotary base plate. This rotary base plate is mounted to the main body. The feeding tray is rotated on top of this rotary base plate.

In order to rotate the whole mechanism an aluminum collar was fixed at the bottom of the bottom wider aluminum plate. This aluminum collar was gripped by four rollers at two points, where at each point two rollers (idler roller and driven roller) compress the collar from the inner and also the outer side. The inner roller is directly coupled to a sprocket wheel that is driven by a chain. The drive sprocket is directly coupled to a DC electric motor that mounts on to the main body. The idler roller is compressed using a spring tension. Otherwise it will tend to slip the aluminum collar that is mounted underneath the rotating tray. The rollers are fixed on to the platforms which mount below the rotary base plate.

The rollers are manufactured using Teflon due to the high wear resistive material property. To provide the required friction between the aluminum collar and the rollers, the nylon rollers itself will be insufficient to rotate the total weight of the tray when it is loaded with the paddy. Therefore, an extra rubber layer was pasted on the contact surface of the rollers.

2.1 Plant Feeding System

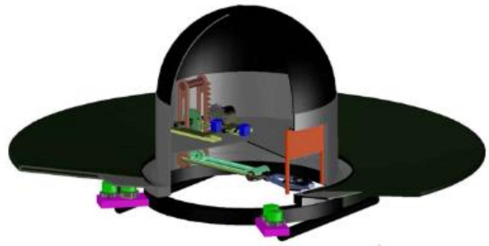

Figure 7. Planting Tray

This is designed to separate the rice plants from the tray and continuously feed them in to the planting arm gripper. The feeding system consists of aluminum blades which are fixed on to the opening of the main body. This opening is provided to feed the rice plants in to the main body and in to the gripper. Aluminum is selected as the material for the blade, because of its resistivity to corrosion and also due to its formability and light weight.

Though the actual planting tray is made using aluminum the planting tray which is used in the prototype is made using wood and metal. The main body of the planting tray is made by rolling a metal sheet and all the rings are made using wood.

3. Developing the Carrier

Platform is the main part that holds the machine together. This will be made of iron sheet galvanized to be protected from water and made into a U shape to support the wheel holders. This will also give additional ground clearance so that even if there are any obstacles in between it can omit it. This plate will be made to the size of 20cm tested with the prototype so that it could fit into many paddy fields' foot paths. In the prototype machine wood is used as the main platform of the carrier. This is because it is made to be cost effective. And easy to manufacture. Wood is the perfect choice as a good type of wood shall hold a considering amount of weight.

A wide belt is used in to make more contact area. A wide track gives more advantage on muddy surfaces since it does not get stuck. Foot path has an uneven surface. Use of tracked vehicle gives more stability to the vehicle and ease in climbing and moving in the rough terrains.

Electrical motors are used to drive the belt of the vehicle. Electrical motors are used in the ease in controlling. With a PMW (Pulse Width Modulation) signal it can be easily controlled rather than the use of engines. This also makes the APT eco-friendlier because of zero emission. It is not healthy to the use of tractors as they pollute the environment by emitting gas as well as engines oil and fuel which adds toxic substances to our daily diet.

The prototype has the L shaped wheel holders to mount the belt. The belt used shall be a timing belt width of 1 inch. The belt used for the prototype is a timing belt of a vehicle. The belt driving power shall be given by two 12V 80rpm motors concentrically fixed to each other with two drive shafts driving wheel shall be rotated.

Figure 8. Automated Paddy Transplanter

III. Discussion and conclusion

The construction of the arm in the prototype APT was done using Nylon. When fabricating things material tended to melt and soften due to high temperatures. One of the main reasons for melting was the absence of the cooling system in the milling machine. Also after assembling the prototype arm, at the mid joint of the lower arm should rotate 90 degrees from its original position. But it was only rotated around 75-80 degrees. The reason for that was found out to be the play that occurred at the link joints and unwanted friction between upper arm sliders and brackets that mounted the upper arm to the support plate. To solve that problem, the distance between the brackets were increased and also the link joints were replaced by nylon joints.

It was unable to obtain the conical shape in the tray due to unavailability of resources to roll aluminum plates in to the conical shape. Therefore, the design had to be changed accordingly, and as well the materials used to for fabrications were changed in order to achieve the manufacturability which is an essential parameter to be considered.

Another problem that occurred once the design was completed was that the reach of the arm was not enough to plant paddy. Therefore, a height adjuster for the plant tray was manufactured. The two connecting rods of the planting tray are fixed to the height adjuster. A flexibility is given by this configuration to obtain various heights to the planting tray.

IV. Acknowledgement

We would like to acknowledge everyone who helped us in numerous ways.

IV. References

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