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Development of System Rice Intensification (SRI) Paddy Transplanter

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Abstract: The System of Rice Intensification (SRI) practices have been developed in order to increase the production and quality of rice. Based on SRI practices the rice seedlings are transplanted at the young ages, 15 days old with just 2 leaves and carefully planting of just one seedling per hill and space the hills optimally widely in a square pattern of 25×25 cm for better usage of water, sunlight, minerals, space, nutrient, weeding and pest management within shallow depth (1-2 cm) in the moist soil condition. The existing method of mechanical transplanting of paddy which planted between 5 and 8 seedlings per stand is claimed to be inefficient to produce higher yield. From the survey that was carried out, most farmers are looking forward to single-planting translators as it is impossible to do it manually. Modifications have to be carried out on the planting claw (kuku kambing) so that it will only catch one seedling at a time, redesign the seedling tray to allow the SRI transplanter to catch one seedling at a time and determine the best soil condition suitable for the SRI practices. No doubt that the new develop transplanter for SRI will be the future machines for the farmers in Malaysia. Evidence have shown that the SRI practices in paddy cultivation has resulted in the increase in yield as well as superior quality paddy because of its shorter crop cycle, less need for seeds and fertilizer, less chaffy grain because of higher percentage grain filling, little or no lodging from wind or rain and higher head rice recovery rate, so more milled rice from a given amount of paddy and reduced labour demand while boosting productivity. The most important factors that influence the performance are soil moisture content, system of raising seedlings in nursery, degree of land labelling and finally the size of planting claw.

Keywords: Age of seedling transplanting, nursery management, rice cultivation, system of rice intensification, translators

INTRODUCTION

System Rice Intensification (SRI) is an age-old cultural operations of paddy rice cultivation that were collected and analyzed then later on modified by Thurn *et al*. (2006) He was able to make the following crop husbandry methodology i.e., use of younger and tender seedlings, avoidance of root damage, wider spacing, creating aerobic soil condition and enhancing organic matter content that leads to the alleviation of the sufferings of million farmers for decades (Uphoff, 2006).

A specialized implement fitted to transplant rice seedling in paddy field have been under development for years by different researchers improving performance, components functions, simplifying the mechanism and handling but until today there is no single machine fully automated for SRI system. A machine transplanting rice requires less time and labor compared to manual, increasing area coverage per person from 700-10,000 m^2 per day. Rice transplanter was first developed in Japan in 1960's and the earliest attempt in mechanization of rice dated back to late 19^{th} century.

An increase in land under cultivation and the scattered nature of farm holdings in Japan made it a necessity to device means of consolidating farming operations. This idea paves a way to design and fabricate automated control system that allows a single farmer having control over fields. The Defense Advanced Research Project Agency (DARPA) Grand Challenge and Urban Challenge as reported by Thurn *et al*. (2006) and Urmson *et al*. (2008), respectively were using sensors consisting of many systems in controlling their vehicle, but in the field of agriculture robotics were used mainly in simple farming operation. A six row automated transplanter was design and demonstrated by a manufacturing company Yanmar Corporation in Osaka, Japan having a base wheel of PV14 utilizing principle of Real-Time Kinematic Global Positioning System (RTKPS) in detecting position of transplanter while Fiber-Optic Gyroscopic (FOG) measure inclination and angle of heading but when compared with existing transplanters of the time its wheel base was larger resulting in higher turning radius and takes time at field edge so in 2002 the wheel was removed and replace with smaller wheel base of PH6 by a transplanter manufacturing company Iseki

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Table 1: Evolutional trends of paddy transplanter

Type	Features	Principle of operation	Contribution	Set-back
1. IRRI manual transplanted 4, 5 and 6-rows.	Wooden skid, main frame assembly, tray indexing assembly, pivoted picker bar assembly, handle assembly, racket, seedling tray assembly, picker and pawl mechanism.	Manually operated by pulling through the field with the handle push down to pick the seedlings and put it in puddle soil and then retracted to next position.	Has a transplanting rate of 0.034 ha/h with 81% time on actual transplanting operation, reduces man days requirements and cost of production.	Suitable for only 14-days and above seedlings, soil moisture influences the transplanting efficiency and at water depth of 0cm-30cm only.
2. Modified IRRI 5-row manual transplanted.	In addition to above the following changes are in cooperated in operating handle, picker arm assembly, stop block, cam and cam follower, carriage bar assembly, ratchet assembly bracket, sprocket (ratchet) and turn buckle.	Propelled manually by hand as above.	Addition of springs to prevent distortion of picker arm holder frame, modification on stop block on pivot arm with adjusting screw, additional reinforcement of pin bracket and turn buckle was replaced by hook screw.	Costly, seedlings were cut at the process of transplanting.
3. AMI Manual rice transplanted	Handle, planting mechanism, rubber feed roller, float, seedling tray, wheel, sprocket, feeding roller handle and gear box.	Utilizing a continuous strip of seedling mat.	Reduces cost of machine, number of missing hills.	The weight of the machine makes its operation a tedious task while also the seedling raising operation is labor intensive.
4. AMI 4-row Machine transplanted.	Engine, shelves of reserve seedlings, brake, main clutch, handle bar, side clutch, transplanting clutch, fork, traction wheel, transplanting arm and seedling tray.	Mat seedlings.	Seedlings can be grown better on nursery, no need for hand transplanting along levee,	The machine is costly, need skill to operate.

Corporation in Matsuyama, Japan as reported by Nagasaka *et al*. (2002) a single computer was used to processed all the data and controlling the actuators until 2004 when the wheel base of PH6 was modified to improve field efficiency with RTKPS and FOG maintained. The controlling unit was changed to a Programmable Logic Controller (PLC) prior a rice transplanter uses 20 seedlings mats to cover an area of 1,000 m^2. Seedlings supplied continuously and a six row can take 12 seedling mats at time, long strain of hydroponic rice seedlings were developed making it easier to roll the mats eliminating frequent loadings in operation (Tasaka, 1998). Table 1 shows the evolutional trends of paddy transplanter.

CLASSIFICATION OF PADDY TRANSPLANTERS

Transplanters classification based on two parameters:

- Type of nursery requirements
- Prime mover

On the basis of nursery, two types were identified to include:

Washed seedlings: Use washed roots seedling on mat that has four to six leaves appearance about 20 to 30 cm long washed at time of transplanting. In some instances overgrown roots are pruned to facilitate easier transplanting operation requiring about 175 people per hour per hectare.

Mat-type on polythene sheet: The seedlings are nursed on a mixed soil sample with a known quantity of nutrients additives fallowed by sprinkling a pre-germinated seeds on the soil of thickness 1.5-2.0 cm and allowed to grow for a period in between 20-25 days in the nursery before uprooting to permanent field. The method is preferred because it requires less labor about 50 workers in an hour per days' work (Anoop *et al*., 2007).

Secondly on the prime mover requirements transplanters are classified as follows:

- Manual
- Animal drawn
- Power tillers
- Tractor mounted
- Self-Propelled

Manual transplanter: Hand-operated traditional manual transplanter called IRRI type designed imitate manual system using one hand to operate the transplanter the other hand to propel the transplanter forward. The number of row transplanting varies from 2, 3 and up to six. Figure 1 below shows a six row transplanter that uses mat raised seedlings. Constructed to have main frame housing the seedling tray and mat movement mechanism, two wooden floats, picker arrangement and handle. The machine weighs 20 kg. Row spacing of 20×20 cm between plants and adjustable to suite conveniences of the working

Fig. 1: IRRI a manual transplanter in operation

Fig. 2: www.kubota.global.net/english shows a Japanese-type walk behind transplanter

Fig. 3: IRRI shows a Chinese type transplanter

conditions. In operation the operator pulled the handle back to retract planting fingers at the same propelling the machine forward. The machine output is 0.4 ha per day saving about 45% production cost and 50% labour requirements a s reported by Garg *et al*. (1997). Figure 1 shows A Manual transplanter in operation.

Animal drawn transplanter: Despite research inanimal drawn power transplanter inpuddling rice fields transplanting operation little is achieved under submerged soil conditions. Favouring the growth of younger seedlings by repeated ploughing and harrowing. Change the soil to homogenous suspension of smaller particles creating less permeable soil to water. Degree of easiness is a function of some of the following parameter like soil type, tillage implement, moisture content and the prevailing cultural practices.

Power tillers: Power tillers (KPP 315) series has two-lines a single wheel powered by gasoline engine. Provide efficient working capability and durability weighing about 70 kg. Advantages are easily transferable from one paddy ridge to slope, adequate row spacing to accommodate plants requirements to favors root transplanting stability, increase of production to up to 25%. Hydraulic facility to aid wet land operation and a provision of a pump to clean the machine after operation.

Tractor mounted: Has a capacity of 6-10 rows transplanting width. Powered by a tractor engine of 25 h powers via power take-up shaft connected to arrangement of linking mechanism of pulley/belts. Provision at tractor rear wheel and transplanter are made to remove soil in puddle soil condition to facilitate smoother operation. Major constrains are poor quality of work in undulated fields reaching up to 50% missing hills recorded.

Self-propelled: Are of two categories, first called Walk behind type (Japanese model) a two or four row paddy rice transplanter. Mat seedlings trays are attached consisting of engine unit, drive wheel, power transmission train, float, planting claw, planting members or components, depth adjustment lever, seedling platform. Machines are powered by 1.7 horse power gasoline engine. Weigh almost 60-70 kg and a row spacing of 30 cm. Inter plant spacing of 13-18 cm. Mechanical efficiency is 0.6 ha per day operated at a speed of 2.0 km/h. The major set-back of system is complicated actuating claws arrangement (Singh *et al*., 1985). Figure 2 Shows a Japanese- type Walk behind transplanter.

Another model was the Chinese type utilizing washed seedlings found suitable with mat type of seedlings after little modifications. The machine parameters are 8-row planting capacity of 22.5 cm spacing and hill space of 15-20 cm. Weigh about 280 kg. Consist of engine unit, main body, transmission system, transplanting mechanism and float etc.

The engine provides the tractive power for the wheel and the transplanting system via a universal shaft. Speed can be changed depending on the operation requirements (low/high). Spring arrangements at the transmission provide safety in different field environmental condition. The movement of the claw is set to slide rollers fixed to the planting levers. The machine cover an area of 0.15-0.20 per hour at speed of 1.08-1.3 km per hour transplanting seedlings at 2-4 per hill reducing 40% of cost and 70% labour requirement against the traditional system. Merits are simple and easy to operate, conforming ground undulation and lastly better management of the crop. Figure 3 shows a Chinese type transplanter.

LITERATURE REVIEW

There are different parameters according to Garg (1992) and Narang (1997) influencing the overall performance of paddy transplanters. These are machine members, seedling nursery types and field conditions. Based on which it is possible to develop different machines that differ significantly on planting mechanism, seedling tray mechanism and tray motion mechanism.

According to report by Han *et al*. (1971) Japan was the first country to develop a unit called rice transplanter whose patent was obtained as earlier as in 1898. Thereafter development effort proceeds with the application of mechanical movers for seedling transplanting dating as far back as 1955. Taiwan uses gravity hand operated machine transplanter that was design and fabricated. China invention fallowed in 1956 by manufacturing of six row transplanter doubling efficiency of human labor. Neglected because of constrains associated i.e., uneven placement of seedlings (missing hills) and labour intensiveness of the operation in 1960s. In the year 1965 transplanter using washed seedling came into commercial production and then a year later in 1966 another transplanter that uses mat type of seedling emerges subsequently progress follow suites.

In 1966 four-row transplanter was test run at Technology Terrain College (TTC) Budhani and also Cuttack whose major limitations seriously affected its operation in the field are fatigue in nursery, working, arrangement of seedlings on carriers, pruning and lastly the claw getting stuck to soil preventing picking of the seedlings in operation.

Also in his view Brewel (1988) was optimistic by developing methodological automated rice transplanter guided by global positioning and inertia measurement using controller area network bus. The automated transplanter turns at the headland of rice field and move to the next desired path. Reducing timeliness in operation but reliable and suitable in areas of shortage man power and during peak period of labour demand. Precise operation and efficient.

Gunther *et al*. (2000) developed relationship between steering angle and turning radius of a four wheeled transplanter operated at different speeds in a circular pattern in flooded paddy fields. The result shows experimental values vary greatly from the theoretical values. In 2000's, automated steering systems transplanting units machine became operational, because the image-processing computers were still considered higher in cost. The software was unable to handle diverse climatic conditions leading to obsolesce in trend and need arouse to advance further research on the conventional elementary steering system which also challenged of been unable to detect curved crops. Necessitating the operator steering the machine manually neglecting the steering purpose. The short-coming pave way to development of an automated operation system (Nagasaka *et al*., 2004) Make precision operation for transplanting paddy seedlings more efficiently Using Real Time Kinematic Program Sensor (RTKPS) GPS to locate position and Fibre Optic Gyro (FOG) sensor in measuring inclination as well as direction of vehicle. The advantage is enabling single operator to control a number of machines in several scattered fields Using RTKGPS of 2 cm precision at 10 Hz output data. Leading to development of healthy vigorous seedlings, timeliness of operation and more viable in areas of shortage human labour or peak labour period.

According to Edathiparambil (2002) designing a mechanism that use method of analytical synthesis. A four-bar linkage coupler extension while the path taking plotted on computer screen. The potential links dimensions are taking in recognition of picking, conveying and planting of the seedling so also the return motion. It was developed, tested and technically viable.

Guo and Zhang (2001) Developed kinematic parametric equation (kinematic model) for eccentric planetary gear train without introducing the assumptions which are mainly related to the eccentricity of the system. Prove in excellent agreement with those obtained by direct measurement.

Another researchers Shiratsuchi *et al*. (2008) Introduced the strategic logic of increasing seedlings emergence, length of shoot, the number of leaves with the use of seed-mat hardening and heating techniques. Using of z fold strands seedlings loaded on the carriers of a transplanter eliminating use of nursery boxes which consume space and time. The paper mats used are biodegradable material making transplanting machines faster in operation and simpler in labour requirements, hence increase in production.

Zhou *et al*. (2009) developed a continuous feed and synchronous cave hole alignment precision transplanter. Using electromagnetic directional valve and pneumatic cylinder. Proved the two alignment aid in minimizing labour requirements, improves the seedling transplanting quality and ensures orientation of precision in the placement of seedlings giving way for further researchers in paddy precision seedling.

Jayasundara *et al*. (2009) developed and introduced a motorized modification of rice transplanter. Capable of planting seedlings at 20×20 cm interval. The machine is simple to construction and easy to operate and is easy for driver either female or male to successfully transplant seedlings. Its repair and maintenance service schedule can be done by local people anywhere; lastly the materials for construction are within the fingertips of the farmers.

Lu *et al*. (2010) reviewed creating of non-rice stubble bed for planting seedlings. Less soil pulverization and strong ability to penetrate soil resulting in plant cohesion and water absorption so the nutrient uptake potential of seedlings. This prove feasible device for ditching reasonable, reliable and lastly the quality of operations i.e., trenching, seeding met the agronomic requirements of rice and hence the expected result (higher yields).

Dai *et al*. (2011) contributed to development of software theory model. Using or adopting optimization algorithm in mechanical design to applications in

transplanting mechanism and other machinery of theoretical analysis and the design of new products. This software have aided tremendously in today's automated transplanted design, another eye opener in paddy cultivation break through.

In 2005 Kubota introduce into market a programmable transplanted, with motor sensors, CCD color camera and computer. Using the camera to sense RGB images and interprets the signals into a language of L* a* b* vision for human to determine seedling row locations as well as calculating the angle and movement. The motor steer the transplanted in accordance with its angle, working velocity and displacement but its limitation is deviation of row angle.

In 2007 this company (Kubota) Introduce in Thailand a major paddy rice growing zone transplanting machine to help solve some of the major constrains facing rice farmers in the region. As the time went on the company established its branch in the country to meet demand. In 2010 doubling production of paddy rice in the zone, selling to other countries like India and Vietnam. Manual transplanting characterized by time, labour, energy and resources consuming operations were the major factors considered by Kubota manufacturing company. Leading to series of modifications aimed at solving and improving standard through introduction of features like High Sensitive Transmission (HST) shift, a rotary transplanting to replace reciprocating mechanism results in higher precision.

In the year 2010/2011 the company introduces their latest model. Have robust and powerful engine unit of 17 h power, 1.62 m/sec operating speed, four wheel independent suspensions to absorb undulations with less noise and vibration favouring a smoother operation. In like- wise ventures, agricultural practices have done a lot of transitional transformations with the sole aim of increasing productivity at expense of cheap labour through higher effective utilization of scares resource at the out-most use efficiency. The pioneering transplanter manufacturing company in Japan (Kubota) was known for their untiring efforts in design and fabrication to meet the local needs of the farmers.

METHODOLOGY

The modification and development of the SRI transplanter will be based on requirements i.e., plant physical and mechanical properties and machine design requirement. The basic principles to understand the machine operational and function.The existing transplanter must be modified to allow the planting pattern of 25×25 cm and one seedling per hill. Planting finger is used to catch the seedling from the seedling mat supplied by the seedling tray through the feeding mechanism and then transplant the seedling in the puddle. The existing transplanter catches between 5 to 8 seedlings per hill for planting. Modifications have to be carried out on the planting claw (kuku kambing) so that it will only catch one seedling at a time and moisture content of the soil. Redesign the seedling tray to allow the SRI transplanter to catch one seedling at a time and the planting medium.

RESULTS AND DISCUSSION

Optimum transplanting depth favored greater leaf area per shoot and per leaf lamina and greater maximum tiller number and reduced the percentage tiller mortality. SRI planting method suggested 1 to 2 cm depth, taking care not to invert seedlings root tips when transplanting. The right cohesiveness of soil will cover the root firmly to the soil. The right soil is one that is sufficiently moist rather than continuously flooded to avoid sticking of planting claw with mud and labeled thoroughly to prevent undulations resulting in difference in water label to avert seedling tumbling and floating. Good land labeling is a most for optimum performance. Plant spacing requirement is important to ensure the seedling growth well and to ensure the problems such as lodging of the seedling will not occur and weeds management become easier and also to avoid competition in terms of nutrients, sunlight and mineral salts in soil. Seedlings uniformity is an important parameter achieved through sound nursery practice to ensure even seedling population while transplanting.

CONCLUSION

The shifting of manual transplanting to mechanical transplanting or direct seeding with a reorganization of land and labour resources have brought higher levels of farm productivity and income. The existing method of mechanical transplanting of paddy is claimed to be inefficient to produce higher yield. From the survey that was carried out, most farmers are looking forward to single-planting transplanters as it is impossible to do it manually. The System of Rice Intensification (SRI) transplanting method encourages the planting of one seedling per hill and spaced in 25×25 cm for better usage of water, nutrient and pest management. SRI application produce higher yield with increased exposure of crop to sunlight and nutrient and produce more effective root system. It will have a shorter crop cycle, less need for seeds and fertilizer, less chaffy grain because of higher percentage grain filling, little or no lodging from wind or rain and higher head rice recovery rate, so more milled rice from a given amount of paddy. No doubt that the new develop transplanter for SRI will be the future machines for the farmers in Malaysia.

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